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NOTATIONS IN THIS JOURNAL are the following:

> * 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
1077	January 4–7, 2012	Boston, MA	EXPIRED	Vol 33, No. 1
1078	March 3–4, 2012	Honolulu, HI	EXPIRED	Vol 33, No. 2
1079	March 10–11, 2012	Tampa, FL	January 18	Vol 33, No. 2
1080	March 17–18, 2012	Washington, DC	January 31	Vol 33, No. 2
1081	March 30–April 1, 2012	Lawrence, KS	February 14	Vol 33, No. 2
1082	September 22–23, 2012	Rochester, NY	July 10	Vol 33, No. 3
1083	October 13–14, 2012	New Orleans, LA	August 28	Vol 33, No. 3
1084	October 20–21, 2012	Akron, OH	September 4	Vol 33, No. 4
1085	October 27–28, 2012	Tucson, AZ	September 11	Vol 33, No. 4
1086	January 9–12, 2013	San Diego, CA	TBA	Vol 34, No. 1

BOSTON, MA, January 4–7, 2012

Abstracts of the 1077th Meeting.

00 ► General

1077-00-14 **George E Andrews*** (andrews@math.psu.edu), 306 McAllister Bldg., Mathematics Department, The Pennsylvania State University, University Park, PA 16802. *Our Challenges.*

We live in "interesting times." Basic mathematics education in the United States is inadequate. The Common Core State Standards Initiative has been produced to rise to this challenge. The lecture method of college teaching is viewed as antiquated and expensive. On-line instruction is cutting edge and much cheaper. The value of fundamental mathematical and scientific research has been called into question. The Science of Science Policy using Star Metrics hopes to provide evidence of value. This talk will be devoted to an analysis of these and other challenges and currently proposed responses. Underlying philosophical issues will be addressed. Not everything I say will be gloomy. (Received September 20, 2011)

1077-00-270 **Kurt Jacobs*** (kurt.jacobs@umb.edu), Physics Department, UMass Boston, 100 Morrissey Blvd, Boston, MA 02135, and **Justin Finn** and **Sai Vinjanampathy**. *Real-time feedback control of a mesoscopic superposition.*

We show that continuous real-time feedback can be used to track, control, and protect a mesoscopic superposition of two spatially separated wave-packets. The feedback protocol is enabled by an approximate state-estimator, and requires two continuous measurements, performed simultaneously. For nanomechanical and superconducting resonators, both measurements can be implemented by coupling the resonators to superconducting qubits. (Received August 17, 2011)

1077-00-434 **Sylvia T Bozeman*** (sbozeman@spelman.edu). *Creating Mathematical Scientists Among the Underrepresented.*

The search for mathematicians and mathematics educators among the populations that are so under-represented in the scientific community often seems to be a daunting task. The need more diversity is evident in the K-12 community, on college and university mathematics faculties, and across the scientific workforce. Yet high school students, college and university undergraduates from the underrepresented groups get little encouragement and support to pursue the study of mathematics. At the graduate level still too few earn doctorate degrees in the mathematical sciences. I will present a few strategies that have been shown to increase the numbers, some of

which arise out of my experiences as faculty and an administrator in a Historically Black College. Other strategies result from the insights gained over more than a dozen years as co-director of the nationally recognized EDGE (Enhancing Diversity in Graduate Education) Program, a program that supports women in completing doctoral degrees. This presentation will call on the listeners to help in the identification and implementation of strategies that will increase the number of mathematical scientists in the future from underrepresented groups. (Received August 31, 2011)

1077-00-503 **Fidele F Ngwane*** (ngwanef@mailbox.sc.edu), 807 Hampton St., Walterboro, SC 29488. *Integral Closures of number fields.*

The qth-power algorithm is a recent and efficient method of computing the integral closure of a ring in its field of fractions. Previously, the qth-power algorithm has been used to compute integral closures over finite fields. In this paper we use the qth-power algorithm to compute integral closures over number fields. We also compare our output and timings with the ones obtained using Magma built-in IntegralClosure function. (Received September 06, 2011)

1077-00-512 **Kanadpriya Basu*** (basuk@mailbox.sc.edu), 1523 Greene Street, Leconte College, Dept. of Mathematics, Columbia, SC 29208, and **Dr. Xinfeng Liu**. *Multisite phosphorylation with substrate sequestration can robustly generate bistability.* Preliminary report.

The mitogen-activated protein kinase (MAPK) cascades that are evolutionally conserved from yeast to mammals play a pivotal role in many aspects of cellular functions.The mating decision in yeast is a switch-like or bistability response that allows cells to filter out weak pheromone signals or avoiding improper mating when a mate is sufficiently close. In many cases, scaffold proteins are thought to play a key role during this process. The molecular mechanisms that control the bistability decision is not yet fully understood. Here we show that bistability mechanism can arise from multisite phosphorylation system with substrate sequestration when phosphorylation and dephosphorylation occurs at different locations. This scaffold binding in a multisite phosphorylation system can robustly result in multiple steady states. We argue that the scaffold protein plays an important role in creating bistability by the generic mathematical models, and by treating parameters symbolically, we also thereby reduce the complexity of calculating steady states from simulating differential equations to finding the roots of polynomials, of which the degree depends on the number of phosphorylation sites N.In addition we present some results considering the complex spatio-temporal case. (Received September 06, 2011)

1077-00-513 **Treena Basu*** (sircar@mailbox.sc.edu), 1523 Greene Street, LeConte College, Columbia, SC 29208, and **Dr.Hong Wang**. *A fast finite difference method for fractional diffusion equations.* Preliminary report.

Fractional diffusion equations model phenomena exhibiting anomalous diffusion that can not be modeled accurately by the second-order diffusion equations. Because of the nonlocal 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.

In this paper we develop a fast finite difference method for fractional diffusion equations, which only requires storage of $O(N)$ and computational cost of $O(N \log^2 N)$ for a one dimensional fractional diffusion equation or $O(N \log N)$ for a two dimensional fractional diffusion equation 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. (Received September 06, 2011)

1077-00-524 **Lalitha Venkataramanan*** (LVenkataramanan@slb.com), One Hampshire Street, MD-253, Cambridge, MA 02420. *Some Applied Math Problems of Interest at Schlumberger.*

The search for oil and gas has three objectives: to identify and evaluate hydrocarbon-bearing reservoirs; to bring hydrocarbons to the surface safely and cost-effectively, without harming the environment; and to maximize the yield from each discovery. The first part of the talk will focus on some areas of research in applied mathematics in Schlumberger. These areas include forward modeling and inversion, uncertainty analysis, telemetry, pattern recognition as well as signal and image processing. The second part of the talk will focus on application of Mellin Transform to analyze downhole nuclear magnetic resonance data to infer petro-physical as well as properties of insitu hydrocarbon. (Received September 06, 2011)

1077-00-843 **Rebecca D. Wasyk*** (wasyk@metsci.com). *Real World Tracking.*

This talk will provide an introduction to Bayesian tracking techniques that are used in solving real world problems. Only a modest understanding of undergraduate probability and statistics will be assumed, so a brief introduction will be provided to the Kalman Filter and particle filters. The remainder of the talk will focus on examples of using these techniques to solve problems that arise working in an industrial setting. (Received September 13, 2011)

1077-00-910 **Pamela E Harris*** (peharris@uwm.edu), Department of Mathematical Sciences, EMS Building, Room E403, P.O. Box 413, Milwaukee, WI 53201-0413. *On the adjoint representation of $\mathfrak{sl}_n$ and the Fibonacci numbers.*

We decompose the adjoint representation of $\mathfrak{sl}_{r+1} = \mathfrak{sl}_{r+1}(\mathbb{C})$ by a purely combinatorial approach based on the introduction of a certain subset of the Weyl group called the *Weyl alternation set* associated to a pair of dominant integral weights. The cardinality of the Weyl alternation set associated to the highest root and zero weight of $\mathfrak{sl}_{r+1}$ is given by the r^{th} Fibonacci number. We then obtain the exponents of $\mathfrak{sl}_{r+1}$ from this point of view. (Article to appear in Comptes rendus Mathematique) (Received September 14, 2011)

1077-00-1013 **Jose Perea*** (joperea@gmail.com) and **Gunnar Carlsson**. *Topology of Spaces of Micro-Images and Applications.*

One of the most celebrated success stories in topological data analysis, is perhaps that of the Klein bottle as a model space for relevant 3×3 patches from natural images. I will explore in this talk how the Klein bottle model can be extended to include other meaningful patches, and describe an application to texture discrimination. (Received September 15, 2011)

1077-00-1074 **Cynthia Robinson*** (fellowships@aaas.org), Washington, DC 20005. *Opportunities at the intersection of science and policy.*

This session will explore fellowship opportunities at the intersection of science and policy, both in terms of "science for policy" and "policy for science". The session will highlight needed skills in the realm of science policy, as well as introduce several ways scientists can learn more about opportunities in science policy, including the AAAS Science & Technology Policy Fellowships. Each of the panelists will share their experiences and insight for 20 minutes, followed by 10 minutes for questions at the end of the session.

The session will: Underscore the importance of scientists' understanding of the impacts of science on the policy-making process, and the impacts of policy-making on the scientific enterprise Describe skills needed to succeed in science policy Describe several avenues to learn more about science policy

"Science and technology are responsible for almost every advance in our modern quality of life. Yet science isn't just about laboratories, telescopes and particle accelerators. Public policy exerts a huge impact on how the scientific community conducts its work." From Beyond Sputnik: U.S. Science Policy in the 21st Century by Homer Neal, Tobin Smith and Jennifer McCormick (Received September 16, 2011)

1077-00-1424 **Fanya Wyrick-Flax*** (ff9267@bard.edu) and **Benjamin Warren** (bwarren@ramapo.edu). *Algebraic Tchoukaillon Representations.* Preliminary report.

We present three algebraic representations of the sowing game Tchoukaillon and construct maps translating between each representation. These maps yield information about the relationships between the pit size and move sequences and in addition enable us to construct a binary addition operation on Tchoukaillon boards. (Received September 19, 2011)

1077-00-1439 **Alice B. Popejoy***, 1321 Duke Street, Suite 210, Alexandria, VA 22314, and **Phoebe S. Leboy** (phoebe@biochem.dental.upenn.edu). *Is STEM Still Just a Man's World? Awards and Prizes for Research in Disciplinary Societies Go Mainly to Men, Despite Growth in Women's Participation.*

Awards are important markers of success in any career, and in academia they play a central role in hiring, promotion and tenure decisions. Unfortunately, striking gender disparities in scholarly recognition have hindered the advancement of women and limited their numbers as leaders in science, technology, engineering and mathematics (STEM). The 2005 CBMS survey reported that women were 9% of all full-time tenured faculty in doctoral-level math departments; yet women received only 4.8% of AMS scholarly awards during the last decade. Similar discrepancies exist for scholarly achievement awards from MAA, SIAM and ASA. Since the low numbers of women in prestigious math departments is apparently not the limiting factor, the cause of this under-recognition for scholarly contributions must be sought elsewhere. Decades of research in the social sciences points to implicit associations, or subconscious social stereotypes, as the mechanism by which both men and women de-value women's intellectual accomplishments. The Association for Women in Science (AWIS) is working with seven disciplinary societies (including AMS, MAA and SIAM) to identify patterns of behavior that perpetuate unconscious bias in the awards selection process and pinpoint ways to mitigate its deleterious effects. (Received September 19, 2011)

1077-00-1539 **Andrew P Maturo*** (maturoandrew@gmail.com), 420 Lexington Ave, Cranford, NJ 07016, and **Nick Robbins** (nrobbins@gettysburg.edu), 300 N Washington St, Gettysburg, PA 17325. *Finding Asymmetric Drumming Rhythms.*

We studied rhythms of length n where n is an odd natural number. We defined asymmetry for odd length rhythms and found the number of asymmetric rhythms given any n and r notes. Using this, we found the total number of asymmetric rhythms given any length and r. (Received September 20, 2011)

1077-00-1614 **Sonja Sandberg*** (ssandberg@framingham.edu). *Applying mathematical tools in public policy.*

This talk will describe for the audience how a person with a mathematical background can contribute their skills in the public policy realm. The author will highlight the skills needed to be successful in this area and describe different opportunities available, such as the AAAS Science & Technology Policy Fellowship. Questions will be taken from the audience. (Received September 20, 2011)

1077-00-1617 **Katherine Socha*** (ksocha@mathforamerica.org). *Careers in Math Policy.*

This talk will describe career options for those interested in math policy. The author will share resources and suggestions on how participants can get involved in policy. Questions will be taken from the audience. (Received September 20, 2011)

1077-00-1844 **Daniel H Ullman*** (dullman@gwu.edu), 801 22nd Street NW, Phillips Hall 107, The George Washington University, Washington, DC 20052. *Is there mathematical work to be done on Capitol Hill?*

The culture of mathematics is in many respects opposite to that of the world of policy. This begs the question of whether mathematicians have anything at all to contribute in the policy arena. I will argue that the answer is yes, even though there are no theorems that require proof on Capitol Hill. Moreover, I contend that a policy analyst who adopts the mathematical perspective will produce recommendations and decisions of greater benefit to constituents. (Received September 21, 2011)

1077-00-1883 **David Weinreich*** (dewmath@gmail.com), 6803 Westmoreland Avenue, Takoma Park, MD 20912. *Radical Mathematicians: A (mostly) non-partisan call to arms.*

While “science” generally fares well in public opinion polls and has bipartisan political support in rhetoric, scientific results and funding for science have increasingly come under attack. This talk will provide a brief overview of issues in science policy and recent political events, including basic definitions and historical context. I will argue that mathematicians have an opportunity and responsibility to be engaged in the political process for the betterment of our field and for the improvement of our country. (Received September 21, 2011)

1077-00-1953 **Wei Zhang*** (zhangwei19890308@gmail.com), 2207 Avenue J, 208, SELECT, Huntsville, TX 77340, and **Jianzhong Wang**. *On Scaling Infinite Products and their Application in Operator Decomposition.*

This thesis investigates scaling infinite products, which is a special kind of infinite products widely used in many areas and their applications in decomposition of differential operators, particularly the operators that occurs in harmonic analysis.

The thesis is outlined as follows. In Section 1, a brief historical review of infinite product is given. the notions and notations that are often used in this thesis are also introduced. In Section 2, the scaling infinite products are introduced and their properties and truncated errors are studied. Several important examples of this kind infinite products are studied in details. In Section 3, the infinite products of functions are expanded to matrices and operators. First, the product decomposition of inverses of matrices is investigated, then infinite product forms of Laplacian and resolvent operator are presented. (Received September 22, 2011)

1077-00-2221 **Jasper O Weinrich-Burd*** (jb9566@bard.edu), NY. *Adinkra Phase Graphs.*

Adinkra Graphs arise in the study of supersymmetry in physics. These graphs all have a base cube structure at their heart, with certain extra edges allowed according to rules derived from physics. Typically, Adinkra graphs are signed graphs, with values ± 1 assigned to each edge. We will explore Adinkra graphs with edge assignments drawing from the complex unit circle. We extend the standard notion of equivalent edge assignments from the real case to our complex Adinkra phase graphs. Finally, we prove that there are the same number of equivalence classes of complex edge assignments as there are of real edge assignments. (Received September 21, 2011)

1077-00-2282 **Spencer O Sims*** (spencer_sims01@yahoo.com), 210 C Holland Hall, 7000 Adventist BL NW, Huntsville, AL 35896, and **Amanda Fernandez**, **Qian Zhang**, **Tyesha Hall** and **Mikias Kidane**. *Mathematics of Sowing Games.* Preliminary report.

Mancala is an ancient popular "sowing" family of board games that originated in Africa and Asia. The board consists of a number of bins and a special bin called the Ruma. Initially a number of stones or seeds are placed in every bin except the Ruma. Sowing occurs when a player picks up stones in a particular bin and distributes them in adjacent bins.Sowing games have not been thoroughly studied, even though they are widespread. This presentation examines the mathematical structures present in single player sowing games like Tchoukaillon, Tchuka Ruma, and various modifications of these games. Computer simulation and proof are used to develop a theory to describe these games. We will analyze interesting patterns, uncover multiple ways to find a winning board, and examine how two different sets of moves can end in the same board state. (Received September 22, 2011)

1077-00-2304 **Luigi Accardi*** (accardi@volterra.uniroma2.it), Centro Interdipartimentale Vito Volterra, Faculty of Economics, Università Torvergata, Via Columbia 2, 00133 Roma, Italy. *Renormalization, Lie algebras and infinite divisibility.* Preliminary report.

In the past ten years several unsuspected relations have emerged among the topics mentioned in the title. The present talk will review the conceptual framework, achievements and open problems.
(Received September 22, 2011)

1077-00-2734 **Josh Frinak*** (Frinakjj@uwec.edu). *Constructing the Moduli Space of* $2|2$*-Dimensional Complex Associative Algebras.*

We study the moduli space of $2|2$-dimensional complex associative algebras, in other words, the codifferentials on a $2|2$-dimensional $\mathbb{Z}_2$-graded complex vector space. Using $\mathbb{Z}_2$-graded generalizations of the fundamental theorem of finite dimensional algebras and Wedderburn's Theorem classifying simple algebras over a field, we construct the moduli space by considering extensions of lower dimensional algebras. We also construct miniversal deformations of these algebras. Using information obtained by calculating cohomology classes we are able to give a complete description of how the moduli space is glued together via jump deformations. (Received September 22, 2011)

1077-00-2894 **David Creech*** (creec1de@cmich.edu) and **Jeff Anway**. *Periodicity and asymptotics of Tchoukaillon sequences.*

Tchoukaillon is a single-player sowing game in which there is a unique board for each natural number, indexed by board size. We will examine the global periodicity properties of Tchoukaillon and the long-term asymptotic behavior that describes the surprisingly complicated relationship between board size and board length. (Received September 22, 2011)

01 ► History and biography

1077-01-73 **Jeff A Suzuki*** (jeff_suzuki@yahoo.com), 39 Derrenbacher St., Kingston, NY 12401. *We The Jury: The Mathematics of Group Decisions From Condorcet to Cournot.*

Condorcet's *Essai sur l'Application de l'Analyse á la Probabilité dès Décisions Rendues à la pluralité des voix* (1785) introduced a stochastic model of human behavior. Although nominally about plurality voting in general, Condorcet quickly focused his attention on the jury system, and asked an all-important question: How much faith can we place in the decision of a jury? We will examine Condorcet's model, and see how it was extended by Laplace, Poisson, and Cournot to become one of the first models that could be used to evaluate the effects of public policy. (Received July 18, 2011)

1077-01-82 **Alejandro R. Garciadiego*** (gardan@servidor.unam.mx), Caravaggio 24, Col. Nonoalco - Mixcoac, Del. Benito Juarez, 03700 Mexico, D. F., Mexico. *Euclid's Elements in Spanish, during the XVII century.* Preliminary report.

Between 1991 and 1996, the Spanish speaking academic world witnessed the publication of its first ever complete edition of Euclid's Elements. During the XXth century, three other unsuccessful attempts were produced in 1944-1946, 1954 and 1968, respectively. There was none during the previous one hundred years. These facts seem to indicate that this mathematical community was indifferent to Euclid's work and, consequently, that its influence was neglectable, at least, in the teaching of elementary geometry, contrary to the effect on other cultures. But the story seems to be completely different from the time of the invention of the press up to the end of the eighteen hundreds. The goal of this talk is to examine some of the characteristics and peculiarities of those versions printed, in particular, during the XVII century. (Received July 20, 2011)

1077-01-90 **Radoslav Dimitric*** (rdimitric@juno.com), NEW YORK. *CONTRIBUTIONS OF RUDJER BOSCOVICH TO CIVIL ENGINEERING AND ARCHITECTURE.* Preliminary report.

One of the great polymaths of the enlightenment era, Roger Boscovich is mostly known for his theory of attractive-repulsive force and his model of atom. But he has also made notable contributions to other fields of hard science, as well as engineering. Here I examine Boscovich' contributions to architecture and civil engineering, such as his work on repairing Di S. Pietro cupola as ordered by the Papal state of the time. (Received July 25, 2011)

1077-01-389 **Martin D. Davis*** (martin@eipye.com), 3360 Dwight Way, Berkeley, CA 94704-2523. *A Survey of Alan Turing's Contributions to Logic, to the Invention of General Purpose Computers, and to Theoretical Computer Science.*

Turing's work will be surveyed in a historical context with emphasis on his historical forebears and the continuing significance of his work. (Received August 28, 2011)

1077-01-418 **Yibao Xu*** (yxu@bmcc.cuny.edu), 199 Chambers Street, New York, NY 10007. *Mathematics in the Republic of China: A Centennial Overview.* Preliminary report.

The Republic of China (ROC) was founded on January 1, 1912. This year the AMS/MAA annual meeting coincides very nearly with the centennial birthday of the ROC. In celebrating this special event, this talk provides a centennial overview of the development of mathematics in the ROC. The talk first outlines the modernization of Chinese mathematics through the lens of study-abroad programs and the creation of mathematical institutions for higher mathematics and research in mainland China. After Japan was defeated in 1945, Taiwan was returned back to China. As a consequence of losing the civil war, the ROC under Chiang Kai-shek retreated to Taiwan. Since 1949, the territory under the control of the ROC basically is the island of Taiwan. The talk then provides a sketch of the establishment of mathematical institutions at universities. It also highlights mathematical contributions made by mathematicians in Taiwan. The third part of the talk showcases how the USA helped the development of mathematics in Taiwan through efforts of Chinese-American mathematicians and also by training younger generations of mathematicians from Taiwan. The last part of the talk focuses on the localization and internationalization of mathematics in Taiwan in the last two decades. (Received September 22, 2011)

1077-01-422 **Niccolo' Guicciardini*** (niccolo.guicciardini@unibg.it). *Newton and the Neo-Pythagorean Tradition.*

Neo-Pythagoreanism is an important component of seventeenth-century mathematics and natural philosophy. Most famously, Kepler conceived of the macrocosm as designed according to geometrical and musical proportions. References to Pythagoras are frequent in Newton's writings. In the so-called classical scholia, Newton referred to Pythagoras as an ancient sage who had expressed knowledge of natural laws in musical terms. Newton also drew an analogy between the color spectrum and the musical scale. Therefore, some scholars have recently maintained that Newton was influenced by Neo-Pythagoreanism. The purpose of this talk is to re-examine the extent of Newton's involvement with the Neo-Pythagorean tradition. (Received September 22, 2011)

1077-01-423 **Andrew P Hodges*** (andrew.hodges@wadh.ox.ac.uk), Wadham College, University of Oxford, Parks Road, Oxford, OX1 3PN, England. *Alan Turing: The creative power of mathematics.* Preliminary report.

Alan Turing's work had great consequences for the engineering of computers and for the philosophy of mind. Discussions of his work have often emphasised these outcomes, and have neglected their roots in mathematical knowledge and culture. This talk will give a picture of Alan Turing as a mathematician with a remarkably broad scope, illustrating some less well-known aspects of his interests and achievements. (Received August 31, 2011)

1077-01-425 **J. J. Tattersall*** (tat@providence.edu), Department of Mathematics, Providence College, 1 Cunningham Square, Providence, RI 02918, and **Asta Shomberg** (ashomberg@providence.edu), Department of Mathematics, 1 Cunningham Square, Providence College, Providence, RI 02918. *C.H. Kummell and the Method of Least Squares.*

When Stephen Stigler, the historian of statistical methods, summed up the major developments in statistical research in America from its origins to 1885, he enumerated the contributions of Robert Adrain, Benjamin Peirce, Charles Sanders Peirce, Simon Newcomb, and Erasmus Lyman De Forest. Stigler remarked that his survey was not complete for he had omitted any discussion of the work on errors-in-variables by R.J. Adcock and C.H. Kummell. We note Adcock's contribution and give an overview of the statistical legacy of Kummell. We also describe his work at Lake Survey and the U.S. Coast and Geodetic Survey, as well as his efforts to promote the subject of statistics as a member of the Philosophical Society of Washington. (Received September 22, 2011)

1077-01-433 **Craig Bauer*** (cbauer@ycp.edu). *Alan Turing and Voice Encryption.* Preliminary report.
Alan Turing's work on encrypting speech is presented in full historical context. The material is presented without assuming any background in the subject from the audience. Undergraduates are especially encouraged to attend. (Received August 31, 2011)

1077-01-455 **John Steele***, Department of Egyptology and AWAS, Box 1899, Brown University, Providence, RI 02912. *Mathematical Schemes in Babylonian Astral Medicine.*
During the last five hundred years BC astronomy came to be used increasingly in the practice of medicine in Babylonia. Medical remedies were sometimes 'activated' by being exposed to the light of particular stars, planets or the moon, and the timing of their application to the patient could be governed by astronomical circumstances. Perhaps more significantly, however, the remedy used in curing a patient was itself sometimes determined by astronomical means. In particular, mathematical astronomical schemes could be used to give associate signs of the zodiac with days of the year and remedies made from ingredients related to those sigs would then be applied on the appropriate day. In this paper I will discuss the mathematical schemes used in Babylonian astral medicine and what this tells us about the connection between mathematics, writing, the sky, and people in the Babylonian world-view. (Received September 02, 2011)

1077-01-501 **Joseph W. Dauben*** (jdauben@att.net). *The Evolution of Geometry in ancient China, from the newly discovered* Shu *and* Suan shu shu *bamboo texts to the* Nine Chapters. Preliminary report.
Ancient Chinese mathematicians developed a wide variety of techniques for computing the areas and volumes of various geometric figures, along with detailed justifications for the results they obtained. By carefully examining the earliest bamboo texts currently known, including the Yuelu Academy's *Shu* and the *Suan shu shu* from Zhangjiashan, it is possible to suggest how and why various advances were made in theory and practice as geometry underwent various developments from the Warring States Period until the end of the Han dynasty. Liu Hui's commentaries on the *Nine Chapters* provide especially illuminating testimony for a number of sophisticated and very successful techniques, some of his own devising, that will also be discussed. (Received September 05, 2011)

1077-01-556 **Richard L. Kremer*** (richard.kremer@dartmouth.edu), Department of History, 6107 Carson Hall, Dartmouth College, Hanover, NH 03755. *On Finding Times of True Syzygy in the Fifteenth Century: Melchion de Friquento's Eclipse Tables of 1437.* Preliminary report.
Computing the times and magnitudes of eclipses was undoubtedly the most complicated task in Ptolemaic mathematical astronomy. And within that task, finding the time required for the luminaries to move from mean to true syzygy proved most difficult since the apparent lunar and solar velocities change over the course of the month and year, respectively. As J. Chabas, B. Goldstein and I have shown, medieval mathematicians (Arabic and Latin) devoted considerable ingenuity to this problem, inventing iterative techniques, special single or double-entry tables, and graphic methods to approximate the changing velocities. In this talk I will analyze another novel approach offered in 1437 by the otherwise unknown Melchion de Friquento of Naples. Uniquely preserved in a Parisian manuscript, Melchion's tables betray both sophistication and confidence, extending as they do to the year 2007. (Received September 22, 2011)

1077-01-743 **Lawrence A. D'Antonio*** (ldant@ramapo.edu), 505 Ramapo Valley Rd, Mahwah, NJ 07430. *Boscovich and the Line of Best Fit.* Preliminary report.
In 1757, Roger Joseph Boscovich, the Croatian-Italian-French physicist, astronomer, mathematician and poet, published an important work on determining the line of best fit. His method, based on minimizing the sum of absolute deviations between a data set and the best fit line, was applied to work on computing the ellipticity of the Earth using lengths of meridian arcs. We review this work of Boscovich and earlier work of Cotes, Euler, and Tobias Mayer. We also consider the influence of Boscovich on later research of Legendre, Laplace, and Gauss. (Received September 22, 2011)

1077-01-1248 **Frédéric Brechenmacher*** (frederic.brechenmacher@math.cnrs.fr), 27 rue Myrha, 75018 Paris, France. *Linear groups in Galois fields between France and the U.S.A. at the turn of the 20th century.*
Although prominent algebraists such as Dickson made extensive references to papers published in France, and despite the roles played by algebra and arithmetic in the development of the American mathematical community, our knowledge of the circulations of knowledge and practices between France and the United States at the beginning of the 20th century is still very limited. It is our aim to tackle such issues through the case study of a collective space of circulations in group theory at the turn of the 20th century. This collective can be

introduced as a network of texts with two main characteristics. The first is a specific approach to finite group theory through general linear groups in Galois fields. This approach involved initially actors in Chicago and in Paris but quickly extended to actors in Stanford, and to other individuals. The other main characteristic is the role of shared references played by some works Hermite, Serret, Mathieu, and Jordan had published in the 1860s. The collective of texts thus revolved on a two-fold periodization. We will see that it can be understood as the space of circulation at the turn of the 20th century of a specific relation Jordan had established to the works of Galois in the 1860s. (Received September 18, 2011)

1077-01-1276 **David E Zitarelli*** (zit@temple.edu), Department of Mathematics, 1805 N. Broad Street, Philadelphia, PA 19122. *Elevating the ranking of American mathematics departments 1900-1940.*

The mathematics department at the University of Missouri contained one of the most competent faculties in the U.S. during the period 1900-1920. Three of the central figures were students of David Hilbert, while others held degrees from Harvard and Chicago. The University of California at Berkeley assembled a first-class core of mathematicians in this period too, with degrees under Felix Klein and E.H. Moore. Berkeley rose to the top of American departments by 1920, declined for more than a decade, and then ascended quickly. Yet Missouri did not reach the top rung at any time up to WWII. We compare the histories of these two departments with an aim toward speculating why one emerged among the leading departments but the other did not. (Received September 22, 2011)

1077-01-1390 **Rebecca Miller*** (rmiller34@uco.edu), Department of Mathematics & Statistics, 100 N University Drive, Edmond, OK 73034. *To Be Woman or Not To Be: The Struggles of Women Mathematicians and How They Have Impacted Mathematics.* Preliminary report.

Women. Our society/civilization would not exist without them. So why does society make the doors of math so heavy for women to open, let alone cross the threshold? What struggles have different women faced throughout history to enter these great doors? What impact have their struggles had on the mathematical community? Often we do not realize others' adversities until we run into the conflict ourselves or are made aware of the conflict. In this talk, I will present research that will not only bring awareness and knowledge of these struggles and their causes to current and future mathematicians, but also show the importance of closing this gender gap by uncovering the impact this gap has had on the mathematical community throughout history. In the words of Sofia Kovalezskaia, the greatest female mathematician of the 18th century,"... is it really possible not to stretch out one's hand, is it possible to refuse to help someone who is seeking knowledge and cannot help herself reach its source?... I consider it is my duty to destroy whatever obstacles I can in the paths of others." (Received September 19, 2011)

1077-01-1416 **Robert E Bradley*** (bradley@adelphi.edu), Adelphi University, Dept. of Mathematics & Computer Science, 1 South Ave., Garden City, NY 11530. *Evolutes in the works of Huygens and Johann(I) Bernoulli.*

Christiaan Huygens (1629-1695) defined the evolute and involute of a curve in his *Horologium Oscillatorium* (1673), his mathematical work on pendulum clocks. Although he did not make use of the differential calculus *per se*, his arguments have some infinitesimal character. Later on, Johann Bernoulli (1667-1748) and his brother Jacob (1654-1705) applied the new differential calculus to the study of these curves, discovering a general formula for the radius of curvature. We present Bernoulli's results, as they appeared in L'Hospital's *Analyse* (1696), comparing and contrasting them to what Huygens was able to achieve with "precalculus" methods. (Received September 22, 2011)

1077-01-1459 **Anjing Qu*** (qaj@nwu.edu.cn), Department of Mathematics, Northwest University, Xian, 710069, Peoples Rep of China. *The Genius in Mathematics.*

I will take the history of Galois theory as a case study to describe two types of genius in mathematics through the story of a middle-aged person and three young people. (Received September 20, 2011)

1077-01-1508 **Jiri Hudecek*** (jh602@cam.ac.uk), Needham Research Institute, 8 Sylvester Road, Cambridge, CB39AF, England. *How to Assess Influence: Wu Wen-Tsun's Work in Measure, Number and Weight.*

Wu Wen-Tsun is a contemporary Chinese mathematician famous for his work in algebraic topology and in computer proofs and mechanisation of mathematics. He received the Chinese Highest National Prize for Science and Technology in 2001 for this work, but also for his "fervent patriotism", which motivated his return to China from France in the 1950s, and his promotion of ancient Chinese mathematics, which, he has claimed, inspired the Wu method of mechanisation of proofs. All literature about him published in China is written in a celebratory style, and so I tried in my PhD dissertation to construct an alternative appraisal of his influence through a combination of quantitative and qualitative assessments. The results are somewhat unexpected, and raise several methodological questions, which can be of wider significance for historians of modern mathematics: how to use citation counts to compare older and newer papers, and papers from different branches of mathematics? Can the significance of a particular result be established from its published reviews, and from its place in standard textbooks? How to combine these two approaches? I will present some concrete answers related to Wu Wen-Tsun's work, as well as more general reflections on these problems. (Received September 20, 2011)

1077-01-1510 **Anne-Sandrine Paumier*** (paumier@math.jussieu.fr). *Human collectives in mathematical practices : the example of the writing of a theorem, the kernel theorem of Laurent Schwartz (1915-2002).*

The kernel theorem ("théorème des noyaux") was first stated by Laurent Schwartz in 1950 at Cambridge during the International Congress of Mathematicians where he was awarded the Fields medal. It is also one of the starting points of his student Alexandre Grothendieck's thesis, where he defines a new class of abstract spaces, nuclear spaces, which are inspired by the theorem's property.

Schwartz' kernel theorem in fact encompassed many mathematical statements that may look very differently one from the other. In the paper, we use the theorem as a probe to study different human collectives involved, such as theoretic physicians, analysts, Bourbaki... We claim that this allow to catch some of their characteristics. We will look in detail at the technical mathematical aspects such as statements, notations...but also at visual aspects and authors' motivations. (Received September 20, 2011)

1077-01-1514 **Sebastien Gauthier*** (gauthier@math.univ-lyon1.fr). *Hans Frederik Blichfeldt.*

This talk deals with the mathematician Hans Frederik Blichfeldt (1873-1945). First we give an overview of the peculiar trajectory of this danish immigrant who made all his career in Stanford University. Then we present a few elements of his mathematical work. Blichfeldt's first interest in mathematics was group theory but in this talk we pay particular attention to his contributions to the geometry of numbers. (Received September 20, 2011)

1077-01-1530 **Sloan Evans Despeaux*** (despeaux@wcu.edu), Dept. of Mathematics and Computer Science, Western Carolina University, Cullowhee, NC 28723. *Mathematics for Public Consumption: Augustus De Morgan's Anonymous Reviews for the* Athenaeum. Preliminary report.

The London-based weekly, the *Athenaeum*, supplied Victorian England with news of the latest developments in the arts, science, and politics. Book reviews represented a regular department of the periodical. While these reviews were usually written anonymously, the editors identified the reviewers in their private marked copies of the journal, now held by City University, London. The editors' marked copies reveal that the vast majority of reviews on mathematics published from 1828 (the journal's founding year) to 1870 (the last year that the identity of the reviewers has been catalogued) were authored by Augustus De Morgan. As a reviewer, De Morgan did not limit himself to mathematical works, and he produced around one thousand reviews for the journal during this period. Interestingly, his comments on mathematics sometimes appeared in reviews of non-mathematical works. This presentation will consider what types of mathematical works De Morgan chose to review and how he presented mathematics to the wide audience of the *Athenaeum*. (Received September 20, 2011)

1077-01-1532 **Josipa Petrunic*** (josipa.petrunic@utoronto.ca). *Cambridge mathematics in the north: Peter Guthrie Tait, Philip Kelland and the local nature of mathematics in Edinburgh, 1858-1865.*

This article relates to mathematics in Edinburgh leading up to and just following the Universities Act (Scotland) in 1858. Philip Kelland, Professor of Mathematics from 1838, and Peter Guthrie Tait, Professor of Natural Philosophy from 1860, were both Cambridge-trained Senior Wranglers. Yet, neither actor advocated a wholesale implementation of Cambridge-style Tripos examination in Edinburgh, despite the fact that the Universities Act provided them with the cultural space and impetus to do so. Despite their collective potential to serve as conduits through which Cambridge mathematics, or at least an analysis-heavy curriculum, could have been more explicitly imposed in the north, neither Kelland nor Tait enforced such a transformation. Rather, their contributions to the development of mathematical curricula in Edinburgh were shaped more by the university's institutional and cultural geography (where natural philosophy was privileged over and above symbolical mathematics) than by their own rigid training in Cambridge-style mathematics. In sum, this article explores the Scottish case study of Kelland and Tait to argue that mathematical knowledge is not simply transferable, but is heavily dependent upon local conditions. (Received September 20, 2011)

1077-01-1562 **Alma Steingart*** (almas@mit.edu), Massachusetts Institute of Technology, Building E51-098, 77 Massachusetts Avenue, Cambridge, MA 02139. *"It Is No Good Baking Cakes If Pies Are Wanted": The American Mathematics Community in the 1970s Job Market Crisis.* Preliminary report.

"This is not a good year for mathematicians looking for a job," lamented a 1970 report on the job market. Reese Prosser, the report's author, blamed the doctoral degree for producing specialized mathematicians. Faced with decreased funding for the sciences, Prosser argued, mathematics departments must graduate students with diverse interests able to work across disciplines. Mathematics departments needed to "redesign their product" because, as he put it, "It is no good baking cakes if pies are wanted." By 1974, the Council of the AMS approved a recommendation to begin a series of summer institutes that would provide mathematicians with continuing education in fields such as statistics, computing, and operations research. Another resolution went further, suggesting that every PhD in mathematics, regardless of his or her expertise, be required to acquire a second "saleable skill" in an area of applied mathematics. This talk analyzes various educational reform proposals forwarded by the AMS and MAA in light of the 1970s funding crisis. I analyze these suggested programs and the reactions they triggered among mathematicians in order to demonstrate how mid-century epistemological shifts in mathematics were conditioned by broader socioeconomic and political changes. (Received September 20, 2011)

1077-01-1593 **Karen V. H. Parshall*** (khp3k@virginia.edu). *Toward Algebra as a General Problem-Solving Technique: Rafael Bombelli to Francois Viète.*

This talk will explore the evolution of algebra in the latter half of the sixteenth century at the hands first of the Italian engineer/architect/mathematician, Rafael Bombelli, and then of the French lawyer/politician/mathematician, François Viète. It will highlight, in particular, the shifting assumptions about what algebra was, about what problems it legitimately addressed and about how it effectively addressed them. (Received September 20, 2011)

1077-01-1669 **Duncan J. Melville*** (dmelville@stlawu.edu), Dept. of Mathematics, St. Lawrence University, Canton, NY 13617. *Who reads mathematics? A case study from Mesopotamia.*

The small town of Meturan lay far from the great urban centers of Mesopotamian learning such as Nippur and Ur. Yet in a small private house, a scholar had amassed a collection of Sumerian literature – and mathematics. The presence of mathematical tablets in the collection indicates an intellectual interest in mathematics outside of scribal schooling. We will discuss the contents of this collection and its implications. (Received September 20, 2011)

1077-01-1816 **Jenny Boucard*** (jenny.boucard@gmail.com). *Analogies between algebra and number theory: Some uses of congruences in France between 1801 and 1850.*

Gauss introduces the notion of congruence in 1801 in his *Disquisitiones Arithmeticae*. The classical historiography usually connects the history of the congruences to the development of algebraic number theory, built around a group of German scientists, with French mathematicians are mostly absent. Galois only stands out and is associated with another aspect of congruences, related to the algebraic theory of equations.

Other French authors, however, published texts on congruences in the first half of the 19th century, with different perspectives. Two of these mathematicians are Poinsot and Cauchy. Our goal is to present their arithmetical researches, and understand their contribution compared to the work of Jacobi, Dirichlet, Kummer, Galois, ... Poinsot develops a theory of order based in particular on the analogy between binomial equations and congruences : we will comment on his publications and their possible influence on the development of the history of number theory and algebra. Between 1829 and 1847 Cauchy publishes many articles based on the consideration of congruences and primitive roots: we'll see how his researches meet the work of Jacobi, Dirichlet, Kummer and Kronecker. (Received September 22, 2011)

1077-01-1938 **Mohammad Moazzam*** (mxmoazzam@salisbury.edu), 1101 Camden Ave., Dept of Math & Computer Science, Salisbury, MD 21804-1845. *Khodjandi: A Tenth-Century Persian Mathematician.*

The history of mathematics is an ever-evolving story as new pieces of the saga are added to the narrative. There are many past mathematicians that are scarcely known—if at all—to the wider mathematical community. Among them is Khodjandi, a Persian mathematician who discovered numerous noteworthy mathematical results more than 1000 years ago. The purpose of this presentation is to showcase some of Khodjandi's work and reveal how his results seem to shed light on some of the contributions that have been highlighted in known mathematics history. This talk should be of interest to anyone who seeks to put together bits of mathematics history as someone might put pieces of a puzzle together. Professors who teach prospective teachers of mathematics might be able to glean some nuggets of information to use in their classes. (Received September 21, 2011)

1077-01-1987 **James H. Moor*** (James.Moor@Dartmouth.edu), Department of Philosophy, Thornton 6035, Dartmouth College, Hanover, NH 03755. *Alan Turing's Philosophy of Mind.* Preliminary report.

Alan Turing's work has had an enormous influence on philosophy of mind during the last sixty years and continues to influence the discussions. Although Turing was not a professional philosopher, he provided intriguing philosophical insights and arguments about two central issues in the philosophy of mind. What are minds and how can we identify other minds? Turing's views on each of these issues will be explained and defended against standard criticisms. Turing's legacy is certain to have an impact on the philosophy of mind for years to come. (Received September 21, 2011)

1077-01-2031 **Stephanie Dick*** (sadick@fas.harvard.edu), Department of History of Science, Harvard University, Science Center 371, Cambridge, MA 02138. *The Design of Intuition: Computing and Mathematical Proof.*

Where does mathematical intuition reside? Is it part of reason? Of the unconscious? Of instinct or the body? Many answers to such questions have been offered through history. The advent of digital computing in the mid-twentieth-century introduced another question: can mathematical intuition reside in a machine? Computers created possibilities for automating mathematical work - including the search for and verification of proofs - and this inspired novel discourse about the nature of mathematical intuition. Some researchers believed that human intuition could, at least in principle, be reduced to a set of rules and imparted to a computer which could then search unaided for proofs. Others believed that intuition could not be formalized and programmed; the discovery of proofs would always require the input of human mathematicians. New relations between intuition and automation are also being explored today, for example in Vladimir Voevodsky's work on new mathematical foundations and proof verification software. This talk will historically explore different ideas about mathematical intuition that emerged in the U.S. in response to the possibility of automating the work of proof and how these ideas shaped and were shaped by interaction and research with computing technology. (Received September 22, 2011)

1077-01-2033 **Caroline Ehrhardt*** (caroehrhardt@free.fr), Service d'histoire de l'éducation, 45 rue d'Ulm, 75005 Paris, France. *The teaching of Algebra in France (1809-1914).*

At the beginning of the 19th century, in France, there was a deep coherence between the algebra that was taught in high schools and universities and algebra as a field of research, namely, at that time, the theory of equations. By contrast, at the end of the 19th century, algebra as a field of research could no longer be reduced to the theory of equations anymore: a new way to make algebra was developing, with new objects and new practices. At the same time, the teaching of mathematics was changing too: there were many more students learning it, and several periodicals were created to reach this new audience. In a broader way, at the beginning of the 20th century, the teaching of mathematics was the topic of debates between mathematicians (French or not), and the French educational systems was reformed. Did the teaching of Algebra follow the evolution of research , or did it become independent of it? In this talk, I will first explain briefly the situation of the teaching of Algebra at the beginning of the 19th century. I will then address the issue of its evolution in the period 1870-1914 by correlating changes in research and in the educational system. Finally, I will suggest some guidelines for a comparison of the situation in France and in the US. (Received September 21, 2011)

1077-01-2224 **Maxsimino Aviles Montes*** (mam074@shsu.edu), 2209 Bobby K Marks, Apt 37, Huntsville, TX 77340, and **Katie Watkins** and **Tatiana Kovyrshina**. *The Magic Behind Franklin Magic Circles.*

Dr. Benjamin Franklin is popularly known for his creation of the lightning rod, bifocals, and many discoveries regarding electricity. He also participated in the fundamental foundations of the United States of America including cowriting the Declaration of Independence. To avoid weariness in congressional debates, Franklin used his intellect to create both magic squares and magic circles. Franklin Magic Circles are whole numbers arranged in concentric circles such that when added in specific patterns the sum will be the same. Franklin believed his discovery to be trivial and that "no one desired [him] to show [them his] method of disposing the numbers. It seems they wish rather to investigate it themselves." In our presentation, we will discuss the re-creation, enumeration, and symmetry operations of Franklins original magic circle, as well as a new, unique Franklin Magic Circle. We will use algebraic techniques to unravel the mysteries of Franklins creation while revealing the fascinating characteristics that define Franklin Magic Circles. (Received September 21, 2011)

1077-01-2253 **Agnes M. Kalemaris*** (akalemar@optonline.net), Mathematics Department, Farmingdale State College, 2350 Broadhollow Road, Farmingdale, NY 11735. *Mathematics at the Science Museum, London, England.* Preliminary report.

If you are "going to London to visit the Queen", go to the Science Museum first! A visit there in May was one of the highlights of a tour with a group of applied mathematicians (AKA electrical engineers). This presentation will discuss some of the treasures in the Mathematics Exhibit at the museum. They range from a set of Napier's bones base sixty (used for astronomy) to a Difference Engine built in the 1980's to Babbage's standards and specifications. Photographs will be included. (Received September 21, 2011)

1077-01-2385 **Laura E. Turner*** (lturner@ivs.au.dk). *Rhetorics of international communication and cooperation: Mittag-Leffler and Swedish mathematics, 1880-1920.* Preliminary report.

Acta Mathematica, founded by the Swedish mathematician Gösta Mittag-Leffler in 1882, is widely understood as the first "international" journal of mathematics with respect to both readers and contributors. However, it is recognized that the journal was intended to advance Scandinavian science on an international stage. Similarly, the sense in which many forms of scientific activity were "international" during this period was linked not only to rhetoric emphasizing the importance of cooperative efforts for scientific progress and mutual gain, but also to an awareness of a widespread "competition in civilization" in science, culture, and technology, seen, for instance, in the World's Fairs. This talk investigates different aspects of the internationalist rhetoric Mittag-Leffler employed in founding *Acta Mathematica* and in establishing the Scandinavian Congress of Mathematicians. It also contrasts the versions of international activity cultivated by Mittag-Leffler with those promoted by some of his contemporaries, such as his Italian colleagues Giovan Battista Guccia and Giuseppe Peano, and promoted by organizational bodies such as the ICM and the IMU. (Received September 22, 2011)

1077-01-2474 **Maryam Vulis*** (maryam@vulis.net), 67-67 Burns St, Apt. 4K, Forest Hills, NY 11375. *Cryptanalysis vs Calvary.* Preliminary report.

This presentation will discuss the role of cryptanalysis in the 1919-1920 Russian-Polish war.

The Polish codebreakers at the Cipher Bureau intercepted the Russian Red Army communications, and in particular secured the Polish Army victory n the 1920 Battle of Warsaw.

The Polish Cipher Bureau gathered quite a number of mathematicians who consequently broke the Enigma cipher. (Received September 22, 2011)

1077-01-2662 **Henry T. Zepeda*** (henry.t.zepeda@hotmail.com), 601 Elm, Phys. Sci. Center, Room 625, Norman, OK 73019. *Proportion Theory in Medieval Astronomical Works.*

In Book 1 of his Almagest, Ptolemy proves several trigonometric theorems that are necessary for his astronomy. Among these is the Menelaus theorem which deals with the relationships of arcs on the surface of a sphere. Because this proposition involved the use of compound ratios, ratios made out of other ratios, proportion theory was necessary for its understanding. Because this proof was difficult and so fundamental to astronomy and astrology, medieval scholars wrote several treatises to explain it, and many commentaries and glosses on the Almagest treated this theorem at length. In these explanations of the theorem, the nature of compound ratios and how to deal with them became a popular topic. Two different understandings of what it meant for a ratio to be made from other ratios were used. These two different conceptions of ratio found in these works influenced the proportion theory of the later Middle Ages and were used extensively in all branches of mathematics as well as in natural philosophy. (Received September 22, 2011)

1077-01-2865 **Clemency Montelle*** (lemency.Montelle@canterbury.ac.nz). *Translating the Elements into Sanskrit: Jagannātha's Rekhaganita.*

Beginning in the eighteenth century, European mathematical ideas increasingly came under scrutiny in India. This was largely due to the efforts of Jayasimha, noted ruler of Jaipur (ruled 1700-1743), who initiated an ambitious and broad program of astronomical reform. As part of this movement, he commissioned a young scholar, Jagannātha, to translate Euclid's Elements into Sanskrit. The resulting work, the Rekah-ganita, was completed shortly before 1727 and was based on an Arabic recension by Nasir al-Din al-Tūsī. We will explore the effects of this transcultural trajectory on the content and presentation of Jagannātha's work and the subtle and distinct differences it has with Euclid's original. More broadly, this comparison will allow us to highlight how Jagannātha overcame some of the technical, linguistic, practical, and philosophical challenges of translating a canonical mathematical work from one culture of inquiry to another. (Received September 22, 2011)

1077-01-2898 **Emil Sargsyan*** (emilsar@gmail.com). *On Pre Robinsonian Non-Standard Theories of the Twentieth-Century.* Preliminary report.

While many historians of mathematics credit Abraham Robinson for offering the first rigorous and functional non-standard analysis, few have investigated previous, yet less successful, attempts at incorporating infinitesimals within the continuum only a few decades prior to the work of Curt Schmieden and Detlef Laugwitz in the late 1950s, and Robinson in the 1960s. Despite the Cantor-Weierstrassian orthodoxy at most universities, a number of mathematicians of the twentieth-century such as the American, Norbert Wiener; the Polish, Leon Chwistek; the German, Ludwig Neder; and the Russian, Nikolai Luzin advocated or offered a theory of infinitesimals. To what extent did these mathematicians anticipate the later, and now mainstream, non-standard analysis of Schmieden, Laugwitz, and Robinson? My talk offers a preliminary philosophical and mathematical overview of these probing endeavors in the foundations of analysis. (Received September 22, 2011)

1077-01-2934 **Marvin Minsky*** (minsky@media.mit.edu), MIT Media Lab, 77 Mass. Ave E14/E15, Cambridge, MA 02139. *The influence of Alan Turing.*

I will attempt to reconstruct how, more than 50 years ago, the ideas of Alan Turing began (and continued) to influence most of the projects that my students and I undertook. (Received September 23, 2011)

03 ► Mathematical logic and foundations

1077-03-152 **John Baldwin*** (jbaldwin@uic.edu), Department of Mathematics MC 249, 851 S. Morgan Streeet, Chicago, IL 60607. *Set Theory and Infinitary Model Theory.*

The fundamental notions of first order stability theory are absolute. We explore the role of this fact in the development of model theory as an independent subject since the 1970's. We then discuss questions and results about the absoluteness of fundamental notions of infinitary model theory. As in the first order case, amalgamation and ω-stability are absolute notions, although of higher complexity. But while $\aleph_1$-categoricity is absolute for first order model theory, for $L_{\omega_1,\omega}$, absoluteness is an open question. (Received September 14, 2011)

1077-03-153 **Johanna N.Y. Franklin*** (johanna.franklin@uconn.edu), Department of Mathematics, 196 Auditorium Road, Unit 3009, Storrs, CT 06269. *Randomness and ergodic theory.*

There has been a great deal of interest recently in the connection between algorithmic randomness and ergodic theory. Random points are regular with respect to measure, and many theorems in ergodic theory state that, given an ergodic transformation T on a probability space, the orbits of almost all points in the space under T will have a certain regularity property. When we put these theorems into the framework of recursion theory, we find that we can relate them to randomness: a point in a recursive probability space is random if and only if it satisfies an ergodic theorem with certain recursion-theoretic restrictions. I will survey the current state of the field, including a result of mine that is joint with Noam Greenberg, Joseph S. Miller, and Keng Meng Ng. (Received September 14, 2011)

1077-03-154 **C. Ward Henson*** (henson@math.uiuc.edu), 1409 West Green Street, Champaign, IL 61801. *Continuous first order logic and Gurarii's universal homogeneous separable Banach Space.*

A continuous, [0,1]-valued generalization of first order logic was developed recently. Its structures are based on bounded metric spaces and equipped with uniformly continuous operations and [0,1]-valued predicates. This talk will provide a brief introduction to this logic as well as pointers to some recent application areas, and then it will concentrate on the model theory of Gurarii's separable Banach space. This space is isometrically universal (for separable Banach spaces) and homogeneous in an almost-isometric sense relative to its finite dimensional subspaces. Lusky showed that the Gurarii space is isometrically unique and that the set of smooth points of norm 1 is an orbit of its automorphism group. In this talk it will be shown how these results look from the point of view of continuous model theory. In particular, the class of separable Gurarii spaces can be realized as the class of separable models of a continuous theory T (of unit balls of Banach spaces). Analysis of the type spaces of T over finite sets of parameters can be used to prove the separable categoricity of T (= Lusky's uniqueness result) as well as to prove new results about the action of the automorphism group of Gurarii's space. (Received September 19, 2011)

1077-03-155 **Julia F. Knight*** (knight.1@nd.edu), University of Notre Dame, Department of Mathematics, 255 Hurley Hall, Notre Dame, IN 46556. *Structures associated with real closed fields and real closed exponential fields.*

Real closed fields and real closed exponential fields have been studied extensively by model theorists. These structures are also interesting from the point of view of computability. Tarski gave an elimination of quantifiers for the theory of the ordered field of reals in order to show that the theory is decidable. It is still unknown whether the theory of the reals with exponentiation is decidable. Macintyre and Wilkie showed that this theory is decidable provided that the real version of Schanuel's Conjecture holds. There are further interesting structures associated with real closed fields, with and without exponentiation: "value group sections", "residue field sections", and "integer parts". I will describe some results on these structures by Mourgues and Ressayre, and some further work with Paola D'Aquino, Karen Lange, Sergei Starchenko, and Salma Kuhlmann. (Received September 15, 2011)

1077-03-156 **Roman Kossak*** (rkossak@gc.cuny.edu), 365 Fifth Avenue, NY, NY 10016. *Twenty Questions.*

In the last chapter of (1), Jim Schmerl and I put together twenty open problems concerning models of PA. Since the book was published, two problems were solved by Ali Enayat, and partial solutions to three other problems were given by Victoria Gitman, and Saharon Shelah. The problems can be roughly divided into three groups: general model theoretic/set theoretic questions about existence of models with special second order properties; permutation group theory questions concerning automorphisms and automorphism groups of recursively saturated models; questions concerning complete types and lattices of elementary substructures specific to models of PA. There is also an important question that stands alone: the Scott set problem. I will talk about selected problems from each group, and I will comment on recent progress.

References

[1] Roman Kossak, James H. Schmerl, *The structure of models of Peano Arithmetic.* Oxford Logic Guides 50, Clarendon Press, Oxford 2006.

(Received September 16, 2011)

1077-03-159 **Dima Sinapova*** (dsinapov@math.uci.edu), University of California at Irvine, Department of Mathematics, 440C Rowland Hall, Irvine, CA 92697. *Prikry Type Forcings and Singular Combinatorics.*

Cardinal arithmetic is of primary importance in set theory. We will discuss relative consistency results about singular cardinal arithmetic in the context of forcing and large cardinals. We will focus on the relationship between the Singular Cardinal Hypothesis, Jensen's square principle, scales, and the tree property. In particular, we will explore constructions involving Prikry type forcings to obtain consistency results. (Received September 14, 2011)

1077-03-246 **Lynn C. Scow*** (lynn@math.uic.edu). *Theories without the independence property.*

A first-order theory has the *independence property (IP)* if there is some formula in the language of the theory that defines a random graph relation on tuples from any saturated enough model of the theory. In [Laskowski, 1992], it was shown that a theory fails to have the independence property just in case any uniformly definable class of subsets is a Vapnik-Chervonenkis class. Given a set X, a class of subsets $\mathcal{C}$ is a *Vapnik-Chervonenkis class* if for any finite set $F \subset X$, intersections $C \cap F$ with $C \in \mathcal{C}$ give less than the maximal number of subsets of F. We will use very homogeneous sequences indexed by ordered graphs in order to characterize this property. (Received August 16, 2011)

1077-03-336 **John Paul Jablonski*** (jjabl365@live.kutztown.edu), 710 Noble Street, Kutztown, PA 19530. *A Proemial Disquisition of Cardinality.*

This presentation centers on aspects of the Cardinal Theory of Sets. I begin with some background definitions, lemmas, theorems, corollaries, and examples and then proceed to present my results. I have proven several theorems on the cardinality of sets, which led to some interesting results on cardinality and the arithmetic of transfinite numbers.

The presentation of the proofs I constructed starts with the concept of finite sets, leads to denumerable sets, and focuses on my original proof of the claim that $|\mathbb{N}| = |\mathbb{N}^*| = |\mathbb{Z}| = \aleph_0$. These results led me to investigate the question the existence of a cardinal number greater than $\aleph_0$ and to my proof of the affirmative.

The talk is organized as follows: I provide basic definitions, lemmas, theorems, and corollaries; I outline several of my arguments; and, that leads to my discovery that there exists a cardinal number β such that

$\beta > \aleph_0$.
(Received August 23, 2011)

1077-03-388 **Grigori Mints*** (gmints@stanford.edu), Department of Philosophy, Stanford University, Stanford, CA 94305-2155. *Ordinal logics and proof theory.*

A short survey of connections between Turing's ordinal logics and restricted conceptions of proof, such as finitist or predicative one. An idea of a completeness proof using universality of the canonical proof search tree.
(Received September 06, 2011)

1077-03-449 **Julia F. Knight*** (knight.1@nd.edu). *The universal Turing machine, and Turing operators.*

Before Turing, there were single-purpose computers, designed to compute a particular function. One of Turing's great contributions was the idea of a universal Turing machine, which could simulate any of the single-purpose machines, by taking as part of its input a set of instructions, a *program*. Modern computers implement this idea.

Turing also defined the notion of relative computability. He imagined a machine that would compute a function $f(n)$, given answers to questions about membership in a set X. Turing imagined the answers coming from an "oracle". We do not need a different computer for each set X. We can use our ordinary universal machine, with an interactive program that may include questions about the oracle set. We write φ_e^X for the function computed using program e with oracle X. A Turing operator is a function $\Phi = \varphi_e$, given by program e, such that for each set $X \subseteq \omega$, φ_e^X is the characteristic function of a set Y. We write $\Phi(X) = Y$.

I will describe some things that we can do with Turing operators, to compare classification problems for various classes of structures. (Received September 01, 2011)

1077-03-476 **Rebecca M. Steiner*** (rsteiner@gc.cuny.edu). *Low$_n$ Boolean Subalgebras.* Preliminary report.

Every low$_n$ Boolean algebra, for $1 \leq n \leq 4$, is isomorphic to a computable Boolean algebra. It is not yet known whether the same is true for $n > 4$. However, it is known that there exists a low$_5$ subalgebra of the computable atomless Boolean algebra which, when viewed as a relation on the computable atomless Boolean algebra, does not have a computable copy. We adapt the proof of this recent result to show that there exists a low$_4$ subalgebra of the computable atomless Boolean algebra which, when viewed as a relation on the computable atomless Boolean algebra, has no computable copy. This result provides a sharp contrast with the one which shows that every low$_4$ Boolean algebra has a computable copy. That is, the spectrum of the subalgebra as a unary relation can contain a low$_4$ degree without containing the degree $\mathbf{0}$, even though no spectrum of a Boolean algebra (viewed as a structure) can do the same. (Received September 03, 2011)

1077-03-507 **David Marker*** (marker@uic.edu), Mathematics, Statistics, and Computer Science, UIC (MC 249), 851 S. Morgan St., Chicago, IL 60607. *Model theory and differential algebraic geometry.*

Model theory provides a new set of tools for approachIng problems in differential algebraic geometry while also raising a new set of interesting questions. I will survey some of these developments. (Received September 06, 2011)

1077-03-983 **Wilfried Sieg*** (sieg@cmu.edu), Department of Philosophy, Carnegie Mellon University, Pittsburgh, PA 15213. *Gödel's theorems, Turing's machines, and mathematical minds.*

The concept of computability is intertwined with investigations on the foundations of mathematics in the early 20th century, most explicitly in the 1930s. That is seen when considering Gödel's incompleteness theorems and Turing's undecidability theorem. They responded to issues emphasized by Hilbert: the consistency and the decision problem.

Around 1950, Gödel and Turing turned attention to mental processes and addressed, in particular, the question: Do the incompleteness theorems justify the claim that the human mind has mathematical abilities that are not shared by any machine? Gödel's view is expressed by the assertion, "The human mind infinitely surpasses any finite machine." Turing predicted that machines would do mathematics on their own - within fifty years.

I will argue that the contrast between these positions is not as stark as it may seem. If one focuses on the real challenge presented by Gödel's theorems, then there is a structurally similar approach to the question that leads to complementary programmatic directions, but is based on dramatically different philosophical perspectives. It can be taken as a challenge for exploring the capacities of the human mathematical mind by constructing automated procedures to find proofs in mathematics. (Received September 15, 2011)

1077-03-1219 **Zhenyun Qin*** (zyqin@fudan.edu.cn), Ann Arbor, MI 48109, **Wenxiu Ma** (wma3@usf.edu), Tampa, FL 33620-5700, and **Hong Cai Ma**, Shanghai. *Painleve integrability of coupled variable coefficient higher-order nonlinear Schrodinger equations with free parameters.* Preliminary report.

By means of singularity analysis, the Painleve integrability is tested for a system of coupled variable-coefficient higher-order nonlinear Schrodinger equations with free parameters. It is shown that only two sub-systems possess the standard Painleve property, and the constraints on coefficients for the Painleve integrability are determined. (Received September 18, 2011)

1077-03-1464 **Meghan Anderson***, manders@math.harvard.edu. *Linear Equations in Valued D-Fields.*

A D-field is a field endowed with a derivative-like operator obeying a (possibly) twisted Leibniz rule. By introducing a valuation that interacts with the operator in an appropriate way, this setting allows us to consider a difference and a differential field in one structure with good model theoretic properties. We'll look at solutions to linear equations in such structures. (Received September 19, 2011)

1077-03-1686 **Gerald E. Sacks*** (sacks@math.harvard.edu). *E-Recursion Theory.*

A survey of E-recursion theory on initial segments of L. Results via priority arguments, forcing and compactness. (Received September 20, 2011)

1077-03-1980 **Allen L. Mann*** (allen.l.mann@gmail.com), Department of Mathematics, Colgate University, 13 Oak Drive, Hamilton, NY 13346. *A logical analysis of the Monty Hall problem.*

A game-show contestant is presented with three doors, one of which contains a prize. After the contestant makes her initial choice, the host opens one of the other doors, showing that it does not contain the prize. He then offers the contestant the opportunity to change her mind. Should the contestant stick with the door she originally choose, or should she switch?

We present a novel analysis of the Monty Hall problem using probabilistic logic with imperfect information. (Received September 21, 2011)

1077-03-1998 **Stephen Flood*** (sflood@nd.edu), Department of Mathematics, 255 Hurley Hall, Notre Dame, IN 46556. *Computing the strength of some combinatorial theorems.* Preliminary report.

Our goal is to classify combinatorial theorems based on the theorems that they can be used to prove. The field of reverse mathematics provides a robust framework for this study. Because there are significant connections between reverse mathematics and computability theory, this classification also helps us understand the computational strength of these combinatorial theorems.

In this talk, we will introduce reverse mathematics and survey the strength of a few noteworthy theorems. We will also discuss new research on the strength of a theorem of Erdős and Galvin which is closely related to infinite Ramsey's theorem. (Received September 21, 2011)

1077-03-2035 **Rahim N Moosa*** (rmoosa@math.uwaterloo.ca), University of Waterloo, Waterloo, ON N2L 3G1. *Some new techniques in differential algebraic geometry from model theory.*

In recent years there have been some developments in model theory (around the "canonical base property" and appearing in the work of Chatzidakis, Pillay, and myself) that when specialised to differentially closed fields would seem to bring new tools to the classification theory of finite-rank differential algebraic varieties. For example the existence of a maximal fibration whose fibres are isomorphic to algebraic varieties over the constants. I will try to translate these model-theoretic developments (which, incidentally, were themselves inspired by theorems on compact Kaehler manifolds from the eighties) into the language of differential algebraic geometry, and give some idea as to how they can be used. (Received September 21, 2011)

1077-03-2392 **Christopher P Porter*** (cporter2@nd.edu), 255 Hurley Hall, Notre Dame, IN 46556. *Algorithmic Randomness and Pathological Computable Measures.* Preliminary report.

Since the early 2000s, a significant amount of work in computability theory has been conducted in the area of algorithmic randomness. The central idea of this area is to consider as random those infinite binary sequences that do not contain any effectively specifiable regularities (where different definitions of randomness correspond to different ways of making "effectively specifiable regularities" precise). This is a natural approach to studying randomness when the underlying probability measure on the collection of sequences is uniform (so that the probability of the occurrence of a 0 is 1/2). However, I will discuss some recent results that show that when we consider randomness with respect to certain non-uniform computable measures, all sorts of pathological behavior emerges. (Received September 22, 2011)

1077-03-2706 **Theodore A Slaman*** (slaman@math.berkeley.edu), Department of Mathematics, University of California, Berkeley, Berkeley, CA 94720-3840. *The Mathematics of Relative Definability.*

Alan Turing had the remarkably prescient insight that understanding the means by which we work with things can be as important as, or even equivalent to, understanding those things. We will discuss some of the mathematical developments arising from his early investigations. (Received September 22, 2011)

1077-03-2750 **Paul Baginski*** (pbaginsk@smith.edu), Department of Mathematics, 44 College Lane, Northampton, MA 01063, and **Tuna Altinel** (altinel@math.univ-lyon1.fr). *Nilpotence in Groups with Bounded Chains of Centralizers.*

A group in which all chains of centralizers have finite length is called $\mathfrak{M}_C$. One often encounters such groups in group theory and in model theory. For example, stable groups are not only $\mathfrak{M}_C$, but they possess a finite centralizer dimension (fcd), a uniform bound on the length of centralizer chains. We have shown that in a $\mathfrak{M}_C$-group G, for any nilpotent subgroup H, there is a definable subgroup $d(H) \leq G$ containing H which is nilpotent of the same nilpotence class as H. For groups with fcd, we obtain that these definable envelopes are uniformly definable in terms of the dimension of G and the nilpotence class of H. These results give an alternate proof of a result of Wagner that the Fitting subgroup of a $\mathfrak{M}_C$ group is definable (and in fact, equal to the set of bounded left Engel elements). We also show that the Hirsch-Plotkin radical for a group with fcd is equal to the set of left Engel elements. (Received September 22, 2011)

1077-03-2897 **Joseph S. Miller*** (jmiller@math.wisc.edu). *A small step beyond the Turing degrees.*

The computable real numbers were introduced in Alan Turing's seminal 1936 paper, "On computable numbers, with an application to the Entscheidungsproblem." They were defined to be the reals with computable decimal expansions, but the following year Turing published a correction, "modifying the manner in which computable numbers are associated with computable sequences, the totality of computable numbers being left unaltered." His second representation avoids the problem of non-uniformity at rationals that have finite decimal expansions and is suitable for applying computability theory to functions on the reals.

It turns out that to measure the complexity of continuous function on the reals we need to go beyond the Turing degrees. This is closely related to the reason that Turing rejected his original definition of the computable real numbers: the difficulty of capturing computability on a connected space (the real numbers) using representations in a totally disconnected space (infinite decimal sequences). We discuss the extension of the Turing degrees to a degree structure that can measure the complexity of objects from analysis. We then turn to an interesting class of objects, Levin's neutral measures, that always have non-Turing degree. (Received September 22, 2011)

1077-03-2911 **Iraj Kalantari** and **Mojtaba Moniri*** (m-moniri@wiu.edu), Department of Mathematics, Western Illinois University, 1 University Circle, Macomb, IL 61455. *Beatty Sequences and Exponential Complexity Issues.* Preliminary report.

We prove results of the following type with implications to algorithms for binary expansions and Beatty sequences of certain low complexity real numbers. Consider two double sequences $(p_n, q_n)_{n\in\mathbb{N}}$ defined by $p_0 = 200$, $q_0 = 500$, $p_{n+1} = p_n - 0.1(q_n - 500)$, and $q_{n+1} = q_n + 0.2(p_n - 100)$; and $(r_n, s_n)_{n\in\mathbb{N}}$ defined by $r_0 = 1$, $s_0 = 10$, $r_{n+1} = 2r_n s_n$, and $s_{n+1} = s_n^2 - 2r_n^2$. Then for all $n \in \mathbb{N}$, the cardinality of $\{i \leq 2^n \mid (q_i - 500)(q_{i+1} - 500) < 0\}$ is odd if and only if $r_n s_n < 0$. (Received September 22, 2011)

1077-03-2928 **Vikram Jeet Singh*** (vikram31782@gmail.com), H.no 908/7 Street no.4, Kot Atma Singh, Ram Bagh, Amritsar, Punjab 143001, India. *AN EPQ Model for Deterioration Items and Exponential Demand Rate Taking into Account the Time Value of Money.* Preliminary report.

In this study we develop an inventory model with exponential demand with Time Value of Money. Deterioration occurs as soon as the items are received into inventory and it follows two parameter Weibull distributions. There is no repair or replacement of deteriorating items during the replenishment cycle. Product transactions are followed by instantaneous cash flow. Shortages are allowed and partially backlogged. The system operates for a prescribed period of a planning horizon. Production rate is demand rate dependent. The problem is discussed under the inflationary environment. (Received September 23, 2011)

1077-03-2963 **W. Hugh Woodin*** (woodin@math.berkeley.edu<mailto:woodin@math.berkeley.edu>), Department of Mathematics, University of California, 721 Evans Hall, Berkeley, CA 94720-3840. *The end of the inner model program: ultimate L or not ultimate L*

The Inner Model Program is the search for generalizations of Gödel's L which are compatible with the existence of large cardinals. There have been a series of notable successes in this program and arguably these successes provide some of our deepest insights into the nature of strong axioms of infinity. Supercompact cardinals quickly emerged 40 years ago as the principal target for the Inner Model Program and are just beyond the level of large cardinals that the current theory can handle (assuming iteration hypotheses). In an unexpected turn of events it is now known that (subject to very general constraints) the solution to the inner model problem for exactly one supercompact cardinal must yield the "final" inner model, ultimate L. Thus the inner model program will either end in ultimate triumph or it will end in ultimate failure with the latter resulting from an "anti" inner model theorem. Which future does the subject face? (Received October 06, 2011)

05 ► Combinatorics

1077-05-8 **Larry Guth*** (lguth@cims.nyu.edu), Courant Institute, 251 Mercer St., New York, NY 10012. *The polynomial method in combinatorial geometry.*

In the last five years, several difficult combinatorial problems have been solved by an unexpected argument using polynomials. The combinatorial problems involved have to do with the way that lines intersect in a vector space. We will discuss the example of the joints problem - a problem about the intersections of lines in $\mathbb{R}^3$. This problem was posed in the early 90's and was open for close to twenty years. We now have a one page proof, which I will explain in all details.

Why are polynomials useful in these questions? I'm not sure that I understand, but I'll discuss this question from one or two perspectives.

After that, I'll discuss some of the other applications of the polynomial method, including the Erdős distinct distance problem for points in the plane. (Received September 21, 2011)

1077-05-40 **Chelsea R. Snyder*** (snydercr1@gcc.edu) and **Christina C. Scurlock**. *Higher Rectification and Polytope Numbers: The Simplex Case.* Preliminary report.

A polytope number is a term in the integer sequence which is determined by the arrangement of points in a polytope. Although the polygonal numbers are easily determined, our understanding of polytope numbers in higher dimensions is not yet complete. H.K. Kim has recently established a method for constructing the number sequence of any uniform polytope in any dimension. We will discuss Kim's inductive process as it applies to birectified simplices. In addition, we will explore higher rectification in relation to polytope numbers to propose conjectures for further research. This project was supervised by Dr. Michael A. Jackson. (Received June 29, 2011)

1077-05-45 **Patrick Bahls*** (pbahls@unca.edu), Department of Mathematics, University of North Carolina, Asheville, CPO #2350, Asheville, NC 28804-8511, and **Nicole A. Gin**. *Clawfreeness of powers of graphs.* Preliminary report.

The question of whether a graph G contains the *claw* $K_{1,3}$ as an induced subgraph is an interesting one. For instance, a good deal is known about the hamiltonicity and more general cycle structure of claw-free graphs, and clawfreeness implies nice properties about certain graph polynomials. The *powers* G^n of a graph G play a similarly important role in many areas of graph theory.

For any $n \in \mathbb{N}$ we determine a minimal collection $\mathcal{G}_n$ of graphs such that $|\mathcal{G}_n| = n$ and if the power G^n contains a claw then some $H \in \mathcal{G}_n$ appears as an induced subgraph of G. We use this result to describe precisely those powers of a tree T which are claw-free and close with several open problems concerning more general graphs G. (Received July 06, 2011)

1077-05-70 **Michael A Jackson*** (majackson@gcc.edu), 100 Campus Drive, Grove City College, Grove City, PA 16127. *Geometric triangulation of interior polytope number sequences.* Preliminary report.

Polytope numbers are figurate number sequences created from the geometry of polytopes. Building on the classical work of polygonal numbers, H.K. Kim has recently outlined a method for computing the polytope number sequence for any convex uniform polytope. In addition, Kim found the sequences for the regular polytopes and showed that every d-dimensional regular polytope number sequence can be written as a linear combination of d-dimensional simplex number sequences with nonnegative integer coefficients. Joon Yop Lee has extended this to show that for any uniform polytope there exists such a linear combination with nonnegative coefficients using a pointed triangulation of the polytope from which the sequence is created. In this talk, we will go over a proof of Lee's result using the geometry of the polytopes. We will use this proof to show that the interior number sequence for a given polytope is also a linear combination of simplex number sequences with the same nonnegative integer coefficients in the reverse order. (Received July 17, 2011)

1077-05-80 **Arthur T. White*** (arthur.white@wmich.edu). *Topological Models of 3-configurations.* Preliminary report.

The iconic model of the Fano plane has several deficiencies, most notably three extraneous intersections of the lines. These are remedied by imbedding K(7), the collinearity (or Menger) graph for the Fano plane, on the torus. This topological approach can be generalized in two directions, as the Fano plane is both PG(2,2) and a 3-configuration. In Proc. London Math. Soc. 3 (70) (1995), 33-55, the author finds topological models for PG(2,n), for all prime powers n. In the present paper we study 3-configurations: finite geometries for which (i) every line has exactly 3 points; (ii) every point is on exactly r lines; (iii) every pair of distinct points belong to at most one line. Topological models are known for the geometries of Pappus and Desargues, and for AG(2,3). If, in (iii) above, "at most" is replaced by "exactly", the collinearity graph is complete and we have a Steiner triple system. Otherwise, if the collinearlity graph is strongly regular, we have a partially balanced incomplete block design. We consider three familiar classes of strongly regular graphs: (a) K(m(n)), where m, n > 1; (b) L(K(n)); (c) L(K(n,n)). We use voltage graphs, medial constructions, and surgery respectively to construct our models. (Received July 19, 2011)

1077-05-91 **Andy Hardt** (hardta@carleton.edu) and **Justin M. Troyka*** (troykaj@carleton.edu). *Restricted Symmetric Signed Permutations.*

The symmetry group $D_4 \oplus \mathbb{Z}_2$ acts on the set of signed permutations by rotations, reflections, and bar operations (flip the sign of each letter). Following Egge's work (2007) on unsigned permutations, we enumerate the signed permutations that, given a symmetry subgroup H and a set R of 2-letter signed patterns, are invariant under H and avoid R. Mansour and West (2002) began this work by enumerating the signed permutations that avoid R, not taking symmetries into account. Dukes and Mansour (2007) continued by enumerating signed involutions that avoid R. In this talk, we consider the remaining subgroups of $D_4 \oplus \mathbb{Z}_2$, thus completing the enumeration. The resulting sequences include the Catalan numbers and the central binomial coefficients, and many of them are given recursively. A few of the sets can be counted in two different ways, yielding combinatorial identities. (Received July 25, 2011)

1077-05-122 **Richard H Hammack*** (rhammack@vcu.edu), Dept. of Mathematics and Applied Mathematics, Virginia Commonwealth University, Box 842014, Richmond, VA 23284-2014. *Cancellation for the direct product of digraphs.*

This talk concerns the *cancellation problem* for the direct product $A \times B$ of digraphs. Given digraphs A, B and C, we say that *cancellation holds* if $A \times C \cong B \times C$ implies $A \cong B$.

A classic result by Lovász gives exact conditions on C that guarantee whether cancellation holds or fails: If C admits a homomorphism into a disjoint union of directed cycles of prime lengths, then there exist non-isomorphic digraphs A and B for which $A \times C \cong B \times C$. Conversely, if no such homomorphism exists, then $A \times C \cong B \times C$ implies $A \cong B$.

However, this does not entirely resolve the cancellation problem. If C is arbitrary, we might reasonably ask what conditions on A (or B) guarantee that $A \times C \cong B \times C$ implies $A \cong B$. This talk spells out those exact conditions. Moreover, for arbitrary A and C we enumerate and describe all digraphs B for which $A \times C \cong B \times C$. The solution involves a new construction called the *factorial* of a digraph. (Received July 28, 2011)

1077-05-124 **Joshua D Laison*** (jlaison@willamette.edu), **Colin Starr** and **Andrea Walker**. *Prime Distance Graphs.*

A graph is a prime distance graph if its vertices can be labeled with distinct integers such that for any two adjacent vertices, the difference of their labels is prime. Surprisingly, the existence of prime distance labelings of some infinite families of graphs is closely related to several well-known statements in Number Theory. In particular, we show that Dutch windmill graphs and paper mill graphs are prime distance graphs if and only if the Twin Prime Conjecture and dePolignac's Conjecture are true, respectively. (Received July 28, 2011)

1077-05-136 **Rosalie J. Carlson*** (rcarlson@hmc.edu), Harvey Mudd College, 340 E Foothill Blvd, Claremont, CA 91711, **Stephen Flood** (sflood@nd.edu), University of Notre Dame, Notre Dame, IN 46556, **Kevin W. O'Neill** (koneill@hmc.edu), Harvey Mudd College, 340 E Foothill Blvd, Claremont, CA 91711, and **Francis Edward Su** (su@math.hmc.edu), Department of Mathematics, Harvey Mudd College, Claremont, CA 91711. *A Turán-type Problem for Circular Arc Graphs.*

A circular arc graph is the intersection graph of a collection of connected arcs on the circle. We consider a Turán-type problem for circular arc graphs: for n arcs, if m and M are the minimum and maximum number of arcs that contain a common point, what is the maximum number of edges the circular arc graph can contain? We establish a sharp bound that, given a fixed minimum m arcs that contain a common point, can be used to show that if the circular arc graph has enough edges, there must be a point that is covered by at least M arcs. In the case $m = 0$, we recover results for interval graphs established by Abbott and Katchalski (1979). We suggest applications to voting situations with interval or circular political spectra. (Received July 29, 2011)

1077-05-190 **Korinne Dobosh***, Department of Mathematics, Montclair State University, Montclair, NJ 07043, and **Samuel Kennedy**, School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623. *Rank numbers of rook's graphs.*

A k-ranking of a graph G is a function $f : V(G) \rightarrow \{1, 2, ..., k\}$ such that if $f(u) = f(v)$ then every $u - v$ path contains a vertex w such that $f(w) > f(u)$. The rank number of G, denoted by $\chi_r(G)$, is the minimum k such that a k-ranking exists for G. Many papers have appeared in the topic of ranking, and several of them investigated the rank number of certain classes of Cartesian products. The rook's graph, denoted by $K_n \times K_m$, is the Cartesian product of complete graphs K_n and K_m. This graph represents the moves of a rook on an $n \times m$ chess board. This graph contains a multitude of paths between any given vertices, and we must consider all paths between two vertices to ensure a labeling satisfies the ranking condition. We will discuss our results, including an explicit formula for $\chi_r(K_n \times K_m)$ for certain m, as well as new bounds for $\chi_r(K_n \times K_m)$ for all n and m, and results involving the structure of all minimal rankings of $K_n \times K_m$. (Received August 10, 2011)

1077-05-191 **Daniel S. Shetler** (dshetler12@my.whitworth.edu), Department of Mathematics, Whitworth University, Spokane, WA 99251, and **Michael Wurtz***, Department of Mathematics, Northwestern University, Evanston, IL 60208. *On Some Multicolor Ramsey Numbers Involving $K_3 + e$ and $K_4 - e$.*

The Ramsey number $R(G_1, G_2, G_3)$ is the smallest n such that for all 3-colorings of the edges of K_n there is a monochromatic G_1 in the first color, G_2 in the second color, or G_3 in the third color. We study the bounds on various 3-color Ramsey numbers $R(G_1, G_2, G_3)$, where $G_i \in \{K_3, K_3 + e, K_4 - e, K_4\}$. The minimal and maximal combinations of G_i's correspond to the classical Ramsey numbers $R_3(K_3)$ and $R_3(K_4)$, respectively, where $R_3(G) = R(G, G, G)$. Here, we focus on the much less studied combinations between these two cases.

Through computational and theoretical means we establish that $R(K_3, K_3, K_4 - e) = 17$, and by construction we raise the lower bounds on $R(K_3, K_4 - e, K_4 - e)$ and $R(K_4, K_4 - e, K_4 - e)$. For some G and H it was known that $R(K_3, G, H) = R(K_3 + e, G, H)$; we prove this is true for several more cases including $R(K_3, K_3, K_4 - e) = R(K_3 + e, K_3 + e, K_4 - e)$.

Ramsey numbers generalize to more colors, such as in the famous 4-color case of $R_4(K_3)$, where monochromatic triangles are avoided. It is known that $51 \leq R_4(K_3) \leq 62$. We prove the surprising theorem stating that if $R_4(K_3) = 51$ then $R_4(K_3 + e) = 52$, otherwise $R_4(K_3 + e) = R_4(K_3)$. (Received August 10, 2011)

1077-05-192 **Maxwell Bileschi***, Department of Mathematics, University of Buffalo, 244 Mathematics Building, Buffalo, NY 14260-2900, and **Meridangela Gutierrez Jhong**, School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623. *A complete characterization of optimal vertex rankings of paths, cycles, and joins of graphs.*

A k-ranking of a graph is a labeling of the vertices with $\{1, 2, ..., k\}$ where any path between two vertices of the same label contains a vertex with a strictly larger label. These rankings have been applied to the scheduling of manufacturing systems, monitoring of communication networks, factorization of Cholesky matrices in parallel, and VLSI layout generation.

Following along the lines of the chromatic number, the rank number of a graph, $\chi_r(G)$, is defined to be the smallest k such that G has a k-ranking. In addition to $\chi_r(G)$-rankings, we investigate sum-optimal rankings, where the sum over all labels is minimized. While k-rankings and sum-optimal rankings have been studied, little has been done to quantify the number of these rankings. We use tools from both graph theory and combinatorics to characterize and enumerate all possible χ_r-rankings and sum-optimal rankings for paths, cycles, and joins of

graphs. It is likely that the ideas presented in this project can be applied to larger families of graphs. (Received August 10, 2011)

1077-05-193 **Ryan Held***, School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623, and **Lauren Stemler**, Dept. of Mathematics, Statistics, and CS, 118 Valentine Hall, 23 Romoda Drive, St. Lawrence University, Canton, NY 13617. *Representations of Graphs modulo N.*

According to Erdos and Evans a graph G has a representation modulo $N > 1$ if all its vertices can be assigned distinct labels from the set $\{0, 1, 2, ..., N-1\}$ such that two vertices in G are adjacent if and only if the difference of their labels is relatively prime to N . Among all possible representation numbers of a graph G, we focus on the smallest N that satisfies these conditions for a graph G, named the representation number of G. Another closely related concept that is of great interest is a representation of G with least number of prime factors. The smallest number of prime factors in a representation of G is referred as the Prague dimension of G. In this paper, we discuss the representation number and the Prague dimension of a complete graph minus a wheel, multiple disjoint wheels of the same size, and multiple disjoint wheels of different sizes. The representation number and new results for wheels and broken wheels are also discussed. (Received August 10, 2011)

1077-05-208 **Geremias Polanco Encarnacion*** (gpolanc2@illinois.edu), Math Department, University of Illinois, 1409 W. Green St., Urbana, IL 61801. *On Minimun Excluded Type Algorithm, Golden Ratio, Beatty and Sturmian Sequences.*

Let α be an irrational number and ρ any real number. The Sturmian sequence $a_n = \lfloor \alpha n + \rho \rfloor$ for $n = 1, 2, 3, ...$ has been greatly studied, specially after the work of Morse and Hedlund relating these types of sequences to dynamical systems. They also have application to other fields of mathematics, as well as various fields of physics, biology and computer science. In particular the case $\rho = 0$, or the Beatty sequence case, has been the theme of much research. Indeed, in this case $\frac{1}{\alpha} + \frac{1}{\beta} = 1$, if and only if the sets $A = \{\lfloor \alpha \rfloor, \lfloor 2\alpha \rfloor, \lfloor 3\alpha \rfloor ...\}$ and $B = \{\lfloor \beta \rfloor, \lfloor 2\beta \rfloor, \lfloor 3\beta \rfloor ...\}$ contain every integer n, with no n appearing in both A and B. We present here an algorith called *minimun excluded with skiping*, and show that sturmian and other sequences can be generated by this algorithm. We also give some characterization for specific families of irrational α's, including the Golden ratio. These families are special because of their unique continued fraction expansion or because of their algebraic nature. (Received August 11, 2011)

1077-05-209 **Ko-Wei Lih*** (makwlih@sinica.edu.tw), P. O. Box 23-216 Taipei, Taipei City, 10699, Taiwan, and **Daphne Der-Fen Liu** (dliu@calstatela.edu). *On the strong chromatic index of cubic Halin graphs.*

A strong edge coloring of a graph G is an assignment of colors to the edges of G such that two distinct edges are colored differently if they are incident to a common edge or share an endpoint. The strong chromatic index of a graph G, denoted $s\chi'(G)$, is the minimum number of colors needed for a strong edge coloring of G. A Halin graph G is a plane graph constructed from a tree T without vertices of degree two by connecting all leaves through a cycle C. If a cubic Halin graph G is different from two particular graphs Ne_2 and Ne_4, then we prove $s\chi'(G) \leq 7$. This solves a conjecture proposed in W. C. Shiu, W. K. Tam, The strong chromatic index of complete cubic Halin graphs, Appl. Math. Lett. 22 (2009) 754–758. (Received August 12, 2011)

1077-05-211 **Briana Foster-Greenwood***, Department of Mathematics, University of North Texas, 1155 Union Circle #311430, Denton, TX 76203-5017. *Reflection groups: Comparing length and codimension.*

The geometry and combinatorics of finite reflection groups exhibits a rich and fruitful history. Modern investigations focus on deformation theory and Hochschild cohomology. We present new results on complex reflection groups comparing absolute reflection length and codimension of fixed point spaces. Analysis of the related posets (using algorithms developed in GAP, among other tools) allows an explicit description of cohomology. (Received August 12, 2011)

1077-05-232 **Michelle A. Lastrina*** (lastrina@iastate.edu). *Sum-list-coloring and sc-greedy graphs.* Preliminary report.

Let $G = (V, E)$ be a graph and let f be a function that assigns list sizes to the vertices of G. It is said that G is f-choosable if for every assignment of lists of colors to the vertices of G for which the list sizes agree with f, there exists a proper coloring of G from the lists. The sum choice number is the minimum of the sum of list sizes for f over all choosable functions f for G. The sum choice number of a graph is always at most the sum $|V| + |E|$. When the sum choice number of G is equal to this upper bound, G is said to be sc-greedy. This poster will illustrate some general results with respect to the sum choice number and sc-greedy graphs as well as provide examples of some graphs that are sc-greedy. (Received August 15, 2011)

1077-05-256 **Jessica Striker***, jessica@math.umn.edu, and **Nathan Williams**, will3089@umn.edu.
Promotion and rowmotion.

We present an equivariant bijection between two actions—promotion and rowmotion—on order ideals in certain posets. This bijection simultaneously generalizes a result of R. Stanley concerning promotion on the linear extensions of two disjoint chains and recent work of D. Armstrong, C. Stump, and H. Thomas on root posets and noncrossing partitions. We apply this bijection to several classes of posets, obtaining equivariant bijections to certain objects under rotation. In particular, we obtain an equivariant bijection between plane partitions of height two under rowmotion and noncrossing partitions with a fixed number of blocks under rotation. (Received August 16, 2011)

1077-05-271 **Ibrahim Abdou Saleh*** (iasaleh@math.ksu.edu), 2128 Prairie Glen Place, Manhattan, KS 66502. *A non commutative cluster structure on some hyperbolic algebras.* Preliminary report.

In this talk, I will introduce a non-commutative cluster structure that is related naturally to some Hyperbolic algebras like Weyl Algebras, classical and quantized universal enveloping algebras of the Lie algebra sl_2 and the quantum coordinate algebra of SL(2). Some properties of this structure will be presented. The cluster structure gives rise to some combinatorial data, called cluster strings, which are used to introduce a class of representations of Weyl algebras. Irreducible and indecomposable representations are also introduced from the cluster strings. (Received August 17, 2011)

1077-05-308 **Richard Ehrenborg** (jrge@ms.uky.edu), 719 Patterson Office Tower, University of Kentucky, Lexington, KY 40506-0027, and **JiYoon Jung*** (jjung0328@uky.edu), 719 Patterson Office Tower, University of Kentucky, Lexington, KY 40506-0027. *The topology of restricted partition posets.*

For each composition $\vec{c}$ we show that the order complex of the poset of pointed set partitions $\Pi^{\bullet}_{\vec{c}}$ is a wedge of $\beta(\vec{c})$ spheres of the same dimensions, where $\beta(\vec{c})$ is the number of permutations with descent composition $\vec{c}$. Furthermore, the action of the symmetric group on the top homology is isomorphic to the Specht module S^B where B is a border strip associated to the composition $\vec{c}$. We also study the filter of pointed set partitions generated by knapsack integer partitions and show the analogous results on homotopy type and action on the top homology.

This is joint work with Richard Ehrenborg. (Received August 19, 2011)

1077-05-320 **Steven V Sam*** (ssam@math.mit.edu) and **Peter Tingley**. *Torus actions, multi-partitions, and crystals.*

The Misra-Miwa model gives a $\widehat{\mathfrak{sl}}_n$-crystal graph structure on the set of all partitions, and each connected component models the basic representation. Recently, Fayers gave a "deformation" of this crystal structure, one for each irrational number in a certain interval. His definition is combinatorial and uses Stembridge's local characterization of crystals. On the other hand, Saito showed how to get crystal structures from Nakajima's quiver varieties. We give a method of extracting a combinatorial model from Saito's construction which depends on a choice of torus action, and show that the resulting combinatorics give Fayers' crystals. This gives an algebraic definition of Fayers' operators, as well as a more conceptual proof that his construction is correct. It also readily generalizes to give families of crystals for all highest weight representations of $\widehat{\mathfrak{sl}}_n$, which we describe combinatorially using multi-partitions. (Received August 21, 2011)

1077-05-364 **Dara Moazzami*** (dmoazzami@ut.ac.ir), University of Tehran, School of Engineering, Faculty of Engineering Science, 14395-195 Tehran, Iran, **Morteza Dadvand** (dadvand@ut.ac.ir), University of Tehran, School of Engineering, Department of Algorithms and Computation, 14395-195 Tehran, Iran, and **Ali Moeini** (moeini@ut.ac.ir), University of Tehran, School of Engineering, Faculty of Engineering science, 14395-195 Tehran, Iran. *Complexity of Tenacity Parameter in Networks.*

In this paper we are settling a long-standing open problem. We prove that it is NP-hard to recognize T-tenacious graphs for any fixed positive rational number T.

The concept of tenacity of a graph G was introduced by Cozzens, Moazzami and Stueckel in 1992, as a useful measure of the "vulnerability" of G. The tenacity of a graph G, T(G), is defined by $T(G) = min\{\frac{|S|+\tau(G-S)}{\omega(G-S)}\}$, where the minimum is taken over all vertex cutsets S of G. We define $\tau(G-S)$ to be the number of vertices in the largest component of the graph G - S, and $\omega(G-S)$ be the number of components of G - S. A connected

graph G is called T-tenacious if $\mid S \mid +\tau(G-S) \geq T\omega(G-S)$ holds for any subset S of vertices of G with $\omega(G-S)>1$. If G is not complete, then there is a largest T such that G is T-tenacious ; this T is the tenacity of G. On the other hand, a complete graph contains no vertex cutset and so it is T-tenacious for every T.
(Received August 26, 2011)

1077-05-372 **Vidya Venkateswaran*** (vidyav@caltech.edu), Mathematics 253-37, Caltech, Pasadena, CA 91125. *Vanishing Integrals for Hall-Littlewood Polynomials.*

In a recent paper, Rains and Vazirani used Hecke algebra techniques to develop (q,t)-generalizations of a number of well-known vanishing identities for Schur functions. However, their approach does not work directly at $q=0$ (the Hall-Littlewood level). We discuss a technique that is more combinatorial in nature, and allows us to obtain generalizations of some of their results at $q=0$ as well as a finite-dimensional analog of a recent summation formula of Warnaar. We will also briefly explain how these results are related to p-adic representation theory. Finally, we will explain how this method can be extended to give an explicit construction of Hall-Littlewood polynomials of type BC. (Received August 31, 2011)

1077-05-387 **Jeffrey Manning*** (jmanning@caltech.edu), MSC 658, California Institute of Technology, 1200 E. California Blvd., Pasadena, CA 91126. *Distinguishing Chromatic Numbers of Planar Maps.*

A map is an embedding of a simple graph in a closed surface. The distinguishing chromatic number, $\chi_D(M)$, of a map M is the minimal number of colors needed to color the vertices of M so that no two adjacent vertices receive the same color, and no nontrivial automorphism of M fixes the coloring. We classify all planar maps M with $\chi_D(M) \geq \chi(M)+2$. As a Corollary of this, we show that $\chi_D(M) \leq 5$ for all planar maps M, with two exceptions. Also, using the faithfulness of planar embeddings of 3-connected planar graphs, we complete the classification of 3-connected planar graphs G with $\chi_D(G) \geq \chi(G)+2$. (Received August 28, 2011)

1077-05-417 **Linda M. Lesniak*** (lindalesniak@gmail.com). *Chvátal's t_0-tough conjecture.* Preliminary report.

For a nonnegative real number t, a noncomplete graph G is $t-tough$ if $|S| \geq t \cdot k(G-S)$ for every vertex cut S of G, where $k(G-S)$ denotes the number of components of $G-S$. In 1973, Chvátal conjectured that there exists a t_0 such that every t-tough graph is hamiltonian. The history and current status of this conjecture will be discussed. (Received August 30, 2011)

1077-05-445 **Risto Atanasov**, **Mark Budden**, **Joseph DiNatale**, **Lindsay Erickson**, **Robert Fenney**, **William Nathan Hack**, **Maxwell Hostetter*** (mh1354@students.armstrong.edu), **Joshua Lambert** and **Warren Shreve**. *Nim on wheel graphs.* Preliminary report.

The game Nim is a two player combinatorial game in which players take stones from distinct piles. Although a complete solution has been found for Nim, the game's graph theory counterpart (appropriately dubbed Nim on graphs) still has many unresolved issues. Nim on graphs is played by moving a game piece along the edges of a graph. Each edge on the graph is assigned a positive integer weight and as the game piece moves along an edge, the player reduces the weight of the edge to a nonnegative integer. In the event that the weight of an edge becomes zero, we remove the edge from the graph. The game ends when the game piece is on a vertex with no incident edges. We expand upon previous strategies for Nim on paths and cycles to explore winning strategies for Nim on wheel graphs. (Received September 01, 2011)

1077-05-457 **Richard P. Stanley***, Department of Mathematics, M.I.T., Cambridge, MA 02139. *Chromatic symmetric functions of certain graphs.*

The *chromatic symmetric function* of a graph G with vertex set $V=\{v_1,\ldots,v_p\}$ is the power series $X_G = \sum_\kappa x_{\kappa(v_1)} \ldots x_{\kappa(v_p)}$, where κ ranges over all proper coloring of G with the colors $1,2,\ldots$. It is a generalization of the chromatic polynomial of G for which we keep track of how many times each color is used. Since X_G is a symmetric function, it can be written as a polynomial in the elementary symmetric functions $e_1, e_2, \ldots$. An intriguing conjecture asserts that this polynomial has nonnegative coefficients when G is the incomparability graph of a $(3+1)$-avoiding poset. We will discuss the significance of this conjecture and mention some interesting special cases. (Received September 02, 2011)

1077-05-482 **David C Clark*** (dcclark@mtu.edu), Department of Mathematical Sciences, 1400 Townsend Drive, Houghton, MI 49931, and **Vladimir D Tonchev**. *Quantum codes from finite geometry designs.*

In the last 15 years, researchers have proposed many different methods for constructing quantum codes from classical codes. We present results which show how finite geometry designs are especially well suited to be used with many of these constructions. Using several of these constructions, we produce infinite classes of quantum codes which inherit their best properties from finite geometry designs. We also give several results concerning the properties of the underlying classical codes. (Received September 04, 2011)

1077-05-483 **Eric Schmutz** (schmutze@drexel.edu) and **Le Yu*** (ly32@drexel.edu), Korman Center 209, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104. *Automorphisms of Random Trees.* Preliminary report.

For each labelled tree T, let $|Aut(T)|$ be the number of automorphisms T has. Let $\mu_n = \frac{1}{n^{n-2}} \sum_T |Aut(T)|$ be the expected order of the automorphism group for uniform random labelled trees on $[n]$. It is well known that there is a constant $\rho_1 > 1$ such that, for all sufficiently large n,

$$\rho_1^{n(1-\epsilon)} < \mu_n < \rho_1^{n(1+\epsilon)}.$$

We have proved that there is a *strictly smaller* constant ρ_0 such that, with asymptotic probability one,

$$\rho_0^{n(1-\epsilon)} < |Aut(T)| < \rho_0^{n(1+\epsilon)}.$$

Thus most trees have an automorphism group that is *much* smaller than the average order: if $\mathbb{P}_n$ is the uniform probability measure in the set of all n^{n-2} labelled trees on $[n]$, then there is a constant $\delta > 0$ such that

$$\mathbb{P}_n \left(|Aut(T)| > \frac{\mu_n}{(1+\delta)^n} \right) = o(1).$$

An asymptotic formula for $\mathbb{E}(\log |Aut(T)|)$ is proved, and we conjecture that $|Aut(T)|$ is asymptotically lognormal. (Received September 04, 2011)

1077-05-491 **Lucas J Rusnak*** (Lucas.Rusnak@txstate.edu), Texas State University, San Marcos, TX 78666, and **Nathan Reff** (reff@math.binghamton.edu), Binghamton University, Binghamton, NY 13902. *An oriented hypergraphic approach to algebraic graph theory.*

Oriented hypergraphs are an oriented incidence structure that extends the concepts of graphs and signed graphs. We demonstrate that the ij^{th} entry of the signed adjacency matrix of an oriented hypergraph is the aggregate number of signed vertex-walks between vertices v_i and v_j. We also show that the Laplacian matrix of an oriented hypergraph, which is the difference of its degree and signed adjacency matrices, is also the product of its incidence matrix and its transpose. Moreover, the familiar line graph results can be replaced by incidence duality. Finally, we discuss a direct combinatorial interpretation of the entries of the Laplacian using the concept of *signed weak walks*. (Received September 04, 2011)

1077-05-514 **Peter John Slater*** (slaterp@uah.edu). *"Nature is tricky, but she is not nasty." - Uncle Paul.*

Keep in mind that we are talking mathematics, more generally science, and not climate and the associated tornados, hurricanes and tsunamis. Mathematicians conceptualize. We seek connections and interrelationships, and we generalize. The point to be made is that adopting the optimism inherent in Uncle Paul's statement is helpful in the endeavors. Illustrations of the principle will be given for complementarity and duality and for distance problems such as centrality, facility location, domination and location theory. (Received September 06, 2011)

1077-05-519 **Hsin-Hao Lai*** (hsinhaolai@nknucc.nknu.edu.tw) and **Ko-Wei Lih**. *Acyclic List Edge Coloring of Planar Graphs.*

A proper edge coloring of a graph is said to be *acyclic* if any cycle is colored with at least three colors. The *acyclic chromatic index*, denoted $a'(G)$, is the least number of colors required for an acyclic edge coloring of G. An *edge-list* L of a graph G is a mapping that assigns a finite set of positive integers to each edge of G. An acyclic edge coloring ϕ of G such that $\phi(e) \in L(e)$ for any $e \in E(G)$ is called an *acyclic L-edge coloring* of G. A graph G is said to be *acyclically k-edge choosable* if it has an acyclic L-edge coloring for any edge-list L that satisfies $|L(e)| \geq k$ for each edge e. The *acyclic list chromatic index* is the least integer k such that G is acyclically k-edge choosable.

In a joint work with Ko-Wei Lih, we establish various upper bounds for the acyclic list chromatic indexes of seveval classes of planar graphs. (Received September 06, 2011)

1077-05-545 **David W. Cook II*** (dcook@ms.uky.edu), 715 Patterson Office Tower, Department of Mathematics, University of Kentucky, Lexington, KY 40506-0027, and **Uwe Nagel** (uwe.nagel@uky.edu). *Enumerations deciding the weak Lefschetz property.*

We introduce a natural correspondence between artinian monomial almost complete intersections in three variables and punctured hexagons. We use this correspondence to investigate the algebras for the presence of the weak Lefschetz property. In particular, we relate the field characteristics in which such an algebra fails to have the weak Lefschetz property to the prime divisors of the enumeration of signed lozenge tilings of the associated punctured hexagon.

We establish formulae for the enumeration of signed lozenge tilings for several families of punctured hexagons. This allows us to establish the presence of the weak Lefschetz property for the associated algebras. We also offer a conjecture of a closed formula for the enumerations of signed lozenge tilings of symmetric punctured hexagons. (Received September 07, 2011)

1077-05-584 **Andrzej K Brodzik*** (abrodzik@mitre.org), The MITRE Corporation, 202 Burlington Road, Bedford, MA 01730. *Design of radar and communication signals with perfect correlation properties.*

Finite chirps are critical in applications such as multi-user radar and sonar, spread spectrum communications, cryptography, and watermarking. In this work, subsets of finite chirps of length equal to square of a prime are examined. The investigation leads to a new, Zak space construction of general polyphase sequence sets with optimal correlation properties, known as perfect sequence sets. The entire collection of perfect sequence sets is given by a partition of the set of perfect auto correlation sequences, obtained by right coset decomposition of the group of all permutations with respect to a certain cyclic group. The construction suggests several further generalizations that can be obtained by operating exclusively on subgroups of the permutation group. (Received September 07, 2011)

1077-05-587 **sarah-marie belcastro*** (sbelcast@email.smith.edu) and **Ruth Haas** (rhaas@email.smith.edu). *Counting Kempe-equivalence classes for 3-edge-colored cubic graphs.*

Maximal two-color chains of graph edges are called *edge-Kempe chains*, and switching the colors along such a chain is called a *edge-Kempe switch*. Given two proper edge colorings of a graph, can you always get from one to the other via a sequence of edge-Kempe switches? (No.) If one edge-coloring of a graph can be transformed into another edge-coloring of that graph by a sequence of edge-Kempe switches, then the two edge-colorings are *edge-Kempe equivalent*. If a graph has at least two proper edge colorings that are not Kempe-equivalent, how many non-equivalent proper edge colorings are there? We attempt to compute the number (denoted $K'(G,3)$) of edge-Kempe equivalence classes of 3-edge colorings for certain types of cubic graphs. Along the way, we will introduce decompositions of cubic graphs and of 3-edge colorings of cubic graphs that assist in our computations. (Received September 07, 2011)

1077-05-594 **Chen Yichao*** (ycchen@hnu.edu.cn), Yu lu shan, Changsha, Hunan 410082, Peoples Rep of China. *Total embedding distributions for some types of graphs.* Preliminary report.

The total embedding distribution of a graph, including the non-orientable embeddings, is known for relatively few classes of graphs, compared to the genus distribution. A new usage of Chebyshev polynomials was found in the study of embedding distribution, using the overlap matrix, we obtain homogeneous (non-homogeneous) recurrence relation for rank distribution polynomial, which can be solved in terms of Chebyshev polynomials of the second kind. The explicit formula for embedding distribution of some well-known classes of graphs are obtained. A splitting theorem for embedding distributions is obtained and was used to calculate embedding distribution of generalized fan graphs. (Received September 08, 2011)

1077-05-611 **Xing Peng*** (pengx@mailbox.sc.edu), 1523 Greene St, Columbia, SC 29208, and **Linyuan Lu** (lu@math.sc.edu), 1523 Greene St, Columbia, SC 29208. *A fractional analogue of Brook's theorem.*

Let $\Delta(G)$ be the maximum degree of a graph G. Brooks' theorem states that the only connected graphs with chromatic number $\chi(G) = \Delta(G) + 1$ are complete graphs and odd cycles. We prove a fractional analogue of Brooks' theorem in this paper. Namely, we classify all connected graphs G such that the fractional chromatic number $\chi_f(G)$ is at least $\Delta(G)$. These graphs are complete graphs, odd cycles, C_8^2, $C_5 \boxtimes K_2$, and graphs whose clique number $\omega(G)$ equals the maximum degree $\Delta(G)$. Among the two sporadic graphs, the graph C_8^2 is the square graph of cycle C_8 while the other graph $C_5 \boxtimes K_2$ is the strong product of C_5 and K_2. (Received September 08, 2011)

1077-05-663 **Neil Hindman*** (nhindman@aol.com), Department of Mathematics, Howard University, Washington, DC 20059. *Central sets and C-sets – similarities and differences.* Preliminary report.

Central sets in $\mathbb{N}$ were introduced by Furstenberg and defined in terms of topological dynamical notions. He showed that given any finite partition of $\mathbb{N}$, one cell must be central and proved an early version of the *Central Sets Theorem*. As a consequence, any central set in $\mathbb{N}$ has strong combinatorial properties such as containing solutions to any partition regular system of homogeneous linear equations. Given a discrete semigroup S, central sets in S are characterized as those that have a minimal idempotent of the Stone-Čech compactification βS of S in their closure and they satisfy a stronger version of the Central Sets Theorem. C-sets are defined as those that satisfy the conclusion of the Central Sets Theorem, and as such enjoy many of the properties of central sets. In some ways they are easier to handle and describe than central sets and in some ways they are harder to work with. I will illustrate these differences and discuss some open problems. (Received September 09, 2011)

1077-05-682 **Rik Sengupta*** (rsengupt@princeton.edu), 0758 Frist Campus Center, Princeton University, Princeton, NJ 08544. *On tree rotations and common parse words.*

A proper 3-coloring of the $2n-1$ vertices of a complete binary tree T with n leaves using the letters $\{0,1,2\}$ so that no two siblings receive the same color is called a *labeling* of T. For such a labeling, the labels on the leaves can be read off in order, and this gives a word *parsed* by T. We examine the number of common parse words of pairs of trees separated by small distances in the rotation graph R_n for binary trees with n leaves. To this end, we fix some tree T^* and define the function $f(T)$ to be the number of common parse words between T and T^*. We prove that $f(T)$ behaves extremely nicely when T and T^* are within small distances in R_n. Our results give rise to a natural conjecture that immediately implies the Four Color Theorem by using an equivalence established by Kauffman (1990). (Received September 10, 2011)

1077-05-686 **Benjamin J. Wyser*** (bwyser@math.uga.edu), Department of Mathematics, University of Georgia, Boyd Graduate Studies Research Center, Athens, GA 30602-7403. *Symmetric subgroup orbit closures on the flag variety, Richardson varieties, and Schubert structure constants for (p,q)-pairs.*

We describe recent results regarding $GL(p,\mathbb{C})\times GL(q,\mathbb{C})$-orbit closures on the flag variety $GL(p+q,\mathbb{C})/B$, as well as a connection between these results and Schubert calculus. Specifically, we observe that a number of these orbit closures (namely, those obeying an easily stated pattern avoidance condition) are Richardson varieties. This observation, combined with a theorem of M. Brion on the decomposition of the cohomology class of such an orbit closure in the Schubert basis, leads to a positive description of Schubert constants $c_{u,v}^w$ in the case that u,v form what we call a "(p,q)-pair". The rule is multiplicity-free, meaning that all such constants are either 0 or 1. The case 0 or 1 is determined by computation of a monoidal action on the "(p,q)-clan" parametrizing the orbit closure. This action is easily described combinatorially, so in the end the rule for $c_{u,v}^w$ boils down to an elementary combinatorial check. Time permitting, we will also discuss analogous results in Lie types C and D. (Received September 10, 2011)

1077-05-694 **Noah Streib*** (nstreib3@math.gatech.edu). *Hamiltonian Cycles and Symmetric Chain Partitions of Boolean Lattices.*

Let $B(n)$ be the subset lattice of $\{1,2,\ldots,n\}$. Perhaps the most famous result concerning $B(n)$ is Sperner's Theorem, which states that the width of $B(n)$ is equal to the size of its biggest level. There have been several elegant proofs of this result, including an approach that shows that $B(n)$ has a partition into w symmetric chains (chains that are "vertically centered"), where w is the width of $B(n)$. A second famous result concerning $B(n)$, taking only a simple induction to prove, is the fact that the cover graph of $B(n)$ is Hamiltonian.

Motivated by the Middle Two Levels Conjecture, which states that the bipartite graph induced by the two largest levels of $B(2n+1)$ is Hamiltonian, we combine the ideas of the preceding paragraph. To this end, we consider posets that have the Hamiltonian Cycle–Symmetric Chain Partition (HC-SCP) property. A poset of width w has this property if its cover graph has a Hamiltonian cycle which parses into w symmetric chains. We show that the subset lattices have the HC-SCP property. Furthermore, using a technique similar to the above-mentioned proof of Sperner's Theorem, we obtain this result as a special case of a more general treatment. (Received September 10, 2011)

1077-05-706 **Thomas Lam*** (tfylam@umich.edu), 555 E William St. #24D, Ann Arbor, MI 48104. *The shape of a random affine Weyl group element, and random core partitions.*

Let W be an affine Weyl group. I will discuss probabilistic aspects of infinite reduced words of W, which are equivalent to walks in the alcoves of the affine Coxeter arrangement not crossing any hyperplane twice. I will show that such walks almost surely have one of finitely many asymptotic directions, and also discuss how this direction, and the probabilities of each direction can be calculated. I will also briefly explain how these results fit in the context of the theory of random partitions. (Received September 10, 2011)

1077-05-722 **Joseph Fox*** (joseph.fox@salemstate.edu), **Ralucca Gera** and **Pantelimon Stanica**. *The Independence Number for the Generalized Petersen Graphs.*

Given a graph G, an independent set $I(G)$ is a subset of the vertices of G such that no two vertices in $I(G)$ are adjacent. The independence number $\alpha(G)$ is the order of a largest set of independent vertices. In this talk, we discuss the independence number for the Generalized Petersen graphs. We present sharp bounds and exact results for subclasses of these graphs. (Received September 11, 2011)

1077-05-725 **P. J. Couch*** (pjc0005@auburn.edu). *The Metamorphosis of Maximum Packings of $2K_n$ with Triples into Maximum Packings of $2K_n$ with 4-cycles.*

The problem of constructing a maximum packing of $2K_n$ with triples having a metamorphosis into a maximum packing of $2K_n$ with 4-cycles is concluded by solving the problem for every $n \geq 11$ such that $n \equiv 2, 5, 8$, or 11 (*mod* 12). (Received September 11, 2011)

1077-05-737 **Chris Godsil*** (cgodsil@uwaterloo.ca), Canada. *Average mixing on graphs.* Preliminary report.

If X is a graph with adjacency matrix A, then we define $H(t)$ to be the operator $\exp(itA)$. The Schur (or entry-wise) product $H(t) \circ H(-t)$ is a doubly stochastic matrix and, because of work related to quantum computing, we are concerned with the related *average mixing matrix*, defined to be

$$\lim_{C\to\infty} \int_0^C H(t) \circ H(-t)\, dt.$$

I will discuss this matrix and some of its properties. These can be surprising, for example it is guaranteed to be rational, and it can in a sense have more symmetry than its underlying graph. (Received September 11, 2011)

1077-05-748 **Seiya Negami*** (negami@ynu.ac.jp). *The distinguishing chromatic numbers of graphs on surfaces.*

A coloring of a graph G is said to be *distinguishing* if there is no automorphism of G, except the identity map, preserving the colors given by the coloring. The minimum number of colors we need to construct a distinguishing coloring of G is called the *distinguishing chromatic number* of G and is denoted by $\chi_D(G)$. We shall show a general theory to estimate an upper bound for the distinguishing chromatic numbers of graphs embedded on a closed surafce, as an application of re-embedding theory for triangulations, which leads to a linear upper bound for those of triangulations with respect to the genus of surfaces. In addition, we shall present some concrete results on graphs embedded on the sphere, the projective plane and the torus. (Received September 12, 2011)

1077-05-752 **Chris Caragianis*** (cjcara01@louisville.edu). *Performance of covert networks.* Preliminary report.

The social structure of an covert organization can be modeled with a graph- placing edges between individuals with direct knowledge of one another. Which graphs best balance the need for secrecy with the need for efficient transmission of information? At the 24th Cumberland Conference, Doty introduced a toughness-like measure for covert network performance and conjectured on the best performing trees. We prove Doty's conjecture and describe infinite families that achieve the best possible order of growth for general graphs. (Received September 12, 2011)

1077-05-754 **Caroline Shapcott*** (cshapcott@drexel.edu). *Part Products of Random S-Restricted Compositions.*

If S is a cofinite set of positive integers, an *S-restricted composition of n* is a sequence of elements of S whose sum is n. We have proved that, for uniform random S-restricted compositions, the product of the part sizes is asymptotically lognormal. In the case of unrestricted compositions (S^c empty), this is an easy consequence of known techniques based on stopped sequences of independent geometric random variables. For the case of 1-free compositions ($S^c = \{1\}$), the techniques are not directly applicable. Nevertheless, I proved asymptotic lognormality, with a relatively sharp error term, by embedding the probability space in an auxiliary space in which the techniques *can* be applied. In the more general case of cofinite sets S, Eric Schmutz and I proved asymptotic lognormality with a slightly weaker error term. The proof involves a completely different technique of decomposing a composition into a sequence of smaller compositions. We believe that the cofiniteness assumption can be relaxed and that the method can be applied to other random variables. (Received September 12, 2011)

1077-05-767 **Bryan A Phinezy*** (bryan.a.phinezy@wmich.edu), 330 S. Kendall Ave., 34, Kalamazoo, MI 49006. *On Locating Sets in Graphs.*

An important problem in pharmaceutical chemistry is the so-called classification problem,which concerns providing mathematical representations of chemical compounds in order to study the compounds (their similarities and differences) by means of these mathematical representations. This problem has been studied with the aid of graph theory. In particular, the vertices of a graph are represented by some sort of codes using distances within the graph. One way of doing this is to choose an ordered set W of vertices of a graph G, and for each vertex v of G, assign a vector that gives the distance from v to the vertices of W. The object is to choose W optimally so that certain pairs of vertices of G are uniquely distinguished. Such a set W is called a locating set in G. Results and open questions are presented in this area of research. (Received September 12, 2011)

1077-05-790 **Mingzhi Xuan*** (mx0004@unt.edu), 1155 Union Circle #311430, Denton, TX 76203. *On Steinhaus Set of Four Points in $\mathbb{R}^2$.* Preliminary report.

A subset S of $\mathbb{R}^2$ is said to be a Steinhaus set (in $\mathbb{R}^2$) of another subset X, if and only if S meets every isometric copy of X in exactly one point. For example, it is easy to see that the Steinhaus set for singleton is the whole $\mathbb{R}^2$ and there is no Steinhaus set for two-point or three-point subset. In this paper, we prove that no four-point subset of $\mathbb{R}^2$ can have a Steinhaus set, using a combinatorial argument. (Received September 12, 2011)

1077-05-801 **Egon Schulte*** (schulte@neu.edu), Northeastern University, Department of Mathematics, Boston, MA 02115. *Semiregular Polytopes and Amalgamated C-Groups.* Preliminary report.

In the classical setting, a convex polytope is semiregular if its facets are regular and its symmetry group is transitive on vertices. The talk is about semiregular abstract polytopes, which have abstract regular facets, still with combinatorial automorphism group transitive on vertices. We analyze the structure of the automorphism group, focusing in particular on polytopes with two kinds of regular facets occurring in an “alternating” fashion. In particular we use group amalgamations to prove that given two compatible n-polytopes P and Q, there exists a universal abstract semiregular (n+1)-polytope which is obtained by “freely” assembling alternate copies of P and Q. We also employ modular reduction techniques to construct finite semiregular polytopes from reflection groups over finite fields. (Received September 12, 2011)

1077-05-811 **Ilanit Helfand*** (ilanit.helfand@gmail.com). *Two-Orbit Polytopes with Two Facet Types.* Preliminary report.

We will explore some properties of polytopes with two flag-orbits which have two facet types, and the implications of these properties. We will also look at a construction of such polytopes and discuss how this relates to constructions of regular polytopes from groups. (Received September 13, 2011)

1077-05-832 **Joel Spencer***, 251 Mercer St, New York, NY 11733. *Finding Needles in Exponential Haystacks.* Preliminary report.

The probabilistic method, aka Erdős Magic, is a powerful methodology that allows one to prove the existence of a combinatorial object (e.g., a coloring) by examining an appropriately defined random object and showing that it has positive probability of satisfying the desired criteria. In some critical cases, this positive probability is exponentially small, leaving the question of algorithmic implementation.

We discuss two recent successes in algorithmic implementation. The Lovász Local Lemma is a probabilistic sieve result which is very effective when events are mostly independent. Recent work of Robin Moser (together with Gábor Tardos and others) allows implementation via a very simple "fix-it" algorithm, though proving the effectiveness of the algorithm is quite subtle.

A quarter century ago this speaker showed that given an n sets on n elements there was a two-coloring of the underlying elements so that all sets had discrepancy less than $6\sqrt{n}$. A random coloring has only exponentially small chance of succeeding. Using semidefinite programming and making a clear advance on the pioneering work of Goemans and Williamson, Nikhil Bansal has given an algorithmic implementation for this problem, and a number of problems involving discrepancy. (Received September 13, 2011)

1077-05-838 **John R Stembridge*** (jrs@umich.edu), Dept. of Mathematics, University of Michigan, Ann Arbor, MI 48109-1043. *W-cells from scratch.* Preliminary report.

A W-graph for a Coxeter group W is a combinatorial structure that encodes a module for the group algebra of W, or more generally, a module for the associated Iwahori-Hecke algebra. Of special interest are the W-graphs that encode the action of the Hecke algebra on its Kazhdan-Lusztig basis. In this talk we will describe a general method for constructing all admissible W-cells for a given finite Weyl group W; this is a class of W-graphs that includes the cells (i.e., strongly connected components) of the Kazhdan-Lusztig W-graph Γ_{KL}. For example it turns out that there are 73 admissible E_6-cells (21 occur in Γ_{KL}) and 175 admissible F_4-cells (17 occur in Γ_{KL}), while for $W = A_n$ for $n \leq 9$, the only admissible cells are the Kazhdan-Lusztig cells. (Received September 13, 2011)

1077-05-848 **Roman Nedela*** (nedela@savbb.sk), Department of Mathematics, Matej Bel University, Tajovskeho 40, 974 01 Banska Bystrica, Slovak Rep. *A recent progress in map enumeration.*

A map is a 2-cell embedding of a graph into a closed surface. Exact formula for the number of rooted edges of given genus is known for $g = 0$ (Tutte 1963), $g = 1$ (Arques 1987), $g = 2, 3$ (Bender and Canfield 1991), $g = 4$ (Giorgetti,Mednykh 2011). Giorgetti, Mednykh and Walsh have recently derived the enumeration formula's up to genus 10. In 1981 independently Liskovets and Wormald derived an enumeration formula for the number of isomorphism classes of spherical maps. In 2006 Mednykh and Nedela developed a general method for the enumeration of isoclasses of maps of fixed genus g. The method requires first to determine the numbers of rooted maps of all genera $\gamma \leq g$ as well as to determine all quotient surfaces of the surface S_g by all actions cyclic groups. Using this machinery the enumeration problem was solved first for genera $\gamma = 1, 2, 3$. Later Giorgetti, Mednykh and Walsh derived the enumeration formulas for genera g, where $4 \leq g \leq 10$. A similar method was successfully used by Breda, Mednykh and Nedela to solve the enumeration problem for the family of all maps and of reflexible maps. An asymptotic analysis of these sequences done by Drmota and Nedela shows that the number of reflexible maps takes about square root of the number of all maps. (Received September 13, 2011)

1077-05-852 **Roman Nedela*** (nedela@savbb.sk), Department of Mathematics, Matej Bel University, Tajovskeho 40, Banska Bystrica, Slovak Rep. *Vertex-transitive polyhedral maps and actions of discrete groups on surfaces.*

The classification of polyhedral vertex-transitive maps of fixed genus g reduces to the problem of classification of actions of discrete groups acting on the surface of genus g. These maps naturally generalise the spherical maps associated with the classical Archimedean solids. Therefore we call them Archimedean maps. The main idea is based on the fact that each Archimedean map on an orientable surface projects onto one- or two-vertex quotient map. For given genus $g \geq 2$ the number of quotients to consider is bounded by a function of g. All Archimedean maps of genus g can be reconstructed from these quotients employing the technique of voltage graphs. A computer aided analysis allows us to produce catologues of Archimedean maps of small genera. (Received September 13, 2011)

1077-05-854 **Ronald J. Gould*** (rg@mathcs.emory.edu), Dept. of Mathematics and Computer Science, Emory University, Atlanta, GA 30322. *The Many Forms of the Matthews - Sumner Conjecture.*

Given a graph H, a graph G is H-free if G contains no subgraph isomorphic to H. The Matthews - Sumner Conjecture states that every 4-connected $K_{1,3}$-free graph is hamiltonian. In this talk we look at this conjecture and a number of other related conjectures, as well as the most recent advances on the problem. (Received September 13, 2011)

1077-05-855 **Benjamin J. Maguire*** (benjamin.maguire@my.lr.edu) and **Thierry Zell** (thierry.zell@lr.edu). *Lower bounds on cliques of* $(2, m)$*-agreeable graphs.* Preliminary report.

A graph G on n vertices is $(2, m)$-agreeable if no subset of m vertices of G induces the empty graph (here, $n \geq m \geq 2$). If G is $(2, m)$-agreeable and if the boxicity of G is at most d, we prove that G must contain a clique of size at least $(2d)^{2-m}\, n$. This generalizes a result of Abrahams, Lippincott, and Zell (case $m = 3$), and can be interpreted as a lower bound on the agreement proportion in the framework of convex approval voting introduced by Berg, Norine, Su, Thomas, and Wollan. (Received September 13, 2011)

1077-05-864 **Jared Adams** (jaxad0127@gmail.com), **Eric M Freden*** (freden@suu.edu) and **Marni Mishna** (mmishna@sfu.ca). *From indexed languages to generating functions.*

We extend the DSV method of computing the growth series of an unambiguous context-free language to the larger class of indexed languages. This technique has applications to enumerative combinatorics in general and in particular, growth series for groups. (Received September 13, 2011)

1077-05-869 **Wayne D. Goddard***, School of Computing and Dept of Math Sciences, Clemson University, Clemson, SC 29631. *The Binding Number of a Graph.*

Nearly 40 year ago, Woodall defined the binding number of a graph. In this talk we review the conjectures he made about pancyclicity and triangles, and discuss related results and conjectures about cycles, independent sets and cliques. (Received September 13, 2011)

1077-05-896 **Richard Ehrenborg** (jrge@ms.uky.edu), University of Kentucky, Department of Mathematics, Lexington, KY 40506, **Mark Goresky** (goresky@math.ias.edu), Institute for Advanced Study, School of Mathematics, Princeton, NJ 08540, and **Margaret Readdy*** (readdy@ms.uky.edu), University of Kentucky, Department of Mathematics, Lexington, KY 40506. *Euler flag enumeration of Whitney stratified spaces.*

The flag vector contains all the face incidence data of a polytope, and in the poset setting, the chain enumerative data. It is a classical result due to Bayer and Klapper that for face lattices of polytopes, and more generally, Eulerian graded posets, the flag vector can be written as a cd-index, a non-commutative polynomial which removes all the linear redundancies among the flag vector entries. This result holds for regular CW complexes.

We relax the regularity condition to show the cd-index exists for non-regular CW complexes and extend the notion of a graded poset to that of a quasi-graded poset. (Received September 15, 2011)

1077-05-913 **Elizabeth J. Kupin*** (ekupin@math.rutgers.edu). *Subtraction-Division Games, Patterns, and Self-similarity.*

This talk will investigate a class of two-player combinatorial games with parameters a, b, and n. The game starts at n, and is a race to say the number 1. Each player on his or her turn can either subtract a from the current number, or divide the current number by b and round up.

Each game has a Sprague-Grundy value associated to it, that among other things indicates whether or not that game is a first player win. We look at sequences of these values for fixed pairs of a and b. While these sequences are not periodic, for many pairs of a and b there are interesting and beautiful patterns that appear. By showing that many of these sequences fit into the category of k-automatic sequences, we will also be able to answer the following more practical question: is there a simple formula for which player wins? (Received September 14, 2011)

1077-05-914 **Janine E. Janoski***, janoski@clemson.edu, and **Neil J. Calkin**, **Brian Bowers**, **Kerry Gannon**, **Katie Jones** and **Anna Kirkpatrick**. *Log-concavity of the Partition Function.* Preliminary report.

A sequence a_n is log-concave if for every $n \geq 1$

$$a_n^2 \geq a_{n+1}a_{n-1}. \tag{1}$$

Let $p(n)$ be the number of partitions of n. We show that $p(n)$ is log-concave for $n \geq 26$. For $n < 26$, $p(n)$ satisfies (1) precisely when n is even. (Received September 14, 2011)

1077-05-923 **Alexander Rosa*** (rosa@mcmaster.ca). *Ringel and Kotzig after fifty years.*

Preparations are underway to commemorate the 50th anniversary of the first truly large international graph theory conference which took place in 1963 in Smolenice, Czechoslovakia. The celebrated Ringel's problem on decomposing the complete graph into trees, and Kotzig's problem on perfect one-factorizations were both formulated at this conference. We will discuss some developments related to these problems which remain still wide open today. (Received September 14, 2011)

1077-05-953 **Daniel J Kleitman***, djk@math.mit.edu. *Favorite Graph Conjectures.*

This talk will contain descriptions and some ideas on four problems in graph theory and related areas that I have enjoyed thinking about from time to time. One of them is as follows. We consider complete tripartite graphs in which two parts each have cardinality 2n on which each edge is directed in exactly one direction, that have diameter two. The question is: how large can the third part be, given these conditions? And a proof of the claimed answer is required. I learned of this problem many years ago from two mathematicians from what was then Yugoslavia, who conjectured what I believe is the right answer. Unfortunately I have lost their names. I am pretty sure that this is a doable problem. (Received September 14, 2011)

1077-05-967 **Margaret Meyerhofer*** (mmeyerho@andrew.cmu.edu). *Parallel Double Rule Application in Signed Graphs.*

In this paper we study the parallel complexity of signed graphs. We provide an algebraic characterization for when n double rules apply in parallel. We demonstrate a transformation from a family of signed graphs into directed graphs. For these transformed graphs we give a necessary and sufficient condition for determining if

n double rules apply in parallel. We also describe a polynomial time algorithm for checking this condition. Finally we discuss transforming signed graphs into labeled graphs to expand our algorithm to additional cases. (Received September 15, 2011)

1077-05-989 **John T. Hird*** (jthird@ncsu.edu), **Naihuan Jing** (jing@math.ncsu.edu) and **Ernest Stitzinger** (stitz@math.ncsu.edu). *Codes of compositions.*

The Bernstein operators are a special set of vertex operators that can generate the Schur functions. We generalize the combinatorial object codes of partitions to codes of compositions and show how this relationship can help us understand the action of the Bernstein operators on Schur functions. We also show the analogous results and combinatorial objects for Schur Q-functions. (Received September 15, 2011)

1077-05-997 **Jesus A DeLoera**, **Yvonne Kemper** and **Steven Klee***, Department of Mathematics, One Shields Avenue, University of California, Davis, CA 95616. *h-vectors of small matroid complexes.*

Stanley conjectured in 1977 that the h-vector of a matroid simplicial complex is a pure O-sequence. We give simple constructive proofs that the conjecture is true for matroids of rank less than or equal to 3, and corank 2. We also verify that Stanley's conjecture holds for all matroids on at most nine elements. (Received September 15, 2011)

1077-05-1006 **Luke Postle**, **Dan Cranston** and **Carl Yerger*** (cayerger@davidson.edu), Department of Mathematics, Box 7059, Davidson, NC 28035. *Modified Linear Programming Weighting for Graph Pebbling.* Preliminary report.

Given a configuration of pebbles on the vertices of a connected graph G, a *pebbling move* is defined as the removal of two pebbles from some vertex and the placement of one of these on an adjacent vertex. The *pebbling number* of a graph G is the smallest integer k such that for each vertex v and each configuration of k pebbles on G there is a sequence of pebbling moves that places at least one pebble on v. We improve on results of Hurlbert who introduced a linear optimization technique for graph pebbling. In particular, we utilize a different set of weight functions that use graphs more general than trees. As a proof-of-concept, we apply new weight functions to some graphs from Hurlbert's paper and show both improvements to Hurlbert's bounds and possible limitations of this method. (Received September 15, 2011)

1077-05-1042 **Gaku Liu*** (xueliu@princeton.edu), 1386 Conservancy Dr. E, Tallahassee, FL 32312. *Minimum Clique Number, Chromatic Number, and Ramsey Numbers.*

Let $Q(n,c)$ denote the minimum clique number over graphs with n vertices and chromatic number c. We investigate the asymptotics of $Q(n,c)$ when n/c is held constant. We show that when n/c is an integer α, $Q(n,c)$ has the same growth order as the inverse function of the Ramsey number $R(\alpha+1,t)$ (as a function of t). Furthermore, we show that if certain asymptotic properties of the Ramsey numbers hold, then $Q(n,c)$ is in fact asymptotically equivalent to the aforementioned inverse function. We use this fact to deduce that $Q(n,\lceil n/3\rceil)$ is asymptotically equivalent to the inverse function of $R(4,t)$. (Received September 15, 2011)

1077-05-1062 **Thomas Tucker*** (ttucker@colgate.edu), Colgate University, Hamilton, NY 13346, and **Ergun Akleman**, **Jianer Chen** and **Jonathan Gross**. *Rotation systems for 2-complexes in orientable 3-manifolds.* Preliminary report.

Given a finite simplical 2-complex K embedded in an oriented 3-manifold, a right-hand rule assigns to each directed edge e of K a cyclic order $\rho(e)$ of the incident 2-simplices, such that $\rho(e^-)=\rho(e)^{-1}$. This $3D$-rotation system induces a planar (usual) $2D$-rotation system for the link $L(v)$ of each vertex v. Conversely, an assignment of a cyclic order $\rho(e)$ to each directed edge which induces a planar embedding of $L(v)$ for each v, defines a thickening T_ρ of K, that is, a regular neighborhood of K in an oriented 3-manifold. Unlike the case for graphs, T_ρ may have non-sphere boundary components, so there is no canonical closed 3-manifold associated with ρ. Nevertheless, the boundary components of T_ρ can be constructed, similar to face-tracing for a $2D$-rotation, so it can be decided whether a given 2-complex has a thickening where all boundary components are spheres. Combining this with the Rubinstein-Thompson sphere recognition algorithm, we can decide whether a given 2-complex has a cellular embedding in the 3-sphere. This approach relates to work of Neuwirth (1968); Archdeacon, Bonnington, Richter, Šìràň, (2002); Repovš, Brodskij, Skopenkov (1999); and Lasheras (1999). (Received September 15, 2011)

1077-05-1126 **Camillia Smith Barnes*** (cbarnes@sbc.edu), PO Box 74, Sweet Briar, VA 24595. *3-shuffles of permutations.* Preliminary report.

A shuffle of words is an interleaving of the letters of the words such that the letters of each original word remain in order. A 3-shuffle is a shuffle of three words, as in, for example, 124573896, which is a 3-shuffle of 123, 456, and 789. In a previous paper, we enumerated distinct 2-shuffles of permutations. In this talk, we will present recent results on enumeration of 3-shuffles of permutations. (Received September 16, 2011)

1077-05-1128 **Jerrold R. Griggs*** (griggs@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *The Δ^2 Conjecture for Graph Labellings with Separation Conditions.*

In 1988 Roberts described a problem posed to him by Lanfear concerning the efficient assignment of channels to a network of transmitters in the plane. To understand this problem, Griggs and Yeh introduced the theory of integer vertex λ-labellings of a graph G. To prevent interference, labels for nearby vertices must be separated by specified amounts k_i depending on the distance i, $1 \leq i \leq p$. One seeks the minimum span of such a labelling. The $p = 2$ case with $k_1 = 2$ and $k_2 = 1$ has attracted the most attention, particularly the tantalizing conjecture that for such "$L(2,1)$"-labellings, if G has maximum degree $\Delta \geq 2$, then the minimum span is at most Δ^2. It has now been proven for all sufficiently large Δ, but remains open for small Δ, even for $\Delta = 3$. (Received September 16, 2011)

1077-05-1166 **William T. Trotter*** (trotter@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Graph Theory Problems Arising from Partially Ordered Sets.*

We discuss some challenging graph theory problems having roots in (or immediate connections to) the combinatorics of finite partially ordered sets. Featured will be: (1) The Middle Two Levels conjecture — the bipartite graph formed by the subsets of size n and $n+1$ of a $2n+1$-element set is hamiltonian; (2) The Monotone Hamiltonian path problem — in the subset lattice, there is a hamiltonian path starting at the empty set so that when a set A is visited, the path has already visited every subset of A, with at most one exception. We will also discuss problems involving posets associated with planar graphs and issues of planarity for diagrams of posets. (Received September 17, 2011)

1077-05-1178 **Adriano M. Garsia*** (garsia@math.ucsd.edu). *Recent progress on the Shuffle Conjecture: Macdonald Polynomials and Parking Functions.*

The Frobenius characteristic $DH_n(X;q,t)$ of Diagonal Harmonics, under the diagonal action of S_n was shown by Mark Haiman in 2000 by Algebraic Geometry to be the image of the elementary symmetric function e_n by the operator ∇ that is an eigen-operator for the modified Macdonald basis $\tilde{H}_\mu[X;q,t]$ with eigenvalue $T_\mu = t^{n(\mu)}q^{n(\mu')}$. It was conjectured in 2002, by Haglund, et all that ,

$$DH_n(X;q,t) = \sum_{PF} t^{area(PF)} q^{dinv(PF)} Q_{ides(PF)}[X]$$

where the sum is over Parking Functions in the $n \times n$ lattice square, "*area*" and "*dinv*" are two elementary Parking Functions statistics and $Q_{ides(PF)}[X]$ is the fundamental Gessel quasi symmetric function indexed by the i-descent set of the diagonal permutation of the Parking unction PF. In this talk we cover some of the recent progress in the resolution of this conjecture. (Received September 17, 2011)

1077-05-1217 **Ping Zhang*** (ping.zhang@wmich.edu), Departement of Mathematics, Western Michigan University, Kalamazoo, MI 49008. *Powers of Strong Digraphs.*

Results dealing with arc colorings of powers of strong digraphs are presented, particularly as they pertain to Hamiltonian properties. (Received September 18, 2011)

1077-05-1229 **Simon Mark Smith** (smsmit13@syr.edu), **Thomas W. Tucker** (ttucker@colgate.edu) and **Mark E. Watkins*** (mewatkin@syr.edu), Syracuse University, Mathematics Department, 215 Carnegie, Syracuse, NY 13244-1150. *Distinguishability of Infinite Groups, Graphs, and Graph Products.*

The *distinguishing number* of a group G of permutations of a set V is the least number of cells in a partition of V such that only the identity element of G fixes setwise every cell of the partition. For $\alpha \in V$, an orbit of the point stabilizer G_α is called a *suborbit* of G. The *distinguishing number* of a graph Γ is the distinguishing number of its full automorphism group acting on $V(\Gamma)$.

We prove that every connected primitive graph with infinite diameter and countably many vertices has distinguishing number 2. Consequently, all infinite, connected, primitive, locally finite graphs are 2-distinguishable; so, too, is any infinite primitive group with finite suborbits. We also show that all denumerable vertex-transitive graphs having a cut vertex and all Cartesian products of connected denumerable graphs of infinite diameter have distinguishing number 2. All of these results follow directly from a versatile lemma which we call The Distinct Spheres Lemma. Determining the distinguishing number of other graph products is in progress. (Received September 18, 2011)

1077-05-1235 **Tariq A Alraqad*** (tariq.alraqad@northern.edu), Department of Mathematics and Sciences, Northern State University, 1200 S Jay St., Aberdeen, SD 57401, and **Mohan Shrikhande**. *Quasi-residual and quasi-derived Hadamard designs.* Preliminary report.

Quasi-residual and quasi-derived designs are defined to be 2-designs with the parameters of residual and derived designs of a symmetric design. If a quasi-residual (resp. a quasi-derived) design is in fact a residual (resp. a derived) design of a symmetric design, then it is called embeddable. Otherwise, it is said to be non-embeddable. The embedding problem of quasi-residual and quasi-derived design into a symmetric design is an old and natural question. Bhattacharya (1944) gave the first example of quasi-residual design which is non-embeddable. We consider quasi-residual and quasi-derived designs with parameters corresponding to residual and derived designs of Hadamard designs. Such designs have parameters $2-(2k, k, k-1)$ and $2-(2k-1, k-1, k-2)$ respectively. We refer to designs with such parameters as quasi-residual and quasi-derived Hadamard designs of order k. We give some results on such designs of small orders. We then use recursive methods in order to obtain infinite families of non-embeddable quasi-residual and quasi-derived Hadamard designs. (Received September 21, 2011)

1077-05-1252 **Marina Dombrovskaya*** (dombrom@math.wustl.edu). *Quotients of subgroup lattices of finite abelian p-groups.* Preliminary report.

Let G be a finite abelian p-group of type λ. It is well-known that the lattice $L_\lambda(p)$ of subgroups of G is the order-theoretic p-analogue of the chain product $[0,\lambda]$. However, any surjection $\varphi : L_\lambda(p) \to [0,\lambda]$ with order analogue properties does not respect group automorphisms. We are interested in the quotient lattice of $L_\lambda(p)$ under the action of a Sylow p-subgroup of the automorphism group of G. This quotient lattice is particularly interesting since it respects group automorphisms, has the property that the size of an orbit of the action is a power of p, and is closely related to the product of chains $[0,\lambda]$. We will describe the quotient lattice mentioned above and discuss its combinatorial properties. (Received September 21, 2011)

1077-05-1300 **Noah Arbesfeld*** (nma@mit.edu). *Partial Permutations Avoiding Pairs of Patterns.*

We continue the study of pattern avoidance in partial permutation initiated in [A. Claesson, V. Jelínek, E. Jelínková, and S. Kitaev. Pattern avoidance in partial permutations. *Electronics Journal of Combinatorics*, 18(1):#P25, 2011]. Namely, we extend previous definitions of shape-Wilf equivalence and $\star$-Wilf equivalence to sets of patterns, and determine new shape-Wilf equivalences and shape-$\star$-Wilf equivalences among pairs of patterns of length 3. Using these results, we deduce infinite classes of shape-Wilf equivalent and shape-$\star$-Wilf equivalent pairs of patterns. We also find all $\star$-Wilf equivalence classes among pairs of permutations of length at most 4. (Received September 19, 2011)

1077-05-1316 **Bor-Liang Chen**, **Ko-Wei Lih** and **Chih-Hung Yen*** (chyen@mail.ncyu.edu.tw). *Conjectures and Results on Equitable Δ-Coloring of Graphs.*

A (proper) k-coloring of a graph G is said to be equitable if the sizes of any two color classes differ by at most one. Let $\Delta(G)$, $\chi(G)$, and $\alpha(G)$ denote the maximum degree, the chromatic number, and the independence number of a graph G, respectively. In 1997, Chen and Yen proposed the following conjecture.

Conjecture 1. Let $r \geq 3$ and a graph G satisfy $\Delta(G) = r \geq \chi(G)$. Then G has no equitable r-coloring if and only if r is odd, G has exactly one component $H = K_{r,r}$, and $\alpha(G-H) = |V(G-H)|/r$.

Also, in 2010, a conjecture was proposed by Kierstead and Kostochka to characterize equitable Δ-colorability in which the notion of an r-equitable graph is involved. A graph G is said to be r-equitable if $r \geq \chi(G)$, r divides $|V(G)|$, and every r-coloring of G is equitable.

Conjecture 2. Let $r \geq 3$ and a graph G satisfy $\Delta(G) = r \geq \chi(G)$. Then G has no equitable r-coloring if and only if r is odd, G has a subgraph $H = K_{r,r}$, and $G-H$ is r-equitable.

In this talk, we will show that the above conjectures are actually equivalent and have been confirmed for G is bipartite or $\Delta(G) \leq 3$. (Received September 22, 2011)

1077-05-1318 **Alan Frieze*** (alan@random.math.cmu.edu), 5000 Forbes Avenue, Pittsburgh, PA 15217. *Analysis of a simple 2-matching algorithm on a random graph.* Preliminary report.

We describe and analyse a simple greedy algorithm that finds a good 2-matching M in a random graph G. A 2-matching is a spanning subgraph of maximum degree two and G is drawn uniformly from graphs with vertex set

[n], cn (c>=15) edges and minimum degree at least three. By good we mean that M has O(log n) components. We then use this 2-matching to build a Hamilton cycle. (Received September 19, 2011)

1077-05-1328 **Catherine Yan*** (cyan@math.tamu.edu), Department of Mathematics, Texas A&M University, MS 3368, College Station, TX 77843-3368, and **William Chen** (chen@nankai.edu.cn), **Svetlana Poznanovik** (svetlana@math.gatech.edu) and **Arthur Yang** (yang@nankai.edu.cn). *Major Index for 01-Fillings of Moon Polyominoes.*

We show how to generalize Foata's second fundamental transformation on permutations to a family of 01-fillings of polyominoes, and use it to extend MacMahon's equi-distribution result of inv and maj to 01-fillings of moon polyominoes. (Received September 19, 2011)

1077-05-1369 **Amin Bahmanian***, 221 Parker Hall Department of Mathematics, Auburn, AL 36849. *Generalizations of Baranyai's Theorem and Embedding Factorizations.*

Let $K_n^h = (V, \binom{V}{h})$ be a complete h-uniform hypergraph on vertex set V with $|V| = n$. Baranyai showed that K_n^h can be expressed as the union of edge-disjoint r-regular factors if and only if h divides rn and r divides $\binom{n-1}{h-1}$. Here we present several generalizations of this result, and solve some related embedding problems. (Received September 19, 2011)

1077-05-1429 **Adam H. Berliner*** (berliner@stolaf.edu), MSCS Dept., 1520 St. Olaf Ave., Northfield, MN 55057, and **Richard A. Brualdi**. 2-*Matching covered loopy graphs.* Preliminary report.

A $\{1,2\}$-matching M of a graph G is a collection of edges such that each vertex of G meets at most two edges of M. A perfect 2-matching of G is a $\{1,2\}$-matching that is a spanning set consisting of pairwise vertex disjoint edges and odd cycles. For a subset of vertices X, $N(X)$ is the set of vertices of G adjacent to at least one vertex in X. A theorem of Tutte asserts that a graph G has a perfect 2-matching if and only if $|N(X)| \geq |X|$ for all independent sets of vertices X. We investigate minimal 2-matching covered graphs, i.e. graphs in which every edge is in some perfect 2-matching and the removal of any edge results in a graph without this property. In particular, we will discuss some classes of minimally 2-matching covered loopy graphs (graphs in which each vertex may contain a loop), where a loop is regarded as a cycle of length one. (Received September 19, 2011)

1077-05-1438 **Olivier Bernardi*** (bernardi@mit.edu). *The Potts model on random lattices.*

The Potts model is a statistical mechanics model which has been extensively studied on the lattice $\mathbb{Z}^2$. In this work, we consider the Potts model on all planar maps. We characterize the partition function of this model (the generating function of maps weighted by their partition function) by certain differential equations. For particular values of the parameters, we also obtain an algebraic equation, which can be used to study the phase transitions. This is a joint work with Mireille Bousquet-Mélou. (Received September 19, 2011)

1077-05-1447 **Jeremy Kepner***, (kepner@ll.mit.edu), MIT Lincoln Laboratory, Lexington, MA. *Spreadsheets, Big Tables, and the Algebra of Associative Arrays.*

Spreadsheets are used by nearly 100M people every day and may be the most commonly used analytical structure on Earth. Likewise triple stores (e.g., Big Table, Dynamo, and HBase) store a large fraction of the analyzed data in the world and are the backbone of modern web companies such as Google, Amazon, and Yahoo. Both spreadsheets and big tables can hold diverse data (e.g., strings, dates, integers, and reals) and lend themselves to diverse representations (e.g., matrices, functions, hash tables, and databases). Triple stores are highly scalable and run on commodity clusters, but lack interfaces to support efficient development of mathematical analytics. D4M (Dynamic Distributed Dimensional Data Model) has been developed to provide a mathematically rich interface to triple stores (and structured query language "SQL" databases). D4M allows linear algebra to be applied to databases. Using D4M, it is possible to create highly complex composable analytics with significantly less effort than using traditional approaches. The central mathematical concept of D4M is the "associative array" which combines spreadsheets, triple stores and sparse linear algebra. This talk describes the D4M technology and the group theory and fuzzy algebra foundations of associative arrays. (Received September 19, 2011)

1077-05-1457 **Dan Roberts*** (dpr0003@auburn.edu). *Maximum packings of complete graphs with stars.*

A k-star is the complete bipartite graph $K_{1,k}$. The problem of finding a maximum packing of λK_n with k-stars is discussed. (Received September 19, 2011)

1077-05-1477 **Kyungyong Lee*** (klee@math.wayne.edu) and **Ralf Schiffler** (schiffler@math.uconn.edu). *Proof of a positivity conjecture by M. Kontsevich.*

We prove a conjecture of Kontsevich, which asserts that the iterations of the noncommutative rational map $F_r : (x,y) -- > (xyx^{-1}, (1+y^r)x^{-1})$ are given by noncommutative Laurent polynomials with nonnegative integer coefficients. (Received September 19, 2011)

1077-05-1485 **Maria Klawe**, **Kathryn L. Nyman*** (knyman@willamette.edu), **Jacob N. Scott** and **Francis Edward Su**. *Double-Interval Societies.* Preliminary report.

Political platforms can be viewed as points lying on a continuum, with more liberal viewpoints to the left and more conservative viewpoints to the right. In this model, a voter's personal preferences are often represented by an "approval interval" on the continuum containing the platforms that voter is willing to support. Inspired by several elections, we ask what can be said of a society in which individual voter preferences are represented by two disjoint approval intervals. We obtain bounds for the case when each pair of voters can approve a common platform. Examples of these double-interval societies leads to some interesting results about arrangements of the letters 0,...,n-1 in which each letter appears exactly twice. (Received September 20, 2011)

1077-05-1487 **Francis Edward Su*** (su@math.hmc.edu), Department of Mathematics, Harvey Mudd College, 301 Platt Blvd, Claremont, CA 91106. *Changing Notions of Agreeability in Voting.*

We examine results of the following type: given a certain notion of 'agreeability' of pairs or groups of voters, what can be said about the popularity of the most popular candidate? Must some candidate be 'electable'? Such questions quickly lead to natural questions about intersections of sets and their resulting intersection graphs. The literature (on interval graphs, Turan graphs, tolerance graphs) contain theorems that have interesting interpretations for voting, and the voting interpretation suggests new mathematical questions. We survey some recent results, tracing the evolution of the concept of agreeability. (Received September 20, 2011)

1077-05-1513 **Nicholas A Loehr** and **Elizabeth M Niese*** (niese@marshall.edu). *A bijective factorization of modified Macdonald polynomials.*

In recent years there has been great interest in the combinatorics of Macdonald polynomials. Recently Descouens and Morita used symmetric function identities to prove a factorization of the modified Macdonald polynomials when one parameter is set to a root of unity. They pose the problem of finding a bijective proof of this factorization using Haglund's combinatorial formula for the modified Macdonald polynomials. In this talk I present a bijective proof of this factorization. (Received September 20, 2011)

1077-05-1568 **Breeanne Baker*** (bab207@lehigh.edu) and **Garth Isaak**. *The k-Fixed-Endpoint Path Partition Problem.*

Given a graph G and a set T of k vertices, a k-fixed-endpoint path partition of G with respect to T is a set of vertex-disjoint paths which cover the vertices of G and in which every vertex in T is an endpoint of a path. The k-fixed-endpoint path partition problem is to find the minimum size of such a path partition. In general, this problem is NP-hard; however, solutions are possible for certain graph classes. This talk will focus on highly structured graph classes. (Received September 20, 2011)

1077-05-1569 **Jonathan Novak*** (jnovak@math.mit.edu), 77 Massachusetts Avenue, Building 2, Cambridge, MA 02139. *Monotone Hurwitz numbers and the HCIZ integral.*

It is a remarkable fact that the asymptotic expansion of certain integrals over the space of N by N Hermitian matrices afford analytic realizations of generating functions enumerating maps on surfaces. In order to carry this relationship over to maps whose vertices may be coloured, on has to integrate over two interacting matrices. The principal obstruction to performing such an integration turns out to be a different matrix integral, this time over the unitary group, known as the Harish-Chandra-Itzykson-Zuber integral. I will discuss joint work with I. Goulden and M. Guay-Paquet which sheds some light on the combinatorial structure of the HCIZ integral: it turns out that this integral acts as a generating function for a desymmetrized version of the double Hurwitz numbers which we call "monotone" double Hurwitz numbers. (Received September 20, 2011)

1077-05-1574 **Marcelo Aguiar*** (maguiar@math.tamu.edu), 3368 Tamu, College Station, TX 77843, and **Swapneel Mahajan** (swapneel@math.iitb.ac.in). *Algebra based on real hyperplane arrangements.*

We discuss an algebraic theory based on the geometry of real hyperplane arrangements. We focus on the notion of Hopf monoid, for which the key ingredient is furnished by the projection maps of Tits. Geometric structures associated to arrangements afford examples of Hopf monoids. We discuss examples arising from chambers, subarrangements, and generalized zonotopes. When specialized to the braid arrangement, we recover Hopf algebraic structures on combinatorial objects such as graphs, linear orders, and generalized permutahedra. This is joint work in progress with Swapneel Mahajan. (Received September 20, 2011)

1077-05-1582 **Mark Ellingham*** (mark.ellingham@vanderbilt.edu). *Chmutov's generalized duality and the gem representation of embedded graphs.* Preliminary report.

In 2009 Chmutov introduced an operation of 'generalized duality' for graphs embedded in surfaces, where a dual is taken using only a subset of the edges. He showed that a certain specialization of the Bollobás-Riordan polynomial is invariant under this operation; this generalizes the usual duality relation for Tutte polynomials for connected planar graphs. Chmutov defined his operation in terms of 'arrow presentations' of embedded graphs, which are related to the usual ribbon graphs or band decompositions. With this definition it seems quite difficult to see how the structure of an embedding changes when this operation is applied. In this talk we show that Chmutov's operation is expressed very simply in terms of the 'gem' (graph-encoded map) representation of embedded graphs introduced by Robertson in 1971 and investigated further by Lins and Bonnington and Little. We apply this to describe how generalized duality changes the structure of an embedding in some naturally occurring situations. (Received September 20, 2011)

1077-05-1584 **Stephen G Hartke** and **Derrick Stolee*** (s-dstolee1@math.unl.edu). *Uniquely K_r-saturated graphs.* Preliminary report.

A graph is uniquely K_r-saturated if it does not contain an r-clique but for every edge e in the complement $\overline{G}$ there is a unique r-clique in $G+e$. Removing a dominating vertex creates a uniquely K_{r-1}-saturated graph, so we focus on graphs with no dominating vertex. Previous work found a limited number of these graphs and it was conjectured that there are a finite number for each r and that each such graph was regular. Using a custom computational method, we find several new graphs of orders 13–18 as well as a new infinite family. Moreover, one of these graphs is irregular. (Received September 20, 2011)

1077-05-1594 **Sibel Ozkan** and **Erik E Westlund*** (ewestlun@kennesaw.edu). *Some planar Hall completable graphs.* Preliminary report.

If φ is a partial proper m-coloring of the vertices $V_0 \subseteq V$ of a graph G, we may define an associated list-assignment $L = L_\varphi$ in a natural way so that φ has a completion to a proper m-coloring of G if and only if G has a proper L_φ-coloring. (G, L) is said to satisfy *Hall's condition* if, for all subgraphs $H \leq G$, $|V(H)| \leq \sum_{\sigma\in\mathcal{C}} \alpha(H_\sigma)$, where $\alpha(H_\sigma)$ is the independence number of the subgraph $H_\sigma \leq H$ induced on the vertices having color σ in their lists. Hall's condition is necessary for G to have a proper L-coloring. G is said to be Hall m-completable, for some $m \geq \chi(G)$, if every partial proper m-coloring φ, such that (G, L_φ) satisfies Hall's condition, has a completion. We say G is *Hall completable* if G is Hall m-completable for all $m \geq \chi(G)$. We give a brief survey of results; mainly restricting attention to familiar planar graphs such as prisms and ladders. (Received September 20, 2011)

1077-05-1599 **Tomohiro Sasamoto** and **Lauren K Williams*** (williams@math.berkeley.edu). *A curious relation between two Markov chains.*

A Markov chain is a collection of states, together with transition probabilities that describe how likely it is to move from one state to another. What happens when one makes some of those probabilities *negative*? There is no reason that such an operation should have any meaning.

The asymmetric exclusion process (ASEP) is a Markov chain on a lattice of n sites, in which particles can hop left and right, subject to the condition that there is at most one particle per site. They can also enter and exit the lattice at the left (with probabilities alpha and gamma), and exit and enter the lattice at the right (with probabilities beta and delta). We will explain that if one sets delta equal to NEGATIVE beta, the resulting "steady state probabilities" describe a different Markov chain ... more specifically, an exclusion process on a semi-infinite lattice. Additionally, we will describe the rich tableaux combinatorics that describes the steady state distributions of both models. (Received September 22, 2011)

1077-05-1636 **Luis G Serrano*** (serrano@lacim.ca), CP 8888 Succ. Centre Ville, Montreal, Quebec H2X3Y7, Canada, and **Christian Stump** (christian.stump@lacim.ca), CP 8888 Succ. Centre Ville, Montreal, Quebec H2X3Y7, Canada. *Bijections between k-triangulations, k-fans of Dyck paths, and certain pipe dreams.*

We present a bijection between k-triangulations of an n-gon and k-fans of Dyck paths (both generalizations of well known Catalan objects). This bijection goes through widely used objects in combinatorics such as pipe dreams and flagged tableaux. If time pemits, we will discuss a generalization of the associahedron obtained in this manner, and mention a conjectured cyclic sieving phenomenon. (Received September 20, 2011)

1077-05-1637 **Ralucca Gera*** (rgera@nps.edu), 1 University Way, Montrey, CA 93955, and **Linda Eroh** and **Steven Winters**. *Closed 3-stop distance in graphs.*

A delivery person must leave the central location of the business, deliver packages at a number of addresses, and then return. Naturally, he/she wishes to reduce costs by finding the most efficient route. This motivates the following: Given a set of k distinct vertices $\mathcal{S} = \{x_1, x_2, \ldots, x_k\}$ in a simple graph G, the closed k-stop-distance of set $\mathcal{S}$ is defined to be

$$d_k(\mathcal{S}) = \min_{\theta \in \mathcal{P}(\mathcal{S})} \Big(d(\theta(x_1), \theta(x_2)) + d(\theta(x_2), \theta(x_3)) + \ldots + d(\theta(x_k), \theta(x_1)) \Big),$$

where $\mathcal{P}(\mathcal{S})$ is the set of all permutations of $\mathcal{S}$. The closed 2-stop distance is twice the standard distance between two vertices. We study the closed k-stop center and closed k-stop periphery of a graph, for $k = 3$. (Received September 20, 2011)

1077-05-1639 **James E Gossell*** (JEG84240@ucmo.edu), Mathematics and Computer Science, W. C. Morris 222, University of Central Missouri, Warrensburg, MO 64093, and **Peter Johnson**, Auburn University. *A Geometric Extremal Result for Cubic Arrays.*

Imagine a game in which your goal is to select as many points as you can from an $n \times n$ square lattice in $\mathbb{Z}^2$. There is just one rule: No three points in your selected set may form a right triangle. For $n \geq 2$ you will find that you can pick up to $2n - 2$ points from the lattice without forming any right triangles. But try as you may, it is impossible to avoid forming a right triangle if you pick at least $2n - 1$ points.

In this talk, we will examine a 3-dimensional variation to this game: How many points can you pick from an $n \times n \times n$ cubic lattice in $\mathbb{Z}^3$ without forming a right triangle in any plane parallel to one of the coordinate planes? We will give a tight bound on the maximum number of points one can pick without forming such a right triangle. Several similar, but unsolved problems will also be mentioned. (Received September 20, 2011)

1077-05-1655 **Jonathan L. Gross*** (gross@cs.columbia.edu). *Embeddings for Bounded Treewidth and Bounded Degree.*

Let $\mathcal{F}$ be any family of graphs of bounded treewidth and bounded degree. We construct a quadratic-time algorithm for calculating the genus distribution of the graphs in $\mathcal{F}$, that is, for the number of cellular embeddings in each orientable surface from minimum to maximum genus of G. For a given graph G with decomposition tree T, we first calculate a *partitioned genus distribution* for each subgraph induced on the vertices in a node of T, and we reassemble the graph G by iteratively amalgamating these subgraphs. With each amalgamation step, we calculate a partitioned genus distribution of the subgraph of G resulting from the amalgamation. Since the number of non-zero values in the genus distribution grows quadratically with the number of vertices, quadratic-time is unimprovable. This result for genus distribution complements an algorithm of Kawarabayashi, Mohar, and Reed for calculating the minimum genus of a graph of bounded treewidth in linear time. (Received September 20, 2011)

1077-05-1664 **Brittany C Shelton*** (bcs207@lehigh.edu) and **Mark Skandera**. *Combinatorial Interpretations of Quantum Elementary Characters.* Preliminary report.

Combinatorial interpretations have been used to show the total nonnegativity of homogeneous and elementary immanants. The irreducible character immanants are known to be totally nonnegative as well. However, providing a combinatorial interpretation remains an open problem. To find such combinatorial interpetations we explore the quantum analogs of the S_n-characters associated to the above mentioned immanants. In this talk, we will discuss a combinatorial interpretation of the quantum elementary characters. The goal of this research is to use results for the quantum characters to get insight into S_n-character immanants. (Received September 20, 2011)

1077-05-1679 **M. N. Ellingham** and **Justin Z. Schroeder*** (justin.z.schroeder@vanderbilt.edu). *An orthogonal latin square construction for orientable hamiltonian embeddings of $K_{n,n,n}$.* Preliminary report.

An orientable hamiltonian embedding of a graph G is a drawing of G on an orientable surface such that no edges cross and the boundary of every face is a hamilton cycle. In this talk we develop a connection between latin squares and orientable hamiltonian embeddings of the complete tripartite graph $K_{n,n,n}$. In particular we show that a pair of orthogonal latin squares of order n with one additional property yields an orientable hamiltonian embedding of $K_{n,n,n}$ that is 2-colorable and has faces with some additional structure. The presentation concludes with a construction for such latin squares when $n = 2pq$, where $p, q \geq 2$. (Received September 20, 2011)

1077-05-1694 **Elizabeth Moseman*** (lizz.moseman@gmail.com). *Improving the Computational Efficiency of the Blitzstein–Diaconis algorithm for Generating Graphs of Prescribed Degree.*

When generating a random graph, if more structure is desired then is given in the popular Erdős–Renyi model, one method is to generate a degree sequence first then create a graph with this degree sequence. Blitzstein and Diaconis (among others) developed a sequential algorithm to create a random graph from a degree sequence. This algorithm is assured to always terminate in a graph with the degree sequence; unfortunately, it is slow. This work focusses on the subroutine of the previous algorithm which determines the candidate edges, improving the runtime of the overall algorithm from $O(mn^2)$ to $O(mn)$. (Received September 20, 2011)

1077-05-1696 **Yichao Chen*** (ycchen@hnu.edu.cn), College of Mathematics and Econometrics, HuNan University, ChangSha, HuNan 410082, Peoples Rep of China. *On the total embeddings for some types of graphs.*

Genus distributions problems have frequently been investigated in the past quarter century, since the topic was inaugurated by Gross and Furst. However the total embedding distribution of a graph, including the non-orientable embeddings, is known for relatively few classes of graphs, compared to the genus distribution. In this talk, we find explicit formula for the total embedding distribution of some well-known classes of graphs like: Closed-end ladders, Ringel ladders, Mobius ladders, circular ladders and Fan graphs etc. Our formula here is derived with the aid of Mohar's overlap matrices , Gustin's represention of rotation systems for cubic graphs, the Chebyshev polynomials of the second kind and a splitting technique for embedding distribution. (Received September 20, 2011)

1077-05-1719 **Devin R Bickner*** (dbickner@iastate.edu). *Counting Binary Normal Networks.*

Evolution can be represented using directed, acyclic graphs, in which vertices represent species, leaves represent extant species, and edges represent relationships between species. Trees have been used as the standard model. Recently, networks, which allow the inclusion of hybridization, have become more popular. Consider a set of leaf labels X. The number of binary rooted trees on X is known. However, the number of general networks on X is infinite. We will discuss a special class of networks called *normal* networks. We will discuss a method for finding an upper bound on the number of binary normal networks on X using special deletion and addition operations, as well as some related results. (Received September 20, 2011)

1077-05-1740 **Stephen T. Hedetniemi*** (hedet@clemson.edu), School of Computing, Clemson University, Clemson, SC 29634. *My Favorite Graph Coloring and Domination Conjectures.*

This talk will discuss aspects of several well-known and several not so well-known conjectures and open problems in graph theory, including: (1) the 1963 Vizing Conjecture about the domination number of the Cartesian product of two graphs; (2) the 1966 Hedetniemi Conjecture about the chromatic number of the tensor product of two graphs; (3) the 1981 Path Partition Conjecture; (4) the 1991 Kulli-Sigarkanti Conjecture about the inverse domination number of a graph; (5) the 1995 Hedetniemi Conjecture about the monotonicity of the Queen's domination number; (6) the 1995 problem of the complexity of a nearly perfect bipartition; (7) the 1999 Gu Conjecture about the domination number of prisms; (8) the 1998 Hedetniemi Conjecture about the achromatic and pseudoachromatic numbers of trees; (9) the 2004 problem of the iterated domination and iterated irredundance numbers of planar graphs; and (10) the 2011 problem of the existence of a graph G having a repeating γ-graph sequence.

(Received September 20, 2011)

1077-05-1761 **Yanting Liang*** (yliang@smcm.edu), Mathematics and Computer Science Department, St. Mary's College of Maryland, St. Mary's City, MD 20686. *Mod $(2p+1)$-orientations in graphs.*

An orientation of an undirected graph G is a mod $(2p+1)$-orientation if under this orientation, the net out-degree at every vertex is congruence to zero mod $2p+1$. A graph H is mod $(2p+1)$-contractible if for any graph G that contains H as a subgraph, the contraction G/H has a mod $(2p+1)$-orientation if and only if G has a mod $(2p+1)$-orientation (thus every mod $(2p+1)$-contractible graph has a mod $(2p+1)$-orientation). Jaeger in 1984 conjectured that every $(4p)$-edge-connected graph has a mod $(2p+1)$-orientation. It has also been conjectured that every $(4p+1)$-edge-connected graph is mod $(2p+1)$-contractible. I will introduce some recent results on mod (2p+1)-orientations in graphs. (Received September 20, 2011)

1077-05-1804 **Keenan Monks** (monks@college.harvard.edu), **Ken G. Monks*** (monks@scranton.edu), **Ken M. Monks** (monks@math.colostate.edu) and **Maria Monks** (monks@math.berkeley.edu). *On the Distribution of Arithmetic Sequences in the* $3x+1$ *Graph.* Preliminary report.

In a previous paper, K. M. Monks proved that every arithmetic sequence intersects every connected component of the digraph $\mathcal{G}$ of the famous $3x+1$ dynamical system $C(x) = \begin{cases} x/2 & x \text{ is even} \\ 3x+1 & x \text{ is odd} \end{cases}$ on the positive integers. In this talk, we study the specific distribution of arithmetic sequences in $\mathcal{G}$ to obtain stronger results for certain arithmetic sequences. In particular, we determine the structure of groups first constructed by K. M. Monks and use them to the find short paths in $\mathcal{G}$ from an arbitrary positive integer x to an element of a given arithmetic sequence. We show that every nontrivial infinite back-tracing path in $\mathcal{G}$ must contain an integer congruent to $2 \bmod 9$. We then use similar methods to show that every nontrivial cycle and every divergent orbit in the positive integers contains an integer congruent to 20 mod 27. (Received September 21, 2011)

1077-05-1811 **Hana Kim*** (hakkai14@skku.edu), Department of Mathematics, Sungkyunkwan University, Suwon, Gyeonggido 440-746, South Korea, **Gi-Sang Cheon** (gscheon@skku.edu), Department of Mathematics, Sungkyunkwan University, Suwon, Gyeonggido 440-746, South Korea, and **L. W. Shapiro** (lou.shapiro@gmail.com), Department of Mathematics, Howard University, WA DC 20059. *Combination of ordered trees associated with nonnegative integer sequences.*

For a sequence $A = (a_k)_{k\geq 0}$, $a_0 = 1$ of nonnegative integers, *A-ordered tree* is an edge-colored ordered tree satisfying the following conditions:

(i) the set of possible outdegrees of nonroot vertices is $\{k|a_k \neq 0\}$;

(ii) the rightmost edge from a nonroot vertex of degree k is colored by a_k colors.

In this talk, we consider an enumeration problem for A-ordered trees. In particular, the generating functions for vertices and leaves of those trees are given respectively. Further, we discuss a combination of A- and B-ordered trees, and explore how the combination of two ordered trees can be translated in the real world. (Received September 21, 2011)

1077-05-1823 **Sergey Kitaev**, **Pavel Salimov**, **Christopher Clark Severs** and **Henning Arnor Ulfarsson*** (henningu@ru.is), Menntavegi 1, 101 Reykjavik, Iceland. *Restricted rooted non-separable planar maps.* Preliminary report.

Tutte founded the enumeration theory of planar maps in a series of papers in the 1960s. Such a planar map is *rooted* by distinguishing one directed edge, and furthermore, called *non-separable* if it contains no loops or cut vertices. Rooted non-separable planar maps have connections, for example, to pattern-restricted permutations, and they are in one-to-one correspondence with the $\beta(1,0)$-trees introduced by Cori, Jacquard and Schaeffer in 1997. In this preliminary report we discuss enumeration of 2-face-free rooted non-separable planar maps and obtain restrictions on $\beta(1,0)$-trees giving k-face-free rooted non-separable planar maps. Moreover, we discuss multiple-edge-free rooted non-separable planar maps. Finally, we enumerate so-called primitive rooted non-separable planar maps (which are a basis for generating all rooted non-separable planar maps) and discuss some equinumerous objects such as certain permutations avoiding a mesh pattern, introduced by Brändén and Claesson in 2011. (Received September 21, 2011)

1077-05-1827 **Dan Archdeacon***, dan.archdeacon@uvm.edu. *Orthogonal Heffter systems, current graphs, and bi-embedding graphs on surfaces.* Preliminary report.

We examine a classical problem in design theory and its relation to the Map Color Theorem (MCT).

A Heffter 3-system is a partition of the integers 1,...,3n into n triples (x,y,z) such that either x+y=z or x+y+z=6n+1. These are used to construct Steiner Triple Systems (STS). A generalization to Heffter s-systems constructs s-cycle systems. We introduce the concept of orthogonal Heffter s- and t-systems, relate the concept to current graphs, and then to their derived surface embeddings. There is a beautiful interaction between design-theoretic properties of Heffter systems and the resulting surface embeddings.

As an example of a far-reaching theory, we study when there is an embedding of the complete graph into an orientable surface such that the faces can be 2-colored with one class all triangles and the other class all t-cycles. This generalizes the concept of bi-embedding STS's with a cyclic symmetry that is in turn related to the MCT. (Received September 21, 2011)

1077-05-1834 **Robin Christian**, **R. Bruce Richter** and **Gelasio Salazar*** (gsalazar@ifisica.uaslp.mx). *Embeddability of infinite graphs.*

Robertson and Seymour proved that there is a function $f(g)$ tending to infinity so that, if a graph G does not embed in any surface of Euler characteristic at least $2-2g$, then G has one of the following as a minor:

(1) $f(g)$ disjoint copies of either $K_{3,3}$ or K_5;

(2) $f(g)$ copies of either $K_{3,3}$ or K_5 that are disjoint except for a common vertex;

(3) $f(g)$ copies of either $K_{3,3}$ or K_5 that are disjoint except for two common vertices; or

(4) $K_{3,f(g)}$.

We have proved the following extension to infinite graphs.

Theorem. A countable graph G embeds in some orientable surface if and only if G does not contain as a minor one of the following graphs:

(1) infinitely many disjoint copies of either $K_{3,3}$ or K_5;

(2) infinitely many copies of either $K_{3,3}$ or K_5 that are disjoint except for a common vertex;

(3) infinitely many copies of either $K_{3,3}$ or K_5 that are disjoint except for two common vertices; or

(4) $K_{3,\infty}$.

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1077-05-1837 **Michael Young*** (myoung@iastate.edu), **Leslie Hogben**, **My Huynh**, **Kirill Lazebnik**, **Anna Cepek**, **Travis Peters** and **Minerva Catral**. *Zero Forcing Number and Maximum Nullity of Subdivided Graphs.*

For a simple, undirected graph G the zero forcing number $Z(G)$ is the minimum number of blue vertices initially needed to force all vertices in G blue according to the color change rule. The color change rule states that in a graph where each vertex is colored blue or white, a vertex v can force an adjacent vertex w to be colored blue, if v is blue and w is the only white neighbor of v.

The maximum nullity $M(G)$ of G is the largest possible nullity over all real symmetric matrices whose ijth entry (for $i \neq j$) is nonzero whenever $\{i,j\}$ is an edge in G and is zero otherwise. The minimum rank $mr(G)$ of G is $|G| - M(G)$. It is known that $M(G) \leq Z(G)$ for all G.

The complete subdivision graph $\overline{\overline{G}}$ is obtained from G by subdividing each edge once. This talk will cover results relevant to $Z(H)$ and $M(H)$ for an edge subdivision graph H of G and to the open question of whether $Z(\overline{\overline{G}}) = M(\overline{\overline{G}})$ for all graphs G. (Received September 21, 2011)

1077-05-1839 **Olof Heden**, **Julianne Lehmann**, **Esmeralda Nastase*** (nastasee@xavier.edu) and **Papa Sissokho**. *Extremal Sizes of Subspace Partitions.*

Let $V = V(n,q)$ be the vector space of dimension n over the finite field with q elements. A subspace partition of V is a collection of subspaces of V whose pairwise intersection is the zero vector. Vector space partitions have been extensively studied, but they have been proven difficult to characterize. In this talk, we determine the *minimum size* of a subspace partition of V in which the largest subspace has dimension t, and the *maximum size* of a subspace partition of V in which the smallest subspace has dimension t. Furthermore, we discuss the following application. A partial t-spread of V is a collection of t-dimensional subspaces of V, whose pairwise intersection is the zero vector. We apply the result on the minimum size of a subspace partition of V to find the minimum size of a maximal partial t-spread in $V(n+t-1,q)$.

This is joint work with Olof Heden, Julianne Lehmann, and Papa Sissokho. (Received September 21, 2011)

1077-05-1851 **Abbas Mahdi Alhakim***, 3 Hammarskjold Plaza, 8th floor, New York, NY 10017. *Generating All de Bruijn Sequences Using Preference Functions of Different Spans.* Preliminary report.

A nonbinary Ford sequence, or prefer-higher sequence–is a de Bruijn sequence generated by simple rules that determine the priorities of what symbols are to be tried first, given an initial word of size n which is the order of the sequence being enerated. This set of rules is generalized by the concept of a preference function of span $n-1$, which gives the priorities of what symbols to appear after a substring of size $n-1$ is encountered. In this paper we characterize preference functions that generate full de Bruijn sequences. More significantly, We establish that any preference function that generates a de Bruijn sequence of order n also generates de Bruijn sequences of all orders higher than n, thus making the Ford sequence no special case. Consequently, we define the preference function complexity of a de Bruijn sequence to be the least possible span of a preference function that generates this de Bruijn sequence. (Received September 21, 2011)

1077-05-1852 **V. C. Mavron**, **T. P. McDonough** and **M. S. Shrikhande*** (shrik1m@cmich.edu), Department of Mathematics, Central Michigan University, Mt. Pleasant, MI 48859. *On quasi-symmetric designs with intersection difference three.*

In a recent paper, Pawale (Des Codes Cryptogr, 2010) investigated quasi-symmetric $2-(v,k,\lambda)$ designs with intersection numbers $x>0$ and $y=x+2$ with $\lambda>1$ and showed that under these conditions either $\lambda=x+1$ or $\lambda=x+2$, or D is a design with parameters given in the form of an explicit table, or the complement of one of these designs. In this paper, quasi-symmetric designs with $y-x=3$ are investigated. It is shown that such a design or its complement has parameter set which is one of finitely many which are listed explicitly or $\lambda\le x+4$ or $0\le x\le 1$ or the pair (λ,x) is one of $(7,2),(8,2),(9,2),(10,2),(8,3),(9,3),(9,4)$ and $(10,5)$. It is also shown that there are no triangle-free quasi-symmetric designs with positive intersection numbers x and y with $y=x+3$. (Received September 21, 2011)

1077-05-1853 **M Drew LaMar*** (mdlama@wm.edu), College of William and Mary, Biology Dept, Quantitative Biology Laboratory, 2111 Integrated Science Center, Williamsburg, VA 23185. *Split digraphs.*

We will generalize the class of split graphs to the directed case and show that these split digraphs can be identified from their degree sequences in two ways: the first is an extension of the concept of splittance to directed graphs, while the second states that a digraph is split if and only if its degree sequence satisfies one of the Fulkerson inequalities (which determine when an integer-pair sequence is digraphic) with equality. Time permitting, we will then show how split digraphs appear in the uniform sampling of directed graphs from a fixed degree sequence. (Received September 21, 2011)

1077-05-1869 **Paul Wrayno*** (paul.wrayno@wku.edu), 1906 College Heights Blvd #11078, Bowling Green, KY 42101. *On the Number of Edges in Bipartite 2-factor Isomorphic Graphs.*

A graph, G, is 2-factor isomorphic if it contains a 2-factor, F, and all other 2-factors are isomorphic to F. In other words, if a 2-factor is viewed as a collection of cycles that covers all vertices, then all 2-factors are composed of the same collection of unlabeled cycles. Faudree, Gould, and Jacobson give a formula and a construction for the maximum number of edges for bipartite 2-factor hamiltonian graphs as a function of $|V(G)|$. In this talk I generalize this result to any chosen 2-factor, any 2-factor with a fixed number of cycles, and find an overall maximum as a function of $|V(G)|$. I will also provide a general construction that attains these bounds. (Received September 21, 2011)

1077-05-1874 **Paul Horn*** (phorn@math.harvard.edu), **Václav Koubek** and **Vojtěch Rödl**. *Edge disjoint isomorphic subgraphs in uniform hypergraphs.*

We show that any k-uniform hypergraph with n edges contains two edge disjoint subgraphs of size $\tilde{\Omega}(n^{2/(k+1)})$ for $k=4,5$ and 6. This is best possible up to a logarithmic factor due to a upper bound construction of Erdős, Pach, and Pyber who show there exist k-uniform hypergraphs with n edges and with no two edge disjoint isomorphic subgraphs with size larger than $\tilde{O}(n^{2/(k+1)})$. Furthermore, this extends results Erdős, Pach and Pyber who also established the lower bound for $k=2$ (eg. for graphs), and of Gould and Rödl who established the result for $k=3$. (Received September 21, 2011)

1077-05-1880 **Dennis Stanton*** (stanton@math.umn.edu), School of Mathematics, University of Minnesota, 206 Church St SE, Minneapolis, MN 55455. *The negative q-binomial.*

Interpretations for the q-binomial coefficient evaluated at -q are discussed. A (q,t)-version is established, including an instance of a cyclic sieving phenomenon involving unitary spaces over finite fields. This is joint work with S. Fu, V. Reiner, and N. Thiem. (Received September 21, 2011)

1077-05-1886 **Micaela Harris**, **Ruth Haas**, **Kristina Martin*** (rhaas@smith.edu), **Shira Polster** and **Julie Woods**. *The Rainbow Domination Number of a Graph.* Preliminary report.

Let $G=(V,E)$ be a graph and $c:V\to\{1,2,\dots,k\}$ be a (not necessarily proper) $k-$ coloring of the vertices of G that uses all k colors. A set $S\subset V$ is an *rainbow dominating set* for G if i) Every vertex in S is assigned a different color; and ii) S is a dominating set, that is, every vertex in $V(G)/S$ is adjacent to a vertex of S. We define the *rainbow domination number* of a graph to be the least number k such that every onto k coloring of G has a Rainbow domination number. We determine the rainbow domination number for certain graphs. (Received September 21, 2011)

1077-05-1894 **Wilfried Imrich*** (imrich@unileoben.ac.at), Gubattagasse 2, 8700 Leoben, Austria. *Vertex Transitive Infinite Median Graphs.*

Median graphs are generalizations of trees and can be characterized as retracts of hypercubes, both in the finite and in the infinite case.

In the finite case all regular median graphs are hypercubes, and thus vertex transitive. In the infinite case the structure of regular, respectively of vertex transitive median graphs, is much richer. We present the following results, most of them obtained together with Sandi Klavžar:

- For a given degree there are only finitely many vertex transitive median graphs whose blocks are finite. We list them for small degrees.
- There is only one infinite cubic median graph with two ends. It is vertex transitive.
- There are regular median graphs of degree four with two ends that are not vertex transitive.
- We characterize all locally finite vertex transitive median graphs with two ends.
- We characterize all locally finite vertex transitive median graphs with nonlinear, polynomial growth.

The methods used range from theorems about the number of orbits in finite median graphs, the fixed cube property of finite median graphs, to properties of the free product of graphs, and the lattice dimension of partial cubes. (Received September 21, 2011)

1077-05-1897 **Drew Armstrong*** (armstrong@math.miami.edu), Department of Mathematics, University of Miami, Coral Gables, FL 33146. *Rational Catalan Combinatorics.* Preliminary report.

Given a positive rational number $a/b \in \mathbb{Q}$ in lowest terms, we define the rational Catalan number:

$$\mathrm{Cat}(a/b) := \frac{1}{a+b}\binom{2a+b-1}{a}.$$

Note that $\mathrm{Cat}(n/1)$ is familiar. We will show through examples that there is a rich theory of "rational Catalan combinatorics" waiting to be explored. (Received September 21, 2011)

1077-05-1906 **Chris Godsil** and **Simone Severini*** (simoseve@gmail.com), Department of Physics & Astronomy, University College London, London, WC1E 6BT, England. *Control by quantum dynamics on graphs.*

We address the study of controllability of a closed quantum system whose dynamical Lie algebra is generated by adjacency matrices of graphs. We characterize a large family of graphs that renders a system controllable. The key property is a novel graph-theoretic feature consisting of a particularly disordered cycle structure. Disregarding efficiency of control functions, but choosing subfamilies of sparse graphs, the results translate into continuous-time quantum walks for universal computation. (Received September 21, 2011)

1077-05-1924 **Senmei Yao*** (smyao@math.wvu.edu), 320 Armstrong Hall, P.O.Box 6310, Morgantown, WV 26505. *Group Connectivity in Line Graphs.*

Tutte introduced the theory of nowhere zero flows and showed that a plane graph G has a face k-coloring if and only if G has a nowhere zero A-flow, for any Abelian group A with $|A| \geq k$. In 1992 Jaeger et al extended nowhere zero flows to group connectivity of graphs: given an orientation D of a graph G, if for any $b : V(G) \mapsto A$ with $\sum_{v \in V(G)} b(v) = 0$, there always exists a map $f : E(G) \mapsto A - \{0\}$, such that at each $v \in V(G)$,

$$\sum_{e = vw \text{ is directed from } v \text{ to } w} f(e) - \sum_{e = uv \text{ is directed from } u \text{ to } v} f(e) = b(v)$$

in A, then G is A-connected. Let Z_3 denote the cyclic group of order 3. Jaeger et al conjectured that every 5-edge-connected graph is Z_3-connected. We proved the following:

(i) Every 5-edge-connected graph is Z_3-connected if and only if every 5-edge-connected line graph is Z_3-connected.
(ii) Every 6-edge-connected triangular line graph is Z_3-connected.
(iii) Every 7-edge-connected triangular claw-free graph is Z_3-connected.

In particular, every 6-edge-connected triangular line graph and every 7-edge-connected triangular claw-free graph have a nowhere zero 3-flow. (Received September 21, 2011)

1077-05-1926 **Thomas Milligan*** (tmilligan1@uco.edu), 100 N. University Dr., Edmond, OK 73034, and **Xander Rudelis**. *Minor monotone floor and ceiling of certain graph parameters.* Preliminary report.

A graph parameter is minor monotone if it preserves the minor relation. We consider the transformation of real-valued graph parameters into related minor monotone graph parameters using two different methods. The minor monotone floor and the minor monotone ceiling of a number of graph parameters are considered. Particular attention is given to parameters that relate to the zero-forcing number and other matrix related graph parameters. Results dealing with the Hadwiger conjecture are also considered. (Received September 21, 2011)

1077-05-1931 **Wilfried Imrich*** (imrich@unileoben.ac.at), Gubattagasse 2, 8700 Leoben, Austria. *Conjectures reaching from groups and graphs to graphs and groups.*

In 1957 Hanna Neumann proved that for non-trivial subgroups U, V of finite ranks $r(U), r(V)$ in a free group

$$r(U \cap V) - 1 \leq 2(r(U) - 1)(r(V) - 1).$$

She conjectured that the factor 2 is superfluous.

We outline a graph-theoretic proof of her result. The proof, using a construction similar to the direct product of graphs, makes some generalizations of the conjecture plausible.

The second conjecture concerns the direct product of graphs. Although the prime factorization of finite connected nonbipartite graphs is unique, this is not so for bipartite graphs. Hammack conjectures that every finite connected bipartite graph has a unique bipartite prime factor. He proves it if this factor is K_2.

The last conjectures pertain to the Distinguishing number $D(G)$ of a graph, that is, the smallest number of colors needed to color the vertices so that only the identity automorphism preserves all colors.

It is known that the Radon graph has distinguishing number 2. Here new types of uncountable random graphs are defined. We conjecture that they also have distinguishing number 2.

The fourth conjecture states that for infinite cardinals n, m, where $n < m < 2^n$, the distinguishing number of the Cartesian product of K_n with K_m is 2. (Received September 21, 2011)

1077-05-1935 **Joel Brewster Lewis*** (jblewis@math.mit.edu), 77 Massachusetts Avenue, Cambridge, MA 02139, and **Ricky Ini Liu**, **Alejandro H. Morales**, **Greta Panova**, **Steven V Sam** and **Yan X Zhang**. *Matrices with restricted entries and q-analogues of permutations.*

Classical formulas show that the number of invertible $n \times n$ matrices over a finite field with q elements is a natural q-analogue of $n!$, and more generally that the number of $n \times n$ matrices of rank r is a q-analogue of the number of ways to place r nonattacking rooks on an $n \times n$ board. In this talk, we study the functions that count matrices of given rank over a finite field with specified positions equal to 0. We show that the number invertible matrices with zero diagonal is a natural q-analogue of the number of derangements (i.e., permutations with no fixed points). More generally, we show that the number of matrices of given rank with certain entries equal to 0 is a q-analogue of rook placements with restricted positions.

In addition, we study the question of when the number of matrices with given size, rank, and prescribed entries equal to 0 is a polynomial in the size q of the field. We also consider a variety of related questions concerning symmetric and skew-symmetric matrices. Most of our proofs are elementary, and we frame some of our results in the context of Lie theory. (Received September 21, 2011)

1077-05-1937 **Nathaniel Dean*** (nd17@txstate.edu), Department of Mathematics, Texas State University, 601 University Drive, San Marcos, TX 78666. *Some of My Unsolved Problems in Graph Theory.* Preliminary report.

Over many years I've posed several problems in graph theory, and most of them are still unsolved. Several of them are related to cycle modularity, chords in cycles, chromatic number of the plane, crossing numbers, and eulerian digraphs. I'll try to explain why I posed these problems and demonstrate connections to other areas such as topology, statistics, mathematical programming, number theory, nanotechnology, and geometry. (Received September 22, 2011)

1077-05-1941 **Ashwini Aroskar*** (aaroskar@andrew.cmu.edu) and **James Cummings**. *Limits, Regularity and Removal for Relational Structures : A measure theoretic approach.*

Szemeredi's Regularity Lemma states a large graph can be well-approximated by graphs that are almost random[1]. A well-known application of this result is in the proof of the Graph Removal lemma[2]. Our work builds on known results for k-uniform hypergraphs including the existence of limits, a Regularity Lemma and a Removal lemma[3,4]. Our main tool is the theory of measures on ultraproduct spaces which shows a correspondence between these spaces and the Euclidean space. We have extended this correspondence to measurable functions on these spaces. We show the existence of a limit object for sequences of relational structures and retrieve known limits for graphs and digraphs. We also state and prove Regularity, Removal and Generalized Removal Lemmas for relational structures. Generalized Removal deals with the removal of a family of structures and has applications in property testing. We also explore extensions of these results to weighted structures such as weighted graphs. 1)Szemerédi, E.Proc.Colloq.Int. CNRS(1976), 399-401 2)Erdös, P. et al. Graphs and Combinatorics(1986), 2(1), 113-121 3)Elek, G. & Szegedy, B. preprint, arXiv.org:0705.2179 4)Elek, G. & Szegedy, B. preprint, arXiv.org:0810.4062 (Received September 21, 2011)

1077-05-1945 **Peter Hamburger**, **Alexandr V. Kostochka** and **Christopher Stocker*** (christopher.stocker@wku.edu), Department of Mathematics, Western Kentucky University, 1906 College Heights Blvd. # 11078, Bowling Green, KY 42101. *A hypergraph version of a graph packing theorem by Bollobás and Eldridge.*

Two n-vertex hypergraphs G and H *pack* if there is a bijection $f\colon V(G) \to V(H)$ such that for every edge $e \in E(G)$, the set $\{f(v)\colon v \in e\}$ is not an edge in H. Sauer and Spencer showed that any two n-vertex graphs G and H with $|E(G)| + |E(H)| < \frac{3n-2}{2}$ pack. Bollobás and Eldridge proved that, with 7 exceptions, if graphs G and H contain no spanning star and $|E(G)| + |E(H)| \leq 2n-3$, then G and H pack. We generalize the Bollobás – Eldridge result to hypergraphs containing no edges of size 0, 1, $n-1$, or n. As a corollary we get a hypergraph version of the Sauer – Spencer result. (Received September 21, 2011)

1077-05-1949 **Ping Li*** (liping@math.wvu.edu), 320 Armstrong Hall P.O. Box 6310, West Virginia University, Morgantown, WV 26506-6310. *Graphs with $(k \pm \epsilon)$-edge-disjoint spanning trees.*

(i) For a graph G that does not have k-edge-disjoint spanning trees, we are to determine the minimum number of edges that must be added to result in a graph with k-edge-disjoint spanning trees.
(ii) For a graph G with k disjoint spanning trees, we are to determine which edge e such that $G - e$ also has k edge-disjoint spanning trees. (Received September 21, 2011)

1077-05-1950 **J. Haglund*** (jhaglund@math.upenn.edu) and **M. Visontai** (mirko@math.upenn.edu). *Stable multivariate Eulerian polynomials and generalized Stirling permutations.*

Stirling permutations were introduced by Gessel and Stanley in their study of Stirling numbers of the first and second kind. They also introduced a natural analog of the Eulerian polynomial for these permutations. ln this talk we show there is a multivariate analog of their Eulerian polynomials which is stable in the sense of Borcea and Brändén. As a corollary we obtain a result of Bona, that these polynomials have only real zeros. Our methods utilize elements in the recent proof of the Monotone Column Permanent Conjecture by Brändén, Visontai, Wagner, and the speaker. (Received September 21, 2011)

1077-05-1956 **Carla D. Savage*** (savage@csc.ncsu.edu), Department of Computer Science, Box 8206, North Carolina State University, Raleigh, NC 27695-8206, and **Gopal Viswanathan** (gviswan@ncsu.edu), Department of Computer Science, Box 8206, North Carolina State University, Raleigh, NC 27695-8206. *The $1/k$ - Eulerian Polynomials.*

We introduce the $1/k$ - Eulerian polynomials, defined combinatorially as the distribution of a certain statistic over "k-inversion sequences". These polynomials arise naturally in the theory of lecture hall partitions, via an associated "k-lecture hall polytope".

We show that the Ehrhart polynomial of the k-lecture hall polytope can be computed explicitly. From this, the exponential generating of the $1/k$ - Eulerian polynomials is derived (and their name is explained). In doing so, we uncover a connection between the $1/k$ - Eulerian polynomials and the joint distribution, over the symmetric group, of excedance and number of cycles. (Received September 21, 2011)

1077-05-1965 **Alejandro H. Morales*** (ahmorales@math.mit.edu), Department of Mathematics MIT, Building 2, Room 2-489, 77 Massachusetts Avenue, Cambridge, MA 02139-4307, and **Karola Mészáros**. *Flow polytopes and the Kostant partition function for signed graphs.*

Flow polytopes and the Kostant partition function are inherently related. This surprising connection has been studied with combinatorial methods by Postnikov and Stanley, and subsequently by Baldoni and Vergne using residue techniques. The combinatorial nature of flow polytopes and the Kostant partition function is showcased by the well-known Chan-Robbins-Yuen polytope, which is the flow polytope of the complete graph. Namely, an evaluation of the Kostant partition function is equal to the volume of this polytope, which in turn is the product of Catalan numbers by a theorem of Zeilberger. We use combinatorial techniques similar to those of Postnikov and Stanley to establish the relationship between volumes of flow polytopes associated to signed graphs and a variant of the Kostant partition function. We then study a generalization of the Chan-Robbins-Yuen polytope with the Kostant partition function in mind. (Received September 22, 2011)

1077-05-1966 **Nate R Harman*** (nateharman1234@yahoo.com), 56 Cowls Rd, Amherst, MA 01003. *Families of Half-Transitive Graphs.*

A graph is called half-transitive, or $\frac{1}{2}$-arc transitive, if it is both vertex and edge transitive but not arc-transitive. In a recent survey of edge transitive graphs of small order this type of symmetry was by far the least common, and only a handful of constructions for such graphs were previously known. We give several new constructions for infinite families of half-transitive graphs, and introduce new methods for preventing the occurrence of unwanted symmetries. (Received September 21, 2011)

1077-05-1981 **Eric M Nelson*** (nelson@math.colostate.edu). *Transitive BLT-sets.* Preliminary report.
As BLT-sets arose from derivation of flocks their connections are just as plentiful. Through flocks, they are related to projective planes (via Thas-Walker and hyperbolic vibrations), generalized quadrangles, fibrations, as well as most recently, hemisystems and cometric 4-class association schemes. These connections as well as progress towards computing the group of the Mondello BLT-sets (the last known infinite family with unknown group) will be presented. (Received September 21, 2011)

1077-05-2021 **Allen J. Schwenk*** (schwenk@wmich.edu), Department of Mathematics, Western Michigan university, Kalamazoo, MI 49008. *Some History on the Reconstruction Conjecture.* Preliminary report.
We present a bit of the history for the reconstruction conjecture. Ulam defined a pair of graphs G and H to be hypomorphic if their vertices can be labeled so that $G-u_i$ is isomorphic to $H-v_i$ for each i with $1 \leq i \leq n$. He then conjectured that any pair of hypomorphic graphs must be isomorphic. But this presentation doesn't even use the word reconstruction and is not the format that people generally use when they talk about this problem. How did we come to the language of reconstruction of G from its deck of vertex deleted subgraphs, the concept of a legitimate versus illegitimate deck, pseudo-similar vertices, and so on? Is this conjecture more likely to be true or false? (Received September 22, 2011)

1077-05-2026 **Nicola Pace*** (npace@fau.edu), Department of Mathematical Sciences, Florida Atlantic University, 777, Glades Road, Boca Raton, FL 33431. *On 3-nets realizing a finite group in a projective plane.*
Let $\mathrm{PG}(2,\mathrm{K})$ be a projective plane over an algebraically closed field K. A realization of a finite group G is a triple (α,β,γ) of maps from G to the point set of $\mathrm{PG}(2,\mathrm{K})$ such that $a\cdot b=c$ if and only if $\alpha(a),\beta(b),\gamma(c)$ are three collinear points, for every $a,b,c\in G$. This is an embedding of the dual 3-net corresponding to G.

A basic construction is based on the abelian group structure on the cubic curve and realize cyclic and direct products of two cyclic groups. An infinite family, due to Pereira and Yuzvinsky, comprises 3-nets realizing dihedral groups and the existence of 3-nets realizing the quaternion group of order 8 was proved by Urzua. In a recent work with G. Korchmaros and G. Nagy, we give a complete classification of 3-nets realizing a finite group in characteristic zero. If the characteristic of K is larger than the order of the group, the same classification holds true in apart from three possible exceptions Alt_4, Sym_4 and Alt_5.

In this talk, I will show the main constructions, tools and key results that lead to the classification theorem. I will also present a different approach using intersection of cosets of plane cubic curves. (Received September 21, 2011)

1077-05-2036 **Daniel Schaal*** (daniel.schaal@sdstate.edu), Dept. of Mathematics and Statistics, South Dakota State University, Brookings, SD 57006, and **Melanie Zinter**. *On Continuous Rado Numbers.*
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. The integers S(t) are called Schur numbers and are known only for t = 2, t = 3 and t = 4. 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 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 introduce a variation of the classical Rado numbers. The least integer n, provided that it exists, such that for every coloring of the real numbers from 1 to n with t colors there exists a monochromatic solution to L is called the t-color continuous Rado number for L. (Received September 21, 2011)

1077-05-2046 **Seth Pettie*** (pettie@umich.edu), University of Michigan, EECS Department, 2260 Hayward St., Ann Arbor, MI 48109. *An Introduction to Davenport-Schinzel Sequences, Forbidden 0-1 Matrices, and Their Geometric Applications.*
The *forbidden substructure method* is an elegant technique for bounding the complexity of geometric objects or the running time of geometric or non-geometric algorithms. One simply (i) *transcribes* the object or algorithm execution as a sequence (or 0-1 matrix), (ii) shows that this sequence (or matrix) avoids some *forbidden substructure* σ, then (iii) applies an "off-the-shelf" bound on the length of any such σ-free sequence (or the density

of a σ-free matrix). The power of the method rests on step (iii): having a large library of bounds on extremal properties of σ-free sequences/matrices.

Let $\mathrm{Ex}(\sigma, n)$ be the maximum length of a sequence over an n-letter alphabet, none of whose subsequences are isomorphic to a sequence σ, or the maximum number of 1s in an $n \times n$ 0-1 matrix, none of whose submatrices contain the 0-1 matrix σ. In this talk I will give several examples of the forbidden substructure method in discrete geometry, then survey what is known about $\mathrm{Ex}(\sigma, n)$ and the properties of σ that influence its growth. Open problems of interest to the speaker may be mentioned in passing, mumbled. (Received September 21, 2011)

1077-05-2060 **Torina Deachune Lewis*** (lewist@cookman.edu), **Talmage James Reid** and **Laura Sheppardson**. *Bicircular Matroids with Circuits of at Most Two Sizes.*

Young reports that Murty was the first to study matroids with all hyperplanes having the same size. Murty called such a matroid an "Equicardinal Matroid". Young renamed this matroid a "Matroid Design". Further work on determining properties of these matroids was done by Edmonds, Murty, and Young. These authors were able to connect the problem of determining the matroid designs with specified parameters with results on balanced incomplete block designs. The dual of a matroid design is one in which all circuits have the same size. Murty restricted his attention to binary matroids and was able to characterize all connected binary matroids having circuits of a single size. Lemos, Reid, and Wu provided partial information on the class of connected binary matroids having circuits of two different sizes. Here we determine the connected bicircular matroids with all circuits having the same size. We also provide structural information on the connected bicircular matroids with circuits of two different sizes. The bicircular matroids considered are in general non-binary. Hence these results are a start on extending Murty's characterization of binary matroid designs to non-binary matroids. (Received September 21, 2011)

1077-05-2062 **Svante Linusson*** (linusson@math.kth.se). *On the bunkbed conjecture and related problems.*

I will describe what is known about a problem on percolation on product graphs $G \times K_2$. Here G is any finite graph and K_2 consists of two vertices $\{0, 1\}$ connected by an edge. In edge percolation every edge in $G \times K_2$ is present with probability p. An old conjecture, dating at least to Kateleyn in 1985, says that for all G and p the probability in this situation that $(u, 0)$ is in the same component as $(v, 0)$ is greater than the probability that $(u, 0)$ is in the same component as $(v, 1)$ for every pair of vertices u, v in G.

In recent work this conjecture was generalized in several steps and similar statements for randomly directed graphs were formulated and proved. The methods lead in particular to a proof of the original conjecture for outerplanar graphs G. (Received September 21, 2011)

1077-05-2075 **James Carraher*** (s-jcarrah1@math.unl.edu), **Ilkyoo Choi**, **Michelle Delcourt** and **Lawrence Erickson**. *Cops and robbers location game.*

We consider a cops and robbers game on a finite graph G where a single cop seeks a single robber. The cop does not know the location of the robber, but on each turn the cop can probe a vertex and obtain the distance from the probed vertex to the robber. The cop wins if he or she can determine where the robber is located. If the cop can not determine the robber's location then the robber may move to an adjacent vertex. We show that if the girth of the graph G is at most 5 then the robber can never be caught. For large subdivisions of the complete graph and grid, we demonstrate a winning strategy for the cop. (Received September 21, 2011)

1077-05-2084 **Henry Escuadro*** (escuadro@juniata.edu) and **Futaba Fujie-Okamoto**. *Total Detection Numbers of Graphs.*

Let G be a connected graph of order $n \geq 3$ and let $c : E(G) \to \{1, 2, \ldots, k\}$ be a coloring (or labeling) of the edges of G for some positive integer k (where adjacent edges may be colored the same). The *color code* of a vertex v of G is the ordered k-tuple

$$\mathrm{code}_c(v) = (a_1, a_2, \cdots, a_k) \text{ (or simply } \mathrm{code}_c(v) = a_1 a_2 \cdots a_k),$$

where a_i is the number of edges incident with v that are colored i for $1 \leq i \leq k$. The coloring c is a *detectable coloring* if distinct vertices of G have distinct color codes.

For a detectable coloring $c : E(G) \to \{1, 2, \ldots, k\}$ of a graph G, we define the *value* of c as

$$\mathrm{val}(c) = \sum_{e \in E(G)} c(e).$$

The *total detection number* of G is defined by

$$\mathrm{td}(G) = \min\{\mathrm{val}(c)\}$$

where the minimum is taken over all detectable colorings of G.

In this talk, we investigate the total detection numbers of cycles and complete graphs. (Received September 21, 2011)

1077-05-2099 **Margaret M Bayer*** (bayer@math.ku.edu) and **William Espenschied** (wespens@math.ku.edu). *Graphs of Polytopes.* Preliminary report.

A well-known theorem of Steinitz says that a graph G is the graph of a 3-dimensional polytope if and only if G is planar and 3-connected. No such characterization is known for the graphs of convex polytopes of higher dimensions. In this talk, we discuss old and new results about graphs of polytopes of dimension four and higher. We look at the issue of dimensional ambiguity: the graph of a polytope of dimension d can at the same time be the graph of polytopes of other dimensions. For example, we describe polytopes of dimensions up to $3d/2$ having the same graph as the d-dimensional crosspolytope. The Gale diagram of a polytope is one tool used. (Received September 21, 2011)

1077-05-2127 **Bonnie C. Jacob** and **Jobby Jacob*** (jxjsma@rit.edu). *From sum optimal to max optimal graph rankings.*

Given a graph G, and a non-negative integer a, a function $f : V(G) \to \{a, a+1, \ldots, b\}$ is an $[a, b]$-ranking of G if for $u, v \in V(G)$, $f(u) = f(v)$ implies that every uv path contains a vertex w such that $f(w) > f(u)$. That is, f is an $[a, b]$-ranking of G if and only if the function defined by $g(v) = f(v) - a + 1$ is a k-ranking of G.

We use this generalization of k-rankings to explore l_p norm optimality for all positive integers p and for $p = \infty$. The l_∞ optimality produces the rank number of a graph when $a = 1$. We will discuss the effect of different l_p norms on optimal rankings of graphs. (Received September 21, 2011)

1077-05-2136 **Frank A. Firke*** (firkef@carleton.edu), **Evan D. Nash** and **Peter M. Kosek**. *Extremal Graphs Without 4-Cycles.*

Determining the largest number of edges in a C_4-free graph on n vertices is a problem that remains unsolved for general n. However, we extended previous work by Füredi to prove an upper bound for the number of edges in a C_4-free graph on $q^2 + q$ vertices for q even. This upper bound is achieved if and only if there is an orthogonal polarity graph of a projective plane of even order q. (Received September 21, 2011)

1077-05-2137 **Tingyao Xiong*** (txiong@radford.edu), Department of Mathematics and Statistics, Radford, VA 24141, and **Hung-ping Tsao** and **Jonathan I. Hall** (jhall@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Combinatorial Interpretations of the General Eulerian Numbers.* Preliminary report.

The *Eulerian Polynomials* have been introduced by Euler himself back in 1755. The combinatorial meanings of *Eulerian numbers* which are closely related to Eulerian Polynomials have been discovered by Riordan two hundred years later. The definitions and properties of Eulerian polynomials and Eulerian numbers have been thoroughly studies and extended in both directions of analytical number theory and combinatorics. In this talk, we will generalize the definition of Eulerian polynomials and Eulerian numbers to general arithmetic progressions. Under the new definitions, we have been successful in extending many well-known properties of traditional Eulerian polynomials and numbers to the general Eulerian polynomials and numbers. A new combinatorial interpretation will be given to the general Eulerian numbers, and several new combinatorial properties of permutations will be explored. *Keywords*: Eulerian polynomials, Eulerian numbers, triangular arrays, generating functions, combinatorial interpretation. (Received September 21, 2011)

1077-05-2172 **David S Rolnick*** (drolnick@mit.edu). *On the Classification of Stanley Sequences.*

An integer sequence is said to be *3-free* if no three elements form an arithmetic progression. The *Stanley sequence* $S(a_0, a_1, \ldots, a_k)$ is the greedily-derived 3-free sequence $\{a_n\}$ having initial terms $a_0, a_1, \ldots, a_k$ and with each subsequent term $a_n > a_{n-1}$ chosen minimally such that the 3-free condition is not violated. Odlyzko and Stanley conjectured that Stanley sequences divide into two classes based on asymptotic growth patterns, with one class of highly structured sequences satisfying $a_n \approx O(n^{\log_2 3})$ and another class of seemingly chaotic sequences obeying $a_n = O(n^2/\log n)$. We propose a rigorous definition of *regularity* in Stanley sequences based on local structure rather than asymptotic behavior and show that our definition implies the corresponding asymptotic property proposed by Odlyzko and Stanley. We then construct many classes of regular Stanley sequences, which include as special cases all such sequences previously identified. Finally, we show that certain Stanley sequences possess proper subsets which are also Stanley sequences, a situation which prior authors seem tacitly to have assumed impossible. (Received September 21, 2011)

1077-05-2176 **Melinda D. Lanius*** (mlanius@wellesley.edu) and **Andre Kuney** (akuney@oberlin.edu). *Universal Cycles Under Equivalence Relations.*

Consider all possible length-k words taken from a size-n alphabet. It is classical that we can create a string such that the set of all length-k consecutive substrings of this string consists of each of our words exactly once; this string is called a universal cycle. We examine the question: can we create a universal cycle of length-k words under certain equivalence relations? In this talk, we will introduce a new way of constructing the De Bruijn-like graph that is used to prove the existence of universal cycles. (Received September 21, 2011)

1077-05-2200 **Xiaofeng Gu*** (xgu@math.wvu.edu), Math Department, West Virginia University, Morgantown, WV 26506. *Graphic Degree Sequences and Graphs with a k-factor.*

A sequence $d = (d_1, d_2, \cdots, d_n)$ is graphic if there is a simple graph G with degree sequence d, and such a graph G is called a realization of d. Let k be a positive integer. A k-regular spanning subgraph of a graph is called a k-factor of the graph. In this paper, it is proved that a nonincreasing graphic sequence $d = (d_1, d_2, \cdots, d_n)$ has a realization G with a k-factor if and only if $(d_1 - k, d_2 - k, \cdots, d_n - k)$ is graphic. (Received September 21, 2011)

1077-05-2210 **William B Jamieson*** (jamieson@goldmail.etsu.edu). *Random Set Systems.*

Random graphs have been studied since Erdős and Rényi in 1959. We propose a new discrete random model, the random set system, where subsets of $[n]$ are chosen with probability p. Many properties of random graphs have been thoroughly characterized. We attempt to characterize similar properties for the random set system model. (Received September 21, 2011)

1077-05-2215 **Jeong-Ok Choi** (jeong.choi@trincoll.edu), Mathematics Department, Trinity College, Hartford, 06106, **John P. Georges** (john.georges@trincoll.edu), Mathematics Department, Trinity College, Hartford, CT 06106, **David W. Mauro*** (david.mauro@trincoll.edu), Mathematics Department, Trinity College, Hartford, CT 06106, and **Yan Wang** (wangy@millsaps.edu), Department of Mathematics, Millsaps College, Jackson, MS 39210. *On real number labellings and graph invertibility.*

For non-negative real x_0 and simple graph G, $\lambda_{x_0,1}(G)$ is the minimum span over all labellings that assign real numbers to the vertices of G such that adjacent vertices receive labels that differ by at least x_0 and vertices at distance two receive labels that differ by at least 1. In this paper, we introduce the concept of λ-invertibility: G is λ-invertible if and only if for all positive x, $\lambda_{x,1}(G) = x\lambda_{\frac{1}{x},1}(G^c)$. We explore the conditions under which a graph is λ-invertible, and apply the results to the calculation of the function $\lambda_{x,1}(G)$ for certain λ-invertible graphs G. We give families of λ-invertible graphs, including certain Kneser graphs, line graphs of complete multipartite graphs, and self-complementary graphs. We also derive the complete list of all λ-invertible graphs with maximum degree 3. (Received September 21, 2011)

1077-05-2226 **Teresa W. Haynes*** (haynes@etsu.edu), Department of Mathematics and Statistics, East Tennessee State University, Johnson City, TN 37614. *Two Conjectures Involving Diameter and Total Domination in Graphs.*

We present two intriguing conjectures involving diameter and total domination in graphs. A graph G is diameter 2-critical if its diameter is two, and the deletion of any edge increases the diameter. Murty and Simon conjectured that the number of edges in a diameter 2-critical graph of order n is at most $n^2/4$ and that the extremal graphs are complete bipartite graphs with equal size partite sets. This conjecture has an equivalent form based on a seemingly disparate concept, namely, total domination critical graphs. A graph is total domination critical if the addition of any edge decreases the total domination number. Using this important association with total domination, we have proven the equivalent form of the Murty-Simon Conjecture for graphs whose complements have specified properties. We discuss these results and outline the progress made toward a solution. We conclude the talk by giving a recently posed conjecture that the total domination number of any diameter-2 graph of order n is at most $\sqrt{n} + 1$. We discuss the motivation of this conjecture and list characteristics of any potential counterexample. Results mentioned in this talk are from varying subsets of the following co-authors: Wyatt Desormeaux, Michael Henning, Lucas van der Merwe, and Anders Yeo. (Received September 21, 2011)

1077-05-2248 **Josh Ducey*** (duceyje@jmu.edu), **Andries Brouwer** and **Peter Sin**. *The Smith Normal Form of the Incidence Matrix of Skew Lines in $PG(3, q)$.*

Let A be a matrix with rows and columns indexed by the lines in the finite projective space $PG(3, q)$. Set the (i, j)-entry of A to be 1 if line i and line j do not intersect, otherwise set it to be 0. Thus A is an incidence matrix of the skewness relation on the lines in $PG(3, q)$, and by the well-known Klein correspondence, A may also be viewed as an adjacency matrix for the non-collinearity graph on the points of the Klein quadric in $PG(5, q)$. This is a strongly regular graph.

In this talk the integer invariants of A are described, using the representation theory of the general linear group. This is some of the most recent progress made in the study of the incidence matrices of intersecting linear subspaces in a finite vector space. Joint work with Andries Brouwer and Peter Sin. (Received September 21, 2011)

1077-05-2254 **John Shareshian** and **Michelle L Wachs*** (wachs@math.miami.edu), Department of Mathematics, University of Miami, Coral Gables, FL 33124. *Chromatic quasisymmetric functions and Hessenberg varieties.*

We discuss three distinct topics of independent interest; one in enumerative combinatorics, one in symmetric function theory, and one in algebraic geometry. The topic in enumerative combinatorics concerns a q-analog of a generalization of the Eulerian polynomials, the one in symmetric function theory deals with a refinement of the chromatic symmetric functions of Stanley, and the one in algebraic geometry deals with Tymoczko's representation of the symmetric group on the cohomology of the regular semisimple Hessenberg variety of type A. Our purpose is to explore some remarkable connections between these topics. (Received September 21, 2011)

1077-05-2257 **John D Berman*** (jberm@mit.edu). *Cyclic Closures of Finitely Simple Pattern Classes.*

A pattern class is a lower set in the poset of permutations ordered by pattern involvement, and may be defined as the avoidance set of a minimal basis of permutations. I show that a pattern class X containing only finitely many simple permutations has cyclic closure which contains only finitely many proper pin permutations. In the case that the basis elements of X avoid certain explicit classes of permutations, I extend this result to show that the cyclic closure of X itself contains only finitely many simple permutations and therefore has finite basis. (Received September 21, 2011)

1077-05-2264 **Corey M Manack*** (cmanack@amherst.edu), 58 S East St, Apt 2, Amherst, MA 01002. *A new method for comparing chains of order statistics.* Preliminary report.

Fix $k \leq m \leq n$, and let $X_1, \ldots, X_m, Y_1, \ldots, Y_n$ be continuous, independent and identically distributed random variables. Inspired by dice resolutions from the RISK board game, we derive a new probability distribution that compares the top k performers from the sets $X = \{X_1, \ldots, X_m\}, Y = \{Y_1, \ldots, Y_n\}$. Specifically, we find, for each l between 0 and k, the probability that there are exactly l instances when the i-th top performer from X is greater than the i-th top performer from Y. By virtue of uniformity, we may recast this method of comparison into counting lattice paths of a certain type, invoking the Chung-Feller Theorem and Ballot Numbers in our derivation. Salient and surprising features of the distribution will be discussed, as well as possible applications, if time permits. (Received September 21, 2011)

1077-05-2284 **Wenliang Tang*** (wtang1@mix.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26505, **Erling Wei**, Department of Mathematics, Renmin University of China, Beijing, Beijing 100872, and **Cunquan Zhang** (cqzhang@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26505. *Strong Circuit Double Cover Conjecture in Special Cubic Graphs.* Preliminary report.

Let G be a bridgeless cubic graph and C is any given circuit in G. It was conjectured by Seymour that we can find a family $\mathcal{F}$ of circuits containing C such that every edge of G is covered exactly by two members of $\mathcal{F}$. This is the well-known *Strong Circuit Double Cover Conjecture*, a stronger version of the famous *Circuit Double Cover Conjecture*.

It was proved by Herbert Fleischnera and Roland Häggkvistb that the SCDC conjecture is true if $G \backslash V(C)$ has a Hamilton path $P = v_1 \cdots v_t$ such that v_1 is adjacent to some vertex of C. The conjecture remains open if v_1 is not adjacent to any vertex of C. In this paper we verify the conjecture if v_1 is not adjacent to any vertex of C and P is of order at most 23. (Received September 22, 2011)

1077-05-2295 **Wesley K. Hough*** (houghw12@hanover.edu), 2138 South Sycamore Boulevard, Peru, IN 469707259, and **Derek F. DeSantis**, **Jacob W. Ziefle** and **Rebecca M. Meissen**. *Permutations, Pattern Avoidance, and the Catalan Triangle.* Preliminary report.

In one-line notation, a permutation w of n elements ordered in some way avoids a permutation pattern p of k elements if every subsequence of k elements in w has at least two elements out of order relative to the ordering of p's elements. $S_n(p)$ denotes the set of permutations of n symbols that avoid p. Some of the first questions regarding permutation pattern avoidance arose from sorting methods in computer science. Previous work in this area revealed that the size of $S_n(p)$ for p of 3 elements is equal to C_n, the n-th Catalan number, defined recursively and found in many areas of combinatorics. In this paper, we refine this classical result by relating intuitive partitions of $S_n(p)$ to some well-known refinements of the Catalan numbers. (Received September 22, 2011)

1077-05-2297 **David M Howard*** (howard@technion.ac.il), 111 Spy Pond Pkwy, Arlington, MA 02474, and **Ron Aharoni**, Technion - Israel Institute of Technology, Technion City, 32000 Haifa, Israel. *Rainbow Matchings and the Erdos-Ko-Rado Theorem.*

A *rainbow matching* of a system $(F_1, \ldots, F_k)$ of hypergraphs is a choice of disjoint edges, one from each F_i. The results I will describe are motivated by the following conjecture: Conjecture: Let A be a number such that every subset of $\binom{[n]}{r}$ of size at least A contains a matching of size k. If $F_i \subseteq \binom{[n]}{r}(i = 1, \ldots, k)$ and $|F_i| \geq A$ then $(F_1, \ldots, F_k)$ has a rainbow matching. This is known for $r = 2$ (Meshulam) and for $k = 2$ (Matsumoto,Tokushige). For general k and r we do not even know a formula for the number A above. We make a similar conjecture for r-partite hypergraphs, in which the lower bound is easy to find. We prove the cases $r = 2, 3$ and $k = 2$. At the core of the $r = 3$ case lies a Hall type sufficient condition for the existence of rainbow matchings in bipartite graphs. (Received September 22, 2011)

1077-05-2308 **Craig Eric Larson*** (clarson@vcu.edu), **Taylor Short** and **Bethany Turner**. *Towards Vizing's Independence Number Conjecture.*

The *chromatic index* χ' of a graph is the minimum number of colors that are required so that incident edges are colored different colors. A graph G with maximum degree Δ is *edge critical* if $\chi(G - e) = \Delta$ for every edge e. The independence number α is the cardinality of a largest set of vertices which are pairwise non-adjacent. Vizing conjectured that $\alpha \leq \frac{n}{2}$ for edge-critical graphs. Woodall has shown that $\alpha \leq \frac{3n}{5}$ for these graphs. We discuss improvements on this bound that follow from the Independence Decomposition Theorem: namely that any graph can be decomposed into unique subgraphs $G[X]$ and $G[X^c]$ having certain nice properties. It follows immediately from this theorem that $\alpha \leq \frac{3n}{5}$ for *any* graph where $|X| \leq \frac{n}{5}$. Further improvements are possible using the special structure of edge-critical graphs. (Received September 22, 2011)

1077-05-2310 **Shishuo Fu*** (shishuo.fu@kaist.ac.kr), Department of Mathematical Sciences (BK21), KAIST, 291 Daehak-ro Yuseong-gu, Daejeon, 305-701, South Korea, and **Victor Reiner**, **Dennis Stanton** and **Nathaniel Thiem**. *The negative q-Binomial.*

Interpretations for the q-binomial coefficient evaluated at $-q$ are discussed. A (q, t)-version is established, including an instance of a cyclic sieving phenomenon involving unitary spaces. (Received September 22, 2011)

1077-05-2311 **Federico Ardila***, 1600 Holloway Avenue, San Francisco, CA 94110, and **Jeffrey Doker**, 970 Evans Hall #3840, Berkeley, CA 94720. *Lifted generalized permutohedra and composition polynomials.* Preliminary report.

Generalized permutohedra are the polytopes obtained from the permutohedron by changing the edge lengths while preserving the edge directions, possibly identifying vertices along the way. We introduce a "lifting" construction for these polytopes. We show how this construction gives rise to Stasheff's multiplihedron from homotopy theory, and to the more general "nestomultiplihedra", answering a question of Devadoss and Forcey.

We construct a subdivision of any lifted generalized permutohedron whose pieces are indexed by compositions. The volume of each piece is a polynomial, whose combinatorial properties we investigate. We show how this "composition polynomial" arises naturally in the polynomial interpolation of an exponential function. We prove that its coefficients are positive integers, and we conjecture that they are unimodal. (Received September 22, 2011)

1077-05-2334 **Choongbum Lee**, Department of Mathematics, UCLA, Los Angeles, CA 90095, **Po-Shen Loh*** (ploh@cmu.edu), Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213, and **Benjamin Sudakov**, Department of Mathematics, UCLA, Los Angeles, CA 90095. *Bisections of graphs.*

A bisection of a graph is a bipartition of its vertex set in which the number of vertices in the two parts differ by at most 1, and its size is the number of edges which go across the two parts. Motivated by several questions and conjectures of Bollobás and Scott, we study maximum bisections of graphs. First, we extend the classical Edwards bound on maximum cuts to bisections. A simple corollary of our result implies that every graph on n vertices and m edges with no isolated vertices, and maximum degree at most $n/3 + 1$, admits a bisection of size at least $m/2 + n/6$. Then using the tools that we developed to extend Edwards's bound, we prove a judicious bisection result which states that graphs with large minimum degree have a bisection in which both parts span relatively few edges. A special case of this general theorem answers a conjecture of Bollobás and Scott, and shows that every graph on n vertices and m edges of minimum degree at least 2 admits a bisection in which the number of edges in each part is at most $(1/3 + o(1))m$. We also present several other results on bisections of graphs.

Joint work with Choongbum Lee and Benny Sudakov. (Received September 22, 2011)

1077-05-2335 **Martin Skoviera*** (skoviera@dcs.fmph.uniba.sk), Department of Computer Science, Comenius University, Bratislava, 842 48, and **Michal Kotrbcik**. *Locally maximal embeddings of graph.*

It is well known that the genera of orientable surfaces upon which a given graph has a 2-cell embedding form a contiguous interval of integers. While determining the minimum genus is in general difficult, there exists a polynomial-time algorithm for determining the maximum genus of an arbitrary graph. Beyond this, not very much is known about the distribution of embedding genera of general graphs. In this talk we investigate a new class of embeddings called locally maximal embeddings. Their characteristic property is that changing the position of any single edge in the local rotation at any vertex gives rise to an embedding with the same or lower genus. We describe various properties of these embeddings, some of them indicating surprising differences from maximal embeddings. In addition, we determine the minimum genus of a locally maximal embedding for several classes of graphs, including the complete graphs, complete bipartite graphs and n-cubes. (Received September 22, 2011)

1077-05-2348 **Ji Young Choi*** (jychoi@ship.edu), 1871 Old Main Dr, Shippensburg University, Department of Math, Shippensburg, PA 17257. *Generating Differential Equations for Multi-restricted Stirling numbers.* Preliminary report.

A differential equation with a polynomial solution, is called the generating differential equation for the sequence $\{a_n\}_{n\geq 0}$, if a_n is the coefficient of x^n in the polynomial solution. This talk will present generating differential equations for Multi-restricted Stirling numbers of the second kind, which is a generalization of the differential equation for the Bessel numbers. (Received September 22, 2011)

1077-05-2351 **Kathleen M. Ryan*** (kmr207@lehigh.edu) and **Garth Isaak** (gi02@lehigh.edu). *Degree Matrices of k-edge Colored Graphs.*

Given a k-edge colored graph on n vertices, we define the degree matrix M as the (k x n) matrix whose entry d_{ij} is the degree of color i at vertex v_j, where $1 \leq i \leq k$ and $1 \leq j \leq n$. Given such a matrix M, we address the question of when M is the degree matrix of a graph in a specified family such as the disjoint union of paths, the disjoint union of cycles, or grids. Surprisingly, in some of the seemingly most basic cases that we have considered, the question is equivalent to the constrained number partition problem, which in itself is a special version of the NP hard subset sum problem. In other cases, we discuss necessary and sufficient conditions for when M is realizable as a 2-edge colored graph of a specified family. (Received September 22, 2011)

1077-05-2358 **Rigoberto Florez** (florezr@uscsumter.edu), Division of Mathematics, Science, and Eng., University of South Carolina Sumter, Sumter, SC 29150-2498, and **Darren A Narayan*** (dansma@rit.edu), School of Mathematical Sciences, Rochester Institute of Technology, Rochester, NY 14623-5604. *Maximizing the number of edges in optimal k-rankings.*

A ranking is a vertex coloring where if two vertices have the same label any path connecting them contains a vertex with a larger label. The rank number of a graph is smallest number of colors that can be used in a ranking. Given a graph G we consider the maximum number of edges that may be added to G without changing the rank number. Here we investigate the problem for paths, cycles, complete multipartite graphs, and the union of two complete graphs joined by a single edge. For these families of graphs we provide an explicit characterization of which edges change the rank number when added to G, and which edges do not. (Received September 22, 2011)

1077-05-2361 **Neil Robertson*** (robertso@math.ohio-state.edu), 6520 Wesley Way, Westerville, OH 43082. *On the nature of mathematical conjecture.*

In mathematics truth and beauty go hand-in-hand. The beauty of the subject derives from an appreciation of the truth behind the theory. But, on the working edge of the subject, where conjectures are formulated and turned into theory, it seems to work in the other direction, in the process beauty is being turned into truth. This talk will describe some of the experiences of the speaker concerning what conjectures are and how they are formulated, where the sense of beauty plays an important role in guiding intuition. (Received September 22, 2011)

1077-05-2372 **Taylor F Allison*** (tfallis2@ncsu.edu), 7212 Kennebec Rd, Willow Spring, NC 27592. *Some Results on Permutation Patterns.* Preliminary report.

This talk will consist of recent work done in the area of permutation patterns. One such direction is in the area of pattern avoidance over set partitions, particularly 123-avoiding set partitions. We will discuss a method for counting these partitions, particularly for the 3-partition problem, as well as the n/2 partitions of size 2 (domino partitions). Another area of research is comprised of sorting random permutations with different sorting mechanisms. One of the sorting mechanisms studied was homing, which involves selecting an element and sorting it to its "home". Our results include homing in n-dimensions, homing on multiset permutations, or "rankings", and a conjecture about the number of steps required to home these multiset permutations. (Received September 22, 2011)

1077-05-2386 **Filip Morić** and **David Pritchard*** (daveagp@gmail.com). *Counting Large Distances in Convex Polygons: A Computational Approach.*

In a convex n-gon, let $d_1 > d_2 > \cdots$ denote the set of all distances between pairs of vertices, and let m_i be the number of pairs of vertices at distance d_i from one another. Erdős, Lovász, and Vesztergombi conjectured that $m_1 + m_2 + \cdots m_k \leq k \cdot n$. Using a new computational approach, we prove their conjecture when $k \leq 4$ and n is large; we also make some progress for arbitrary k by proving an upper bound of $(2k-1) \cdot n$. Our main approach revolves around a few known facts about distances, together with a computer program that searches all small configurations of distances generated by two disjoint intervals. We thereby obtain other new bounds such as $m_3 \leq 3n/2$ for large n. (Received September 22, 2011)

1077-05-2387 **Nathan H Reff*** (reff@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902-6000. *Spectral properties of complex unit gain graphs.*

A complex unit gain graph is a graph where each orientation of an edge is given a complex unit, which is the inverse of the complex unit assigned to the opposite orientation. We extend some fundamental concepts from spectral graph theory to complex unit gain graphs. (Received September 22, 2011)

1077-05-2399 **Patrick Bennett** and **Tom Bohman*** (tbohman@math.cmu.edu). *A natural barrier for random greedy hypergraph matching.*

Let r be a fixed constant and let $\mathcal{H}$ be an r-uniform, D-regular hypergraph on N vertices. Assume further that $D \to \infty$ as $N \to \infty$ and that co-degrees of pairs of vertices in $\mathcal{H}$ are at most L where $L = o(D/\log^5 N)$. We consider the random greedy algorithm for forming a matching in $\mathcal{H}$. We choose a matching at random by iteratively choosing edges uniformly at random to be in the matching and deleting all edges that share at least one vertex with a chosen edge before moving on to the next choice. This process terminates when there are no edges remaining in the graph. We show that with high probability the proportion of vertices of $\mathcal{H}$ that are not saturated by the final matching is at most $(L/D)^{\frac{1}{2(r-1)}+o(1)}$. This point is a natural barrier in the analysis of the random greedy hypergraph matching process. (Received September 22, 2011)

1077-05-2412 **Eimear Byrne**, **Michael Kiermaier** and **Alison Sneyd*** (alison.sneyd@ucdconnect.ie). *A Family of Codes with Two Homogeneous Weights.*

It was first shown in [2] that a projective linear code over a finite field with two nonzero Hamming weights determines a strongly regular graph. In [1], this result was extended to show any proper, regular, projective linear code over a finite Frobenius ring with two nonzero homogeneous weights also determines a strongly regular graph. Here we give a construction for an infinite family of proper, regular, projective codes with two nonzero homogeneous weights over the ring $GF(q) \oplus GF(q)$.

References

[1] E. Byrne, M. Greferath and T. Honold, *Ring Geometries, Two-Weight Codes and Strongly Regular Graphs*, Designs, Codes and Cryptography, 48 (1) (2008) 1–16.

[2] P. Delsarte, *Weights of linear codes and strongly regular normed spaces*, Discrete Math., 3 (1972) 47–64.

(Received September 22, 2011)

1077-05-2425 **Katherine V. Johnson*** (s-kfield1@math.unl.edu), 203 Avery Hall, Lincoln, NE 68588. *Weak Discrepancy of Grids.* Preliminary report.

A linear extension of a poset might be considered "good" if incomparable elements appear near to one another. The linear discrepancy of a poset is a natural way of measuring just how good the best linear extension of that poset can be, i.e.

$$\text{lin-disc}(P) = \min_L \max_{x||y} |L(x) - L(y)|,$$

where L ranges over all linear extensions of P mapping P to $\mathbb{N}$. In certain situations, it makes sense to weaken the definition of a linear extension by allowing elements of the poset to be sent to the same integer, while still requiring that $x < y$ implies $L(x) < L(y)$. This is known as a weak labeling. Similar to linear discrepancy, the weak discrepancy measures how nicely we can weakly label the elements of the poset. I will calculate the weak discrepancy of grids, including the surprising result that our freedom really only lies in the two smallest dimensions. (Received September 23, 2011)

1077-05-2436 **Lucia C Petito*** (`lpetito@u.rochester.edu`), **Jessie Deering**, **Anant Godbole** and **William Jamieson**. *Hitting Set Size for Random Set Systems.*

Let Λ be a random set system of $[n] = \{1, 2, ...n\}$, where $\Lambda = \{A_j | A_j \in \mathcal{P}([n]),$ and A_j selected with probability $p\}$. A set $H \subseteq [n]$ is a hitting set of Λ if $|H \bigcap A_j| \geq 1$ for all $A_j \in \Lambda$. We explore the minimum cardinality of H with respect to p and n using probabilistic methods. (Received September 22, 2011)

1077-05-2438 **Keivan Hassani Monfared*** (`k1monfared@gmail.com`), 1103 E CANBY ST., Laramie, WY 82072. *On the Permanent Rank of Matrices.*

The permanent of the $n \times n$ matrix $A = \left[a_{ij}\right]$ is defined to be the sum of all diagonal products of A, that is:

$$\text{per}(A) = \sum_{\sigma \in S_n} \prod_{i=1}^{n} a_{i\sigma(i)},$$

where S_n is the symmetric group of order n.

The term rank of A, denoted termrank(A), is the largest number of nonzero entries of A with no two in the same row or column. The permanent rank of a matrix A, denoted by perrank(A), is defined to be the size of a largest square sub-matrix of A with nonzero permanent.

Here we study the following conjecture relating the perrank and the termrank:

Conjecture: For any matrix A,

$$\text{perrank}(A) \geq \left\lceil \frac{\text{termrank}(A)}{2} \right\rceil,$$

and for even termrank the equality holds if and only if $A = \bigoplus \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}$, up to permutation and scaling of rows and columns of A, and omitting zero rows and columns.

(Received September 22, 2011)

1077-05-2450 **Miles Eli Jones*** (`mej005@ucsd.edu`), 9500 Gilman Dr. #0112, La Jolla, CA 92093, and **Jeffrey Remmel** (`jremmel@ucsd.edu`), 9500 Gilman Dr. #0112, La Jolla, CA 92093. *Consecutive Matches in Permutations and cycle structures of permutations.*

Let $\tau \in S_m$. A permutation $\sigma = \sigma_1 \ldots \sigma_n \in S_n$ has a τ-match at position i if $\sigma_i \ldots \sigma_{i+m-1}$ has the same relative order as τ. A cycle $C = (\sigma_0, \ldots, \sigma_{n-1}) \in S_n$ has a cycle-τ-match at position i if $\sigma_i \ldots \sigma_{i+m-1}$ has the same relative order as τ with the subscripts taken mod n. Let $\mathcal{NM}_n(\tau)$ be the the set of all σ in S_n that have no τ-matches. Let $\mathcal{NCM}_n(\tau)$ be the the set of all σ in S_n that have no cycle-τ-matches within any of the cycles.

Consider the generating functions

$$NM_\tau(t, y, x) = \sum_{n \geq 0} \frac{t^n}{n!} \sum_{\sigma \in \mathcal{NM}_n(\tau)} y^{1+\text{des}(\sigma)} x^{\text{Lmin}(\sigma)}$$

$$NCM_\tau(t, y, x) = \sum_{n \geq 0} \frac{t^n}{n!} \sum_{\sigma \in \mathcal{NCM}_n(\tau)} y^{\text{cdes}(\sigma)} x^{\text{cyc}(\sigma)}.$$

For $\sigma \in S_n$, des(σ) is the number of descents, Lmin(σ) is the number of left-to-right minima, cdes(σ) is the number of descents of each cycle, and cyc(σ) is the number of cycles.

We discuss why these generating functions are equal when τ starts with 1 and give some results for families of patterns that start with 1. (Received September 22, 2011)

1077-05-2452 **Steve Butler*** (`butler@iastate.edu`), 396 Carver Hall, Dept. of Mathematics, Ames, IA 50011. *Applications and limitations of the normalized Laplacian matrix for graphs.* Preliminary report.

By associating a graph with a matrix, we can ascertain properties of the graph by studying the spectrum of the matrix. Some common matrices that have been associated with graphs are the adjacency matrix A, which places a 1 in entries corresponding to edges and 0 otherwise; the Laplacian matrix $L = D - A$ where D is a diagonal degree matrix; and the signless Laplacian matrix $Q = D + A$.

Another matrix we can associate with a graph is the normalized Laplacian, $\mathcal{L} = D^{-1/2}(D - A)D^{-1/2}$, popularized by the work of Fan Chung. This matrix shares many properties in common with A, L, Q but also has differences. In this talk we will survey some of the applications of the normalized Laplacian as well as give some limitations to what the matrix can tell us about a graph. (Received September 22, 2011)

1077-05-2463 **Sarah Alexander*** (sja2117@barnard.edu), **Matthew Hughes** and **Miriam Kuzbary** (mirkuzbary@gmail.com). *Covering Graphs, Voltage Assignments, and Hamiltonicity.*

A voltage graph is a finite undirected graph whose edges are labeled by elements of a group G. A given voltage assignment on a graph gives rise to a covering graph, called the derived graph, using the natural group action of G. We investigate the effects of group and graph structure in the voltage graph on the resulting structure of the derived graph, with particular focus on the occurrence of Hamiltonicity. (Received September 22, 2011)

1077-05-2473 **Joshua N Cooper** (cooper@math.sc.edu), Department of Mathematics, LeConte College, 1523 Greene St., Columbia, SC 29208, and **Aaron M Dutle*** (dutle@mailbox.sc.edu), Department of Mathematics, LeConte College, 1523 Greene St., Columbia, SC 29208. *Fair Duels, Bad Shots, and Thue-Morse.*

Consider a duel between two players, where each has probability p of hitting their opponent. They fire one at a time, according to the following rule. A player is allowed to continue firing until their probability of winning meets or exceeds the probability of their opponent winning, at which point the opponent is the next player. For each p, this determines a sequence of the two players. We show that as p tends to zero, this sequence converges to the Thue-Morse sequence, and highlight some connections to the problem of approximating the zero function by a power series with coefficients in $\{-1, 1\}$. (Received September 22, 2011)

1077-05-2487 **Richard Ehrenborg** (jrge@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506, and **JiYoon Jung*** (jjung@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *Descent pattern avoidance.*

We extend the notion of consecutive pattern avoidance to considering sums over all permutations where each term is a product of weights depending on each consecutive pattern of a fixed length. We study the problem of finding the asymptotic of these sums. Our technique is to extend the spectral method of Ehrenborg, Kitaev and Perry. When the weight depends on the descent pattern we show how to find the equation determining the spectrum. We give two length 4 applications. First, we find the asymptotics of the number permutations with no triple ascents and no triple descents. Second we give the asymptotics of the number permutations with no isolated ascents or descents. Our next result is a weighted pattern of length 3 where the associated operator only has one non-zero eigenvalue. Using generating functions we show that the error term in the asymptotic expression is the smallest possible. (Received September 22, 2011)

1077-05-2509 **Fan Chung**, **Mary Radcliffe*** (mradcliffe@math.ucsd.edu) and **Stephen Young**. *The spectra of several random graph families.*

We consider Multiplicative Attribute Graphs, a random graph model in which nodes are represented by words in an alphabet Γ and the probability that u is adjacent to v is determined by comparing the words corresponding to u and v coordinatewise. We use a Chernoff inequality for matrices to show the eigenvalues of the the normalized Laplacian of this model can be approximated by those of the weighted expectation graph. We apply similar techniques to approximate the spectrum of other random graph families, including Stochastic Kronecker Graphs and other graphs that arise from real-world applications. (Received September 22, 2011)

1077-05-2541 **Stan Dziobiak*** (smdziobi@olemiss.edu), Department of Mathematics, University of Mississippi, Hume Hall 305, University, MS 38677-1848, and **Guoli Ding** (ding@math.lsu.edu), Department of Mathematics, Louisiana State University, Locket Hall 303, Baton Rouge, LA 70803-4918. *On cubic non-toroidal graphs.* Preliminary report.

The classical result of Kuratowski and Wagner ('37) characterizes the class of planar graphs in terms of two excluded minors. Archdeacon ('81) characterized projective-planar graphs in terms of thirty-five excluded minors. The complete list of excluded minors for the torus is still unknown, but is known to number in the tens of thousands. An unpublished result of Robertson and Seymour ('96) states that dodecahedrally connected projective-planar graphs can be characterized by only three excluded minors. In this talk, we report the progress on the analogous result of characterizing dodecahedrally connected toroidal graphs that are non-projective-planar in terms of excluded minors. (Received September 22, 2011)

1077-05-2543 **Krishna Dasaratha**, **Laure Flapan**, **Chansoo Lee**, **Cornelia Mihaila**, **Nicholas Neumann-Chun**, **Sarah Peluse** and **Matthew Stoffregen*** (mstoffie@gmail.com), 305 West Swissvale Avenue, Pittsburgh, PA 15218, and **Thomas Garrity**. *A Family of Multidimensional Continued Fraction Stern Sequences.* Preliminary report.

Stern's diatomic sequence $0, 1, 1, 2, 1, 3, 2, 3, 1, 4, \ldots$ (given by the recursion relation $a_{2n} = a_n$ and $a_{2n+1} = a_n + a_{n+1}$, where $a_0 = 0$ and $a_1 = 1$) is closely linked to continued fractions, and in particular to methods for subdividing the unit interval. This sequence has a number of well-known remarkable combinatorial properties. We have developed a rich family of multidimensional continued fractions, which include such previously known multidimensional continued fractions as the triangle map and the Mönkemeyer map, via various rules for subdividing a triangle. For each of these multidimensional continued fractions, we define an MCF-Stern sequence (and hence a higher dimensional generalization of the Stern diatomic sequence), from the corresponding method used for subdividing the triangle. We then explore several combinatorial results about MCF-Stern sequences, which give rise to the Fibonacci numbers and other well-known sequences. MCF Stern sequences mimic the behavior of Stern sequences, but with new complexity. In particular, we determine the sequence of maximum entries at each level of an MCF Stern sequence, and determine which triples will eventually appear in the MCF Stern Sequence. (Received September 22, 2011)

1077-05-2548 **Joshua Hanes*** (Jhanes@as.muw.edu), Mississippi University for Women, 1100 College St., MUW-100, Columbus, MS 39701, and **Tristan Denley**, Austin Peay State University, 601 College St., Clarksville, TN 37044. *Modular-Distance Labelings of Graphs.* Preliminary report.

In [5] Ferrara, Kohayakawa, and Rödl introduced a way to represent graphs using vertex labels and distances. Here we will consider a modification of this construction, which we shall call **modular distance graphs**. Let V be a non-empty set, $\Phi : V \mapsto Z^+$ be an injective function, and $D_m \subseteq Z^+ \times P$ where P is the set of prime integers. Then the **modular distance graph** $G(\Phi, D_m)$ is the graph with vertex set V and edge set defined by $(u, v) \in E(G) \iff |\Phi(u) - \Phi(v)| \equiv a(\text{mod} p)$ for some $u, v \in V$ and $(a, p) \in D_m$.

We shall consider the parameter $D_m(G) = \min_{G(\Phi,Dm)\cong G} |Dm|$, showing that for any graph with maximum degree Δ $D_m(G) \leq \frac{1}{2}\Delta + (O(\Delta^{\frac{2}{3}}(\log\Delta)^{\frac{1}{3}}))$ and that there graphs for which $D_m(G) > \frac{5\Delta}{12}$. We also show that $D_m(G) \leq 20$ when G is planar. (Received September 22, 2011)

1077-05-2587 **Curtis Clark*** (cuclark@morehouse.edu), 830 Westview Drive, Atlanta, GA 30314. *On $2-1$ Graph Achievement Games.*

Let F be agraph with no isolated vertices. The $2-1$ $F-$achievement game on the complete graph K_n is described as follows. There are two players. Player A first colors two edges of K_n green. Then Player B colors a different edge of K_n red. They continue alternatively coloring the edges with Player A coloring two edges and Player B coloring one edge. The graph F is achievable on K_n if Player A can make a copy of F in his color. The minimum n such that F is achievable on K_n is the $2-1$ achievement number of F, $a_2(F)$. The $2-1$ move number of F is the least number of edges needed by Player A to make F on the complete graph with $a_2(F)$ vertices. We determine the $2-1$ achievement numbers and move numbers for graphs with less than or equal to four vertices, paths, and cycles. (Received September 22, 2011)

1077-05-2593 **K. A. Factor**, **S. K. Merz*** (smerz@pacific.edu) and **S. Yun**. *The $(1,2)$-step competition number of a noninterval tree.*

The $(1,2)$-step competition graph is a generalization of the competition graph of a digraph. Given a digraph D, the competition graph of D is a graph on the same vertex set with edge $\{x, y\}$ if and only if there exists vertex z such that (x, z) and (y, z) are arcs in D. Edge $\{x, y\}$ is in the $(1,2)$-step competition graph provided there exists a vertex $z \neq x, y$ such that either $d_{D-y}(x, z) = 1$ and $d_{D-x}(y, z) \leq 2$, or $d_{D-x}(y, z) = 1$ and $d_{D-y}(x, z) \leq 2$. Introduced by Roberts, the competition number of a graph is the least integer k so that G together with k isolated vertices is the competition graph of some acyclic digraph. Analogously, we can define the $(1,2)$-step competition number of a digraph. The $(1,2)$-step competition numbers of paths, cycles, and stars are known. We consider the $(1,2)$-step competition numbers of additional graphs. (Received September 22, 2011)

1077-05-2608 **Kathryn M Hawley*** (khawley@hmc.edu) and **Taylor Allison** (tfallis2@ncsu.edu). *Covering length-n permutations with n+1.*

We use various probabilistic methods investigate the question of how many $n+1$-permutations are necessary to cover all permutations of length n. Our results include bounds in the proportion of $n+1$-permutations necessary for the existence of a cover and the threshold at which a cover is almost guaranteed to exist. (Received September 22, 2011)

1077-05-2621 **Jason Grout*** (jason.grout@drake.edu), Mathematics and Computer Science, Drake University, 2507 University Ave, Des Moines, IA 50311, and **Steve Butler** (butler@iastate.edu) and **Tracy Hall** (h.tracy@gmail.com). *Computing inertia sets of graphs using variations of zero forcing.* Preliminary report.

Let $\mathcal{S}(G)$ be the set of real symmetric matrices whose off-diagonal nonzero entries correspond to the edges of a simple graph G. The inertia set of G is the set of all ordered pairs (a, b) such that a matrix in $\mathcal{S}(G)$ has a positive eigenvalues and b negative eigenvalues. We describe some recent advances in computing inertia sets of graphs using variations on zero forcing. The implementations are freely available in the Minimum Rank Library for Sage (http://artsci.drake.edu/grout/doku.php/software/minimum_rank_library). (Received September 22, 2011)

1077-05-2629 **Nafiseh Jahanbakht*** (nafiseh1383@gmail.com) and **Kourosh Tavakoli** (ktavakoli@gc.cuny.edu). *Relation between the energy of a digraph and the energy of its underlying graph.* Preliminary report.

The energy of a graph is the sum of the absolute values of the eigenvalues of its adjacency matrix. For the case of digraphs the adjacency matrix is not symmetric and the eigenvalues might be complex numbers. Therefore, the energy of a digraph is defined to be the sum of the absolute values of the real parts of the eigenvalues of its adjacency matrix. In this talk, we study the relation between the energy of a digraph and the energy of its underlying graph. Under some conditions, the energy of a simple digraph G is one half of the energy of its underlying graph. The question is still open in the general case. (Received September 22, 2011)

1077-05-2642 **Simone Severini*** (simoseve@gmail.com), University College London, Gower Street, London, England. *An open problem concerned with the combinatorial structure of unitary matrices.*

Let us take a unitary matrix and replace all the non-zero entries with a one. We obtain the adjacency matrix of a graph (possibly directed). We do not have exact characterizations of graphs obtained in this way. I will state the problem, give concrete motivations, and report some partial results. I will focus on the distinction between having real and complex entries. (Received September 22, 2011)

1077-05-2647 **Joseph Buchanan*** (jmbucha@ilstu.edu), **Ryan C. Bunge**, **Erik Pelttari**, **Greg Rasmuson**, **Alexander Su** and **Sevasti Tagaris**. *On d-modular labelings of the union of two cycles.*

For positive integers r and s, let $K_{r\times s}$ denote the complete multipartite graph with r parts of size s each. Let G be a graph with n edges, d be a positive integer such that $d|2n$ and set $c = 2n/d + 1$. A *d-modular ρ-labeling* of G is a one-to-one function $f : V(G) \to [0, cd)$ such that

$$\{\min(|f(u) - f(v)|, cd - |f(u) - f(v)|) : \{u, v\} \in E(G)\} = \{1, 2, \ldots, \lfloor \frac{cd}{2} \rfloor\} \setminus c\mathbb{Z}.$$

It is known that if a z-partite graph G admits a d-modular ρ-labeling, then there exists a cyclic G-decomposition of $K_{c\times td}$ for every positive integer t such that $\gcd(t, (z-1)!) = 1$. We investigate d-modular labelings of the union of two vertex-disjoint cycles. (Received September 22, 2011)

1077-05-2648 **Guven Yuceturk*** (guven@westga.edu) and **Dean G. Hoffman**. *Parity Balanced Bipartite Graphs.*

Let a, $b \in \mathbb{P}$ and $e \in \mathbb{N}$, and let ϵ_a, $\epsilon_b \in \{0, 1\}$. We say the *bipartite graph* G on bipartition (A, B), where $|A| = a$ and $|B| = b$, is *parity balanced* with parameters $(a, b, e, \epsilon_a, \epsilon_b)$ if

$\forall u \in A$, $deg(u) \equiv \epsilon_a \pmod 2$, and further $\forall v \in A$, $|deg(u) - deg(v)| \leqslant 2$,
$\forall u \in B$, $deg(u) \equiv \epsilon_b \pmod 2$, and further $\forall v \in B$, $|deg(u) - deg(v)| \leqslant 2$.

We will give necessary and sufficient conditions for existence of such graphs. (Received September 22, 2011)

1077-05-2653 **Vaidy Sivaraman*** (vaidy@math.ohio-state.edu). *Signed-graphic representations of matroids.*

This talk is about the class of signed-graphic matroids, focussing particularly on two aspects: (1) Finding explicit signed-graphic representations of certain classes of matroids (2) Finding when two signed graphs have the same frame matroid (analogue of Whitney's 2-Isomorphism Theorem for the class of signed-graphic matroids).

Some families of matroids considered are the wheels, whirls, frame matroids of all-positive complete graphs, all-negative complete graphs, cycles where each edge is replaced with a negative digon. The regular-case of the signed-graphic matroid isomorphism problem involves the projective plane, and that part of the talk will be a based on joint work done with John Maharry, Neil Robertson, and Daniel Slilaty. (Received September 22, 2011)

1077-05-2666 **Sabrina Allen*** (allen18@illinois.edu), **Jelsi Bolt**, **Ryan C. Bunge**, **Scott Burton** and **Saad I. El-Zanati**. *On 2-fold G-designs where G has order at most 4 and edge-multiplicity 2.*

For a positive integer k, let ^2K_k denote the 2-fold complete mutigraph of order k. If G is a bipartite subgraph of $^2K_4$, we find necessary and sufficient conditions for the existence of G-decompositions of ^2K_n. We also report on some results when G is tripartite. (Received September 22, 2011)

1077-05-2671 **Megan Cornett*** (cornett.megan@gmail.com) and **Ellen Sparks**. *On 2-fold graceful labelings of graphs.*

Let $\mathbb{Z}$ denote the set of integers and $\mathbb{N}$ denote the set of nonnegative integers. For integers a and b with $a \le b$, let $[a,b] = \{x \in \mathbb{Z} : a \le x \le b\}$. For a positive integer k, let ^2K_k denote the 2-fold complete mutigraph of order k. Similarly, let $^2[a,b]$ denote the multiset that contains every element of $[a,b]$ exactly two times. Let G be a multigraph of size n, order at most $n+1$, and edge multiplicity at most 2. A *labeling* of G is a one-to-one function $f\colon V(G) \to \mathbb{N}$. If f is a labeling of G and $e = \{u,v\} \in E(G)$, let $\bar{f}(e) = |f(u) - f(v)|$. A 2-*fold graceful labeling* of G is a one-to-one function $f : V(G) \to [0,n]$ such that:

$$\{\bar{f}(e)\colon e \in E(G)\} = \begin{cases} ^2[1, \frac{n}{2}] & \text{if } n \text{ is even,} \\ ^2[1, \frac{n-1}{2}] \cup \{\frac{n+1}{2}\} & \text{if } n \text{ is odd.} \end{cases}$$

A graph G is 2-*fold graceful* if it admits a 2-*fold graceful labeling*. It can be shown that if G with n edges is 2-fold graceful, then there exists a cyclic G-decomposition of $^2K_{n+1}$. We investigate 2-fold graceful labelings of various classes of graphs including several classes of trees. (Received September 22, 2011)

1077-05-2672 **Joshua Sack*** (joshua.sack@gmail.com) and **Henning Arnor Ulfarsson** (henningu@ru.is). *Refined Inversion Statistics on Permutations.*

We study functions from permutations to integers, called statistics, that focus on properties of inversions or non-inversions of the permutation. Inversion statistics that we introduce are k-step inversions, which count the number of inversions with fixed position differences, and non-inversion sums, which take the sum of the differences of positions of the non-inversions of a permutation. We use non-inversion sums to show that for every number $n > 34$, there is a permutation such that the dot product of that permutation and the identity permutation (of the same length) is n. We also provide a distribution function for non-inversion sums and a distribution function for k-step inversions that relates to the Eulerian polynomials. (Received September 22, 2011)

1077-05-2687 **Imran F. Khan*** (imran@cs.columbia.edu), **Mehvish I. Poshni** (poshni@cs.columbia.edu) and **Jonathan L. Gross** (gross@cs.columbia.edu). *Genus Distribution of $P_3 \times P_n$.*

Genus distributions for various ladder-type graphs have been computed during the last couple of decades. This work represents the next natural step, i.e. the computation of the genus distribution of the grid-like graph family $P_3 \times P_n$ using *productions* and *double-root partials*. Double-root partials are defined for a *double-rooted graph* (i.e. a graph with two vertices designated as roots). They capture the various ways in which the two root vertices appear in face-boundary walks of embeddings. These partials are used in deriving productions that help compute the effect of operations like vertex- or edge-amalgamation on the genus distribution of graphs. We use these productions to derive recurrences for computing the genus distribution of an intermediate graph X_{n-1} (that is homeomorphic to $P_3 \times P_n$ minus an edge), using a new kind of surgical operation more complicated than a vertex- or an edge-amalgamation. These recurrences are then used to compute the genus distribution of $P_3 \times P_n$ by the use of productions for edge-addition between the two root vertices of a double-rooted graph, as derived in our earlier work (to be published). Productions and partials were first defined and used in Gross, Khan & Poshni's work in 2010. (Received September 22, 2011)

1077-05-2688 **Mehvish I. Poshni*** (poshni@cs.columbia.edu), **Imran F. Khan** (imran@cs.columbia.edu) and **Jonathan L. Gross** (gross@cs.columbia.edu). *Genus Distributions of 4-Regular Outerplanar Graphs.*

Unlike many of the graph families for which genus distributions have been calculated previously, the family of 4-regular outerplanar graphs does not have a linearly repetitive structure. I will describe an $O(n^2)$-time algorithm for calculating the genus distribution of any 4-regular outerplanar graph. The algorithm makes heavy use of constructs known as productions, which were first introduced by Gross, Khan and Poshni in 2010. These are schematic representations that capture the effect of performing different types of graph operations on graph embeddings, and they model the change produced in the face-boundary walks incident on predesignated vertices and edges. The productions used in this algorithm are adapted from a previous paper by Gross in 2011. Our algorithm breaks down a given instance of a 4-regular outerplanar graph into an auxiliary graph with multiple components. It then uses a depth-first algorithm to construct an *incidence tree* out of those components. Finally, the original graph is reconstructed from the auxiliary graph components by using information embodied in the incidence tree. This involves using productions at each step of a post-order traversal of the incidence tree to compute the genus distribution of the connected component produced at that step. (Received September 22, 2011)

1077-05-2699 **Dusty Sabo*** (sabo@sou.edu), Mathematics Department, Southern Oregon University, 1250 Siskiyou Blvd., Ashland, OR 97520, and **Daniel Schaal**, **Donald Vestal** and **Jacent Tokaz**. *On Disjunctive Rado Numbers.*

Let L represent a linear equation 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, ... , nwith 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 present a variation of Rado numbers. Let L1 and L2 represent linear equations. The least integer n, provided that it exists, such that for every coloring of the integers in the set 1, 2, ... , n with 2 colors there exists either a solution to L1 monochromatic in the first color or a solution to L2 monochromatic in the first color is called the disjunctive Rado number for L1 and L2. We will present some exact disjunctive Rado numbers for particular equations that have recently been determined. (Received September 22, 2011)

1077-05-2708 **Joseph R Chaffee*** (chaffjr@auburn.edu) and **Chris Rodger**. *K_3-decompositions of $\lambda_1 K_m \vee_{\lambda_2} \lambda_1 K_n$.*

Let $\lambda_1 K_m \vee_{\lambda_2} \lambda_1 K_n$ be a graph with two parts M and N in which two vertices are joined by λ_1 edges if they are in the same part and λ_2 edges otherwise. In this paper, we briefly discuss the obvious necessary conditions and then show they are sufficient in certain cases. (Received September 22, 2011)

1077-05-2756 **Fan Chung*** (fan@ucsd.edu), 9500 Gilman Drive, La Jolla, CA 92093. *From random graphs to graph limits and graphlets.* Preliminary report.

We will discuss recent developments in the probabilistic and spectral approaches for graph limits. In particular, we will extend the notion of quasi-randomness, which concerns a class of equivalent properties that random graphs satisfy. For example, we will give several necessary and sufficient conditions for a graph to be the union of two or more quasi-random graphs. One of these characterizations involves eigenvalues and scalable eigenspaces, that we call "graphslets", which dictate the behavior of graph limits for both dense and sparse graphs. (Received September 22, 2011)

1077-05-2784 **Yezhou Wu*** (yzwu@math.wvu.edu), 320 Armstrong, West Virginia University, Morgantown, WV 26505, and **Cun-Qun Zhang** (cqzhang@math.wvu.edu), 320 Armstrong, West Virginia Univeristy, Morgantown, WV 26505. *A new clustering algorithm.*

Clustering method has been applied in many areas as an important statistical tool for data mining. In the graph theory model clustering is a process of detecting dense subgraphs. In this report, a reversed clustering algorithm is introduced. An important feature of this algorithm is that the densities of the subgraphs generated by iteration are convergent. Therefore the final output subgraphs maintain certain densities. (Received September 22, 2011)

1077-05-2793 **Carolyn Kim*** (carolynkim@college.harvard.edu). *Zero Forcing Numbers and Graph Powers.*

Suppose we have an undirected graph $G = (V(G), E(G))$ where some set of vertices $Z \subset V(G)$ is initially colored black and the rest are colored white. By the color change rule, a white vertex turns black if it is the only white neighbor of a black vertex. If all the vertices eventually turn white, Z is called a *zero forcing set* of G, and the minimum size of Z over all zero forcing sets of G is called the *zero forcing number*, $Z(G)$. The zero forcing number has been shown to give a bound on the minimum rank of a graph. In this talk, we show that although in general adding edges to a graph might increase or decrease the zero forcing number, taking the power of a graph always increases the zero forcing number, provided the graph is not already complete: $Z(G^k) < Z(G^{k+1})$ if $G^k \neq G^{k+1}$. We also provide a partial generalization of this result to directed graphs. (Received September 22, 2011)

1077-05-2802 **Andy Parrish*** (atparrish@ucsd.edu). *An additive version of Ramsey's theorem.*
Consider a finite edge-coloring of the complete graph K_n on vertices labeled $1, \ldots, n$. Ramsey's theorem tells us that there are monochromatic complete subgraphs of arbitrary size (depending on n). We show that such a subgraph may be found so that its vertices satisfy a given linear equation, so long as the equation is "graph-regular." The graph-regular equations have an algebraic characterization, and include $x_1+\ldots+x_k = y_1+\ldots+y_k$ for $k > 2$. (Received September 22, 2011)

1077-05-2803 **Filip Cools**, **Jan Draisma**, **Sam Payne** and **Elina Robeva***
(erobeva@math.harvard.edu), 1 Oxford Street, Cambridge, MA 02138. *A Tropical Proof of the Brill-Noether Theorem.*
We exhibit Brill-Noether general graphs in every genus g, confirming a conjecture of Baker and giving a new proof of the Brill-Noether theorem. We achieve this by the following construction. Let Γ be a chain of g loops with generic edge lengths and let $\rho = g - (r+1)(g-d+r)$. If $\rho < 0$, we show that Γ has no effective divisors of degree d and rank r. If $\rho \geq 0$, then Γ has no effective divisors of degree d and rank r containing $(r+g+1)v_0$, where v_0 is a chosen fixed point on Γ. (Received September 22, 2011)

1077-05-2812 **Catherine Kruger*** (cikruger@eiu.edu), **Saad El-Zanati** and **Jessica Klister**. *On Rosa-type labelings of directed graphs.*
Let $\mathbb{Z}$ denote the set of integers. For integers a and b with $a \leq b$, let $[a,b] = \{x \in \mathbb{Z} : a \leq x \leq b\}$. Let K_k^* denote the complete directed graph on k vertices. Let G be a directed graph with n arcs on $\leq n+1$ vertices. A *labeling* of G is a one-to-one function $f\colon V(G) \to [0,n]$. If f is a labeling of G and $e = (u,v) \in E(G)$, let $\bar{f}(e) = f(v) - f(u)$ if $f(v) > f(u)$ and let $\bar{f}(e) = n+1+f(v)-f(u)$ if $f(v) < f(u)$. A labeling f of G is a *directed ρ-labeling* of G if $\{\bar{f}(e) : e \in E(G)\} = [1,n]$. It can be shown that for such a G, there exists a cyclic G-decomposition of K_{n+1}^* if and only if G admits a directed ρ-labeling. If G is bipartite, we define a labeling of G that leads to cyclic G-decompositions of K_{nx+1}^* for every positive integer x. We investigate these and other labelings of some classes of directed graphs and give the corresponding decomposition results. (Received September 22, 2011)

1077-05-2842 **Susan L Hollingsworth*** (shollingsworth@edgewood.edu), Edgewood College, Department of Mathematics, 1000 Edgewood College Drive, Madison, WI 53711. *Packing trees into complete bipartite graphs.*
In 1976, Gyárfás and Lehel conjectured that any finite list $T_2, T_3, \ldots, T_n$ of trees with 2 through n vertices can be packed into K_n, the complete graph on n vertices. This means that the edges of K_n can be partitioned into disjoint sets $E_2, \ldots, E_n$ in such a way that E_i is the set of edges of a tree isomorphic to T_i for $2 \leq i \leq n$. This conjecture is still unresolved.

We examine an analagous conjecture for packing trees into complete bipartite graphs: that is, if $T_{a,a}$ denotes a tree whose partite sets both have size a, which we call a *balanced* tree, we conjecture that any finite list $T_{1,1}, \ldots, T_{n,n}$ of such trees can be packed into $K_{n,n}$, the complete bipartite graph on $2n$ vertices.

We first show that so long as $k < \lfloor\sqrt{7/18n}\rfloor$, any list of balanced trees $T_{1,1}, T_{2,2}, \ldots, T_{k,k}$ can be packed into $K_{n,n}$.

We go on to find restrictions on the degree sequences which guarantee that, if we specify the degree sequences for one of the partite sets, we can find a list of balanced trees $T_{1,1}, T_{2,2}, \ldots, T_{n,n}$ having the specified degree sequences so that these trees can be packed into $K_{n,n}$. (Received September 22, 2011)

1077-05-2862 **Morgan J Rodgers*** (morgan.rodgers@ucdenver.edu). *New Cameron-Liebler line classes relating to point sets of type (m,n) in odd order affine planes.* Preliminary report.
A Cameron-Liebler line class of parameter x in a finite projective space $PG(3,q)$ is a set of lines $\mathcal{L}$ such that every line ℓ in $PG(3,q)$ is concurrent with either $(q+1)x + (q^2-1)$ or $(q+1)x$ lines of $\mathcal{L}$, according to whether or not $\ell \in \mathcal{L}$. The first nontrivial examples were constructed in 1999 by Bruen and Drudge, who described an infinite family having parameters $x = \frac{1}{2}(q^2+1)$ for all odd values of q. Aside from these and a sporadic example in $PG(3,4)$ due to Penttila, all other published results on these line classes have been related to restrictions on their parameter.

We construct new examples of Cameron-Liebler line classes having parameter $\frac{1}{2}(q^2-1)$ in $PG(3,q)$ for many odd values of q, each admitting a cyclic collineation group of order q^2+q+1. We begin with such a group, acting semiregularly on the lines in the space, and attempt to combine the orbits in appropriate ways so that the necessary conditions are satisfied. From these new line classes we are able to construct new points sets of type (m,n) in certain affine planes, that is, point sets with exactly two intersection numbers with respect to lines in the plane. These types of sets are very rare in odd order affine planes. (Received September 22, 2011)

1077-05-2874 **Felix Breuer*** (felix@fbreuer.de), Department of Mathematics, San Francisco State University, 1600 Holloway Ave., San Francisco, CA 10781. *Using Ehrhart theory for solving combinatorial problems.* Preliminary report.

Ehrhart theory offers a number of tools for attacking problems in enumerative combinatorics from a geometric point of view. In particular, Ehrhart theory provides methods for showing that counting functions are polynomials, deriving bounds on their coefficients and finding combinatorial reciprocity theorems. In this talk, I will present a few examples of this approach, dealing with flow polynomials of graphs and chromatic polynomials of graphs and hypergraphs. I will conclude by asking some questions for further research, in particular: What is a combinatorial characterization of the counting functions these methods can be applied to? (Received September 22, 2011)

1077-05-2881 **Jacob Fox*** (fox@math.mit.edu), 77 Massachusetts Avenue, Cambridge, MA 02139-4307. *Chromatic number, clique subdivisions, and the conjectures of Hajós and Erdős-Fajtlowicz.*

For a graph G, let $\chi(G)$ denote its chromatic number and $\sigma(G)$ denote the order of the largest clique subdivision in G. Let $H(n)$ be the maximum of $\chi(G)/\sigma(G)$ over all n-vertex graphs G. A famous conjecture of Hajós from 1961 states that $\sigma(G) \geq \chi(G)$ for every graph G. That is, $H(n) \leq 1$ for all positive integers n. This conjecture was disproved by Catlin in 1979. Erdős and Fajtlowicz further showed by considering a random graph that $H(n) \geq cn^{1/2}/\log n$ for some absolute constant $c > 0$. In 1981 they conjectured that this bound is tight up to a constant factor in that there is some absolute constant C such that $\chi(G)/\sigma(G) \leq Cn^{1/2}/\log n$ for all n-vertex graphs G. In this paper we prove the Erdős-Fajtlowicz conjecture. The main ingredient in our proof, which might be of independent interest, is an estimate on the order of the largest clique subdivision which one can find in every graph on n vertices with independence number α. This is joint work with Choongbum Lee and Benny Sudakov. (Received September 22, 2011)

1077-05-2890 **Michael Andrew La Croix*** (malacroi@alumni.uwaterloo.ca). *Jack Symmetric Functions and the Non-Orientability of Rooted Maps.*

A generating series for rooted orientable maps with respect to vertex- and face-degree sequences can be expressed in terms of Schur symmetric functions. A parallel construction gives the corresponding generating series for all rooted maps in terms of zonal polynomials.

Goulden and Jackson conjectured that an analogous expression involving Jack symmetric functions is the generating series for all rooted maps, with respect to an unknown invariant, marked by a shifted Jack parameter, that measures departure from orientability. A consideration of a partial differential equation satisfied by a specialization of this series suggests a new family of invariants, defined recursively in terms of root edge deletion. Analyzing maps with respect to these invariants may provide combinatorial insight into properties of Jack symmetric functions that have been observed previously in an algebraic setting. (Received September 22, 2011)

1077-05-2903 **Liam Rafferty*** (rafferty@member.ams.org), Dr. Liam Rafferty, 2139 S 4th W Apt. A, Missoula, MT 59801. *An alternate proof that any graph that is mn-colorable is decomposable into two graphs that are m-colorable and n-colorable, respectively.* Preliminary report.

Stefan A. Burr (A Ramsey-theoretic result involving chromatic numbers. J. Graph Theory 4 (1980), no. 2, 241–242) proved that a graph that is mn-colorable can be decomposed into two graphs that are m-colorable and n-colorable, respectively. While Burr explicitly constructed the colorings, we prove the same result using graph homomorphisms. We also provide a new corollary to this theorem. (Received September 22, 2011)

1077-05-2920 **J K Herring*** (jkh011@shsu.edu), **E Meza** and **C M Nieuwoudt**. *The Abelian Sandpile Model.*

In 1987 physicists Bak, Tang, and Westfield introduced the sandpile model to study the dynamics of sandpile avalanches. The sandpile model is represented by a combinatorial graph G. Surprisingly, this model has the structure of a finite abelian group which arises as the cokernel of the Laplacian of the graph G. One of the main problems consists in finding the group associated to a given graph, which is done by computing the Smith Normal Form of the Laplacian. It is a more challenging combinatorial problem to find the structure of the family of groups arising from a given family of graphs. Only a few results are known in this direction. Families of graphs whose sandpile groups have been characterized include cycle graphs, wheel graphs, complete graphs, and complete multipartite graphs. In this talk we will describe the sandpile group of a family of graphs known as book graphs. We will also make connections between the elements in the group and the sandpile configurations in the model. Our proofs are based on a careful study of the Laplacian of these graphs and rely on Linear algebra techniques. (Received September 23, 2011)

06 ► Order, lattices, ordered algebraic structures

1077-06-1035 **Jonathan E Beagley*** (jbeagley@gmu.edu), Department of Mathematical Sciences, 4400 University Drive, Fairfax, VA 22030. *The Order Dimension and Coloring of Planar Point Sets.*

We study the order dimension of the lattice of closed sets for a convex geometry by looking at colorings of two graphs. The Erdős-Szekeres Conjecture of planar point sets in general position can be stated in terms of the clique number of one of these graphs. In 1961 Erdős and Szekeres created a point set of size 2^{n-2} points and contains no vertex set of a convex n-gon. We use these graphs to show that this point set has order dimension $n-1$ and any point set of size more than $n-1$ has order dimension strictly larger than $n-1$. (Received September 15, 2011)

1077-06-1135 **Peter R. W. McNamara*** (peter.mcnamara@bucknell.edu), Department of Mathematics, Bucknell University, Lewisburg, PA 17837, and **Bruce E. Sagan** (sagan@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *The Möbius function of generalized subword order.*

Let P be a poset and let P^* be the set of all finite length words over P. Generalized subword order is the partial order on P^* obtained by letting $u \leq w$ if and only if there is a subword u' of w having the same length as u such that each element of u is less than or equal to the corresponding element of u' in the partial order on P. Classical subword order arises when P is an antichain, while letting P be a chain gives an order on compositions. For any finite poset P, we use discrete Morse theory to give a simple formula for the Möbius function of P^* in terms of the Möbius function of P. This permits us to rederive in an easy and uniform manner previous results of Björner, Sagan and Vatter, and Tomie. (Received September 16, 2011)

1077-06-1800 **Ryan K Therkelsen*** (rtherkelsen@bellarmine.edu), Mathematics Department, Bellarmine University, 2001 Newburg Road, Louisville, KY 40205. *A new description of the Bruhat-Chevalley order on Gauss-Jordan elements in the Renner monoid.* Preliminary report.

The orbits of the action of $GL_n(k)$ on $M_n(k)$ by left multiplication are classified by the matrices in reduced row echelon form. For the Renner monoid of a reductive monoid, the orbits for the similar action on the left by its unit group are classified by the Gauss-Jordan elements. Formally, these are the elements satisfying containment relations of certain cosets of a Borel subgroup of the unit group of the monoid. For $M_n(k)$, the Renner monoid is the set of partial permutation matrices and the Gauss-Jordan elements are exactly those matrices in row echelon form, as we would hope. The inherited Bruhat-Chevalley order on these elements has a very nice combinatorial description — this description will be examined for the case that $M = M_n(k)$ as well as, time permitting, the case that M is a canonical monoid. (Received September 21, 2011)

1077-06-1934 **Martha Lee Hollist Kilpack*** (kilpack@binghamton.edu). *The Algebraic Lattice of Algebraic Closure Operators.*

A closure operator on an infinite set, S, is finitary or algebraic if, for all $A \subseteq S$, the closure of A is equal to the union of the closures of the finite subsets of A. It will be shown, if we take the set of all algebraic closure operators on S it forms, not only a lattice, but an algebraic lattice. (Received September 21, 2011)

08 ► General algebraic systems

1077-08-382 **Valmir Bucaj*** (vbuqaj@gmail.com), 1000 West Court Street, Seguin, TX 78155. *Finding Factors of Factor Rings over the Eisenstein Integers.* Preliminary report.

Eisenstein integers are defined to be the set $Z[\omega] = \{a+b\omega : a, b \in \mathbb{Z}\}$ where $w = (-1+i\sqrt{3})/2$. This set lies inside the set of complex numbers $\mathbb{C}$ and they also form a commutative ring in the algebraic number field $\mathbb{Q}(\omega)$. In this paper we prove a few results related to the factor rings over the Eisenstein integers. In particular we show that the ring $\mathbb{Z}[\omega]$ factored by an ideal generated by any element $m + n\omega$ of this ring, where $g.c.d(m, n) = 1$ is isomorphic to the ring $\mathbb{Z}_{N(m+n\omega)}$, where N is the norm function given by $N(m+n\omega) = (m+n\omega)(m+n\bar{\omega}) = m^2+n^2-mn$. This result helps us quickly answer questions about the number of elements of the factor ring $\mathbb{Z}[\omega]/\langle m + n\omega\rangle$. Then, we give a representation for the factor ring $\mathbb{Z}[\omega]/\langle m + n\omega\rangle$ in terms of simpler rings. Finally, at the end we give a few applications to elementary number theory, more specifically we use some of the results in this paper to find all solutions of the equation $p = m^2 + n^2 - mn$ where p is a prime not congruent to 2 mod 3, and $m, n \in \mathbb{Z}^+$. (Received August 30, 2011)

1077-08-2022 **Florian Pop*** (pop@math.upenn.edu), Department of Mathematics, University of Pennsylvania, 209 South 33rd Street, Philadelphia, PA 19104. *The birational p-adic section conjecture -revisited.*

I will present a "minimalistic" birational p-adic section conjecture for arbitrary complete smooth varieties over p-adic fields. The result generalizes the corresponding result for complete smooth curves over p-adic fields. Some application, among which a "minimalistic" p-adic analog of the Artin-Schreier Theorem, will be given. (Received September 21, 2011)

11 ► Number theory

1077-11-48 **Pace P Nielsen*** (pace@math.byu.edu), Department of Mathematics, Brigham Young University, Provo, UT 84602. *Wieferich primes, heuristics, and computations.* Preliminary report.

A prime p is a Wieferich prime if 2^{p-1} is equivalent to 1 modulo p^2. This condition is a straightforward strengthening of Fermat's little theorem. Wieferich primes were initially introduced in connection to the first case of Fermat's last theorem. Only two such primes are currently known, while heuristics suggest that there should be infinitely many and that we are long overdue for the next one. In this talk, we compare these heuristics with a large amount of computational data. (Received July 06, 2011)

1077-11-96 **L J Balasundaram*** (jagbala@comcast.net), Harvard Institue for Learning in Retirement, 51 Brattle Street, Cambridge, MA 02138. *A Set of Quadratic Equations For Factoring or Primality Determination of odd 6*n + or -1 Type Odd Integers.*

Positive integers of 6*n + or -1 pattern consist of prime numbers and composite integers for integer values n>0. Digital addition of these integers show a repetitive pattern of 5,2 and 8 for (6*n - 1) type integers and 7,4, and 1for (6*n + 1) type integers. Based on this digital addition repetition pattern Quadratic Formulas for for factoring or primality determination of these type of integers are advanced. (Received July 26, 2011)

1077-11-104 **David Applegate**, **Marc LeBrun** and **Neil J. A. Sloane*** (njas@research.att.com), AT&T Shannon Labs, 180 Park Ave., Room C233, Florham Park, NJ 07932-0971. *Dismal Arithmetic.*

Dismal arithmetic is just like the arithmetic you learned in school, only simpler: there are no carries, when you add digits you just take the largest, and when you multiply digits you take the smallest. This paper studies basic number theory in this world, including analogues of the primes, number of divisors, sum of divisors, and the partition function. There are many open problems concerned with the enumeration of primes, divisors, and square roots. (Received July 27, 2011)

1077-11-116 **Jeremy Rouse***, Wake Forest University, P. O. Box 7388, Winston-Salem, NC 27109. *Positive-definite quadratic forms representing all odd, positive integers.* Preliminary report.

Manjul Bhargava and Jonathan Hanke's famous "290-theorem" states that a positive-definite quadratic form with integer coefficients represents every positive integer if and only if it represents the numbers from 1 up to 290. To prove their theorem it is necessary for them to study 6664 particular quadratic forms in four variables and determine which integers they represent (a significant computational challenge). Our goal is to prove a similar theorem for integer-valued quadratic forms representing all odd numbers. This entails the study of 24888 quadratic forms in four variables. We are able to handle all of these forms with a combination of four different computational methods (one of which is completely new) to reach our desired conclusion. (Received July 28, 2011)

1077-11-131 **Himadri Ganguli*** (hganguli@sfu.ca), 8888 University Drive, Department of Mathematics, Burnaby, BC V5A1S6, Canada. *On the behaviour of the Liouville function on polynomials with integer coefficients.*

Let $\lambda(n)$ denote the Liouville function. Complementary to the prime number theorem, Chowla conjectured that

Conjecture (Chowla).

$$\sum_{n\le x} \lambda(f(n)) = o(x)$$

for any polynomial $f(x)$ with integer coefficients, not in the form of $bg^2(x)$, where b is a constant.

Chowla's conjecture is proved for linear functions but for the degree greater than 1, the conjecture seems to be extremely hard and still remains wide open. One can consider a weaker form of Chowla's conjecture, namely,

Conjecture 1 (Cassaigne, et al). *If $f(x) \in \mathbb{Z}[x]$ and is not in the form of $bg^2(x)$ for some $g(x) \in \mathbb{Z}[x]$ and constant b, then $\lambda(f(n))$ changes signs infinitely often.*

Although it is weaker, Conjecture 1 is still wide open for polynomials of degree > 1. In this talk, I will describe some recent progress made while studying Conjecture 1 for the quadratic polynomials. This is joint work with Peter Borwein and Stephen Choi. (Received July 28, 2011)

1077-11-132 **Anna R Haensch*** (ahaensch@wesleyan.edu), Department of Mathematics and Computer Scienc, Wesleyan University, 265 Church St., Middletown, CT 06459. *Almost Universal Inhomogeneous Quadratic Forms.*

A fundamental question in the study of integral quadratic forms is the effective determination of the set of integers represented by a given quadratic form. A related and equally interesting problem is the representation of integers by inhomogeneous quadratic forms; that is, the sum of a quadratic form and a linear form. Such a form is called *almost universal* if it represents all but finitely many positive integers. Examples of such forms are sums of generalized polygonal numbers. For $m \geq 3$, we define the m-th generalized polygonal numbers as

$$p_m(x) = \frac{(m-2)x^2 - (m-4)x}{2}, \quad x \in \mathbb{Z}.$$

In this talk we will present a characterization of positive definite almost universal ternary sums of polygonal numbers $\alpha p_m(x) + \beta p_m(y) + \gamma p_m(z)$, where $m - 2 = 2p$, for a prime p. This generalizes the recent work by Chan and Oh [1] on almost universal ternary sums of triangular numbers. If time permits, we will discuss a characterization of positive definite almost universal ternary inhomogeneous quadratic forms satisfying some mild arithmetic conditions.

[1] W.K. Chan and B.-K. Oh, *Almost universal ternary sums of triangular numbers*, Proc. Amer. Math. Soc. **137** (2009), 3553–3562. (Received July 28, 2011)

1077-11-140 **Amitabha Tripathi*** (at1089@gmail.com), Department of Mathematics, Indian Institute of Technology, Hauz Khas, New Delhi, 110016, India. *On the number of positive integers not representable by a linear form in three variables.*

For positive integers a, b, c that are coprime, we denote by $n(a, b, c)$ the number of positive integers that are not expressible by the form $ax + by + cz$ with x, y, z nonnegative integers. We give exact formulae for $n(a, b, c)$ that covers almost all cases of a, b, c. (Received August 01, 2011)

1077-11-173 **Joseph H. Silverman***, Mathematics Department - Box 1917, Brown University, Providence, RI 02912, and **Chantal David**, Department of Mathematics and Statistics, Concordia University, Montréal, Québec H3G 1M8, Canada. *Elliptic Pseudoprimes and Elliptic Carmichael Numbers.* Preliminary report.

Let $E/\mathbb{Q}$ be an elliptic curve and let $Q \in E(\mathbb{Q})$ be a non-torsion point. We define an *elliptic pseudoprime* for the pair (E, Q) to be a composite integer n such that E has good reduction at all primes dividing n and such that $(n + 1 - a_n)\overline{Q} = \overline{O}$ in $E(\mathbb{Z}/n\mathbb{Z})$. We then define n to be an *elliptic Carmichael number* for E if it is an elliptic pseudoprime for every point in $E(\mathbb{Z}/n\mathbb{Z})$. In this talk I will discuss properties and computations related to elliptic pseudoprimes and Carmichael numbers, including an elliptic Korselt criterion. (Received August 07, 2011)

1077-11-177 **John Voight*** (jvoight@gmail.com), 204 King St Apt 1, Burlington, VT 05401. *On the computation of Galois Belyi maps.*

We discuss methods for the computation of Galois three-point covers of the projective line. We give some applications to inverse Galois theory and modular construction of rational points on curves. (Received August 07, 2011)

1077-11-182 **John W Jones*** (jj@asu.edu), SoMSS, P.O. Box 871804, ASU, Tempe, AZ, AZ 85287-1804. *Number Fields Unramified Away From 2.*

Let G be a finite group. One can if there are any Galois extensions of $\mathbf{Q}$ ramified at 2 (and possibly at infinity) with Galois group G. Using a combination of computational and theoretical techniques, we show that the answer is no for a large number of G. (Received August 08, 2011)

1077-11-188 **Nigel Boston*** (boston@math.wisc.edu), Department of Mathematics, University of Wisconsin, Madison, WI 53706. *Non-abelian Cohen-Lenstra Heuristics.*

In 1983, Cohen and Lenstra observed that the frequency with which a given abelian p-group A (p odd) arises as the p-class group of an imaginary quadratic field K is apparently proportional to $1/|\mathrm{Aut}(A)|$. The Galois group of the maximal unramified p-extension of K has abelianization A and one might then ask how frequently a given p-group G arises. We develop a theory wherein this frequency is inversely proportional to the size of its automorphism group in a new category and then test this against computations. If time permits, I shall describe progress on the real quadratic case. This is joint work with Michael Bush and Farshid Hajir. (Received August 09, 2011)

1077-11-216 **Cassie L Williams*** (williams@math.colostate.edu), Department of Mathematics, 101 Weber Building, Colorado State University, Fort Collins, CO 80523. *Conjugacy classes in GSp_4 and an application to the enumeration of abelian surfaces.* Preliminary report.

While the conjugacy classes of GL_n are straightforward to understand, those of GSp_{2g} are more challenging. We have identified the conjugacy classes of $\mathrm{GSp}_4(\mathbb{Z}/\ell)$ and are interested in using them to determine and understand the classes of $\mathrm{GSp}_4(\mathbb{Z}/\ell^r)$. With this information we can give a new interpretation of the Euler factors of L-functions of abelian quartic CM fields. In 2003, Gekeler considered the Euler factors of the L-function of a quadratic imaginary field, which is related via the class number to the size of an isogeny class of elliptic curves, and found a relationship to the proportion of elements of $\mathrm{GL}_2(\mathbb{Z}/\ell^r)$ with given characteristic polynomial. Our results for $\mathrm{GSp}_4(\mathbb{Z}/\ell^r)$ extend this heuristic from elliptic curves to abelian surfaces. (Received August 13, 2011)

1077-11-217 **Andrei Rapinchuk*** (asr3x@virginia.edu), Department of Mathematics, University of Virginia, P.O. Box 400137, Charlottesville, VA 22904-4137. *Weakly commensurable S-arithmetic subgroups in simple algebraic groups of types B_n and C_n.*

In a joint work with Gopal Prasad (Publ. math. IHES 109(2009), 113-189) we introduced the notion of weak commensurabiity for Zariski-dense subgroups $\Gamma_i \subset G_i(F)$ $(i = 1, 2)$ where G_1 and G_2 are almost simple algebraic groups defined over a field F of characteristic zero. We have been able to determine when two S-arithmetic Zariski-dense subgroups Γ_1 and Γ_2 are weakly commensurable if G_1 and G_2 are of the *same* type. However, weakly commensurable S-arithmetic subgroups can exist in groups of different types, viz., when G_1 is of type B_n and G_2 is of type C_n for some $n \geqslant 3$. I will report on a joint work with Skip Garibaldi in which we have pinned down all situations where this phenomenon happens. This result has some geometric applications. (Received August 13, 2011)

1077-11-285 **Paul Pollack*** (pollack@math.ubc.ca), University of British Columbia, Department of Mathematics, 1984 Mathematics Road, Room 121, Vancouver, BC V6T 1Z2, Canada. *Congruence properties of the multiplicative partition function.*

Let $f(N)$ be the number of unordered factorizations of N, where a *factorization* is a way of writing N as a product of integers all larger than 1. For example, $f(30) = 5$, corresponding to the five factorizations

$$2 \cdot 3 \cdot 5, \quad 5 \cdot 6, \quad 3 \cdot 10, \quad 2 \cdot 15, \quad \text{and} \quad 30.$$

The function $f(N)$ is an analogue in the multiplicative setting of the classical partition function $p(N)$. Congruence properties for $p(N)$ have been extensively investigated since the pioneering work of Ramanujan in the early part of the twentieth century.

In this talk, we outline a proof that for any given residue class, there is a well-defined proportion of the time that f lands there. Moreover, this proportion is positive as long as the residue class contains at least one value of f. The proof allows one to compute these proportions; as a (perhaps surprising) example, $f(N)$ is odd about 57% of the time. We mention some of the issues that arise in the computation of these densities. (Received August 18, 2011)

1077-11-376 **Todd Cochrane** (cochrane@math.ksu.edu), Department of Mathematics, 138 Cardwell Hall, Kansas State University, Manhattan, KS 66506, **Craig V. Spencer** (cvs@math.ksu.edu), Department of Mathematics, 138 Cardwell Hall, Kansas State University, Manhattan, KS 66506, and **Hee-Sung Yang*** (hee-sung.yang@dartmouth.edu), Department of Mathematics, 6188 Kemeny Hall, Dartmouth College, Hanover, NH 03755. *Rational linear spaces on hypersurfaces over quasi-algebraically closed fields.*

A field k is called a C_i field if every form of degree d with coefficients in k having more than d^i variables has a non-trivial zero. C_i theory is a powerful tool in that it provides a sharp bound for the number of variables necessary for an arbitrary form to have a non-trivial zero. Suppose $f_1, \ldots, f_r$ are forms in s variables over $k := \mathbb{F}_q(t)$, a C_2 field, of degrees $d_1, \ldots, d_r$, respectively. Using extensive combinatorial techniques and C_i theory, we determine a bound for the number of variables necessary for $f_1, \ldots, f_r$ to have a projective l-dimensional rational linear space of simultaneous zeros, namely

$$s > l + \sum_{j=1}^{r} \sum_{w=1}^{d_j} w^2 \binom{d_j - w + l - 1}{l - 1},$$

which is considerably sharper than the analogous bound for a single odd-degree form over $\mathbb{Q}$. With this result, we also establish that, given $s > 1 + \sum_{j=1}^{r} \frac{d_j(d_j+1)(2d_j+1)}{6}$, for any $\mathbb{F}_q(t)$-rational zero $\mathbf{a} = (a_1, \ldots, a_s)$, we can find infinitely many s-tuples of monic irreducible polynomials $(\varpi_1, \ldots, \varpi_s)$, with ϖ_m not all equal, so that $(a_1\varpi_1, \ldots, a_s\varpi_s)$ vanishes f_j for $1 \leq j \leq r$. We also prove more general results for forms over C_i fields. (Received September 22, 2011)

1077-11-377 **Andrew V. Sutherland*** (`drew@math.mit.edu`), Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA 02139. *Identifying supersingular elliptic curves.*

Given an elliptic curve E over a field of characteristic p, we wish determine whether E is ordinary or supersingular, and to do so as efficiently as possible. I will review the complexity of several existing algorithms, and then present a new approach based on structural differences between ordinary and supersingular isogeny graphs. This yields a simple algorithm that, given E and a suitable non-residue in $\mathbb{F}_p^2$, determines the supersingularity of E in $O(n^3 \log^2 n)$ time and $O(n)$ space, where $n = O(\log p)$. Both these complexity bounds are significant improvements over existing methods. (Received August 26, 2011)

1077-11-405 **Jonathan P Sorenson*** (`sorenson@butler.edu`), Indianapolis, IN. *Algorithms for Approximately Counting Semismooth Integers.* Preliminary report.

Define the function $\Psi(x, y, z)$ to be the number of integers $n \leq x$ where $n = mp$, m is y-smooth (that is, all prime divisors of m are $\leq y$) and p is prime with $p \leq z$. We loosely define integers counted by $\Psi(x, y, z)$ as *semismooth*. Such integers arise in many integer factoring algorithms with a "large prime" variant, such as the number field sieve.

We look at several algorithms for approximating the value of $\Psi(x, y, z)$ and compare their estimates with exact values of this function for x up to 2^{40}. In particular, we show that for most ranges of x, y, and z, the method of Bach and Peralta (the natural generalization of the Dickman ρ function) is inferior to a method based on numeric integration combined with the fast saddlepoint-based estimate of Suzuki. We also look at several hybrid algorithms. (Received August 29, 2011)

1077-11-406 **Carl Pomerance*** (`carl.pomerance@dartmouth.edu`). *Dense product-free sets.*

A subset S of a ring R is *product free* if $ab \neq c$ whenever $a, b, c \in S$. How large can S be when $R = \mathbb{Z}/n\mathbb{Z}$ or $R = \mathbb{Z}$? It is easy to come up with examples of product-free sets of integers with asymptotic density 1/2, and in $\mathbb{Z}/n\mathbb{Z}$ with almost $n/2$ elements. For example, if p is an odd prime, the quadratic nonresidues for p form a product-free subset of $\mathbb{Z}/p\mathbb{Z}$ of size $(p-1)/2$. So, "1/2" seems to be a natural guess, and in a recent paper with A. Schinzel we proved this for $\mathbb{Z}/n\mathbb{Z}$ for a very large proportion of numbers n and for all $n \leq 9 \times 10^8$. However, in new work with P. Kurlberg and J. Lagarias, we show that for each $\epsilon > 0$, there are numbers n with product-free subsets of $\mathbb{Z}/n\mathbb{Z}$ of size $> (1-\epsilon)n$. The smallest example we were able to find that beats $n/2$ has $n \approx 10^{1.61 \times 10^8}$. If n_ϵ is the least n that beats $(1-\epsilon)n$, we show that n_ϵ tends to infinity about doubly exponentially in $1/\epsilon^{17}$. (Received September 08, 2011)

1077-11-454 **Roy O. Quintero*** (`rquinter@ula.ve`), Av: Tabiskey Castán, Urb: Mirabel, Quinta Belén María, 9-464, Trujillo, Trujillo 3150, Venezuela. *A Note on the Three-pile problem.* Preliminary report.

The main purpose of this research is to find a general version of the well known card trick called Three-pile problem (TPP). First, the TPP is expressed in terms of a basic discrete function defined on a deck of 27 cards and then generalized appropriately for any deck of ab cards. Second, all of its fixed points are found and characterized basically in three types. Finally, we employ this information to generate a simple procedure for a bunch of new brand tricks as TPP. Everything is done by using only undergraduate mathematics as basic properties of the quotient and remainder of the division of integers, modular arithmetic, and naive theory of discrete functions. (Received September 02, 2011)

1077-11-458 **Huilan Li** and **Trueman MacHenry*** (machenry@mathstat.yorku.ca), Dept.of Math. and Stats., York University, Toronto, Ontario M3J1P3. *A New Approach to Multiplicative Arithmetic Function NumberTheory Through Isobaric Polynomials.*

The ring of Isobaric Polynomials (IR) is the Ring of Symmetric Polynomials (SP) on the Elementary Symmetric Polynomial Basis. A local Representation of the group of Multiplicative Functions (MF) under Dirichlet convolution in IR is given. This representation is also a representation of all linear recursions. The isobaric polynomials that represent MF are the Generalized Fibonacci Polynomials (GFP). A Logarithm operator (L) and Exponential operator (E) are introduced into IR. L(GFP) = GLP (Generalized Lucas Polynomials). This yields an (local) isomorphism of MF to AddF (the group of Additive Arithmetic Functions). The operator E gives rise to a (hyperbolic) trigonometry in IR which is induced to MF and AddF, and provides new identities in SP. New methods of handling MF and AddF are also consequences. In addition a new view of McCarthy's theorem and of the Busche-Ramanujan identities is presented. (Received September 02, 2011)

1077-11-472 **Maosheng Xiong*** (mamsxiong@ust.hk), Math. Department, Hong Kong University of Science and Technolog, Hong Kong, Hong Kong. *A note on Artin's primitive root conjecture.*

Let a be a rational number. For simplicity we assume that a is not a prime power of any rational number. A version of Artin's primitive root conjecture states that there are infinitely many primes p such that $a \pmod p$ is a primitive root. In an impressive paper in 1967, Hooley proved under the Generalized Riemann Hypothesis (GRH) that indeed the natural density of such primes exists, is positive and can be expressed explicitly as a infinite product over primes.

Let $f_a(p)$ denote the multiplicative order of $a \pmod p$. The purpose of this paper is to study the distribution of the value $(p-1)/f_a(p)$ as p runs over primes. We prove that under GRH, for any non-negative integer n, the natural density of primes p such that the number of prime factors of $(p-1)/f_a(p)$ equals n always exists, is positive and can be computed explicitly. In particular, when $n = 0$, this implies Artin's primitive root conjecture. (Received September 03, 2011)

1077-11-487 **Jonathan M. Borwein** and **Armin Straub*** (astraub@tulane.edu), 6823 St. Charles Avenue, New Orleans, LA 70118. *Symbolic evaluation of log-sine integrals in polylogarithmic terms.*

Generalized log-sine integrals, first studied systematically by Lewin 50 years ago, appear in many settings in number theory and analysis: for instance, they can be used to express classes of inverse binomial sums. As such they have reappeared in recent work on the epsilon-expansion of Feynman diagrams in physics; they have also proved useful in the study of certain multiple Mahler measures. We sketch these developments and present results which allow for the symbolic computation of log-sine integrals in terms of Nielsen polylogarithms at related argument. In particular, log-sine integrals at pi/3 are shown to evaluate in terms of polylogarithms at the sixth root of unity. (Received September 04, 2011)

1077-11-533 **Benjamin Linowitz*** (benjamin.linowitz@dartmouth.edu), 6188 Kemeny Hall, Hanover, NH 03755. *Selectivity in Quaternion Algebras.*

The subject of embedding number fields into quaternion algebras was the realm of class field theory and is the subject of the famous Albert-Brauer-Hasse-Noether theorem which gives necessary and sufficient conditions for the existence of such an embedding. In this talk we will discuss an integral refinement of the Albert-Brauer-Hasse-Noether theorem. Let R be an order of an indefinite quaternion algebra defined over a number field K and S be an order in a quadratic field extension of K. We determine, for a broad class of orders R, the proportion of isomorphism classes of orders in the genus of R admitting an embedding of S and in particular show that this proportion is either 0, 1/2 or 1. This generalizes work of Chinburg and Friedman in which maximal orders were considered. As an application we will show how this result can be used to produce examples of hyperbolic two-manifolds which are isospectral but not isometric. (Received September 06, 2011)

1077-11-542 **Jaime Gutierrez*** (jaime.gutierrez@unican.es), University of Cantabria, Santander, Spain. *An algorithm for recovering zeroes of multivariate polynomials over a prime finite field.*

We present a strategy for recovering zeroes of multivariate polynomials over a prime finite field. The probabilistic algorithm is inspired in methods for predicting pseudorandom numbers, and it is based on lattice basis reduction. (Received September 07, 2011)

1077-11-597 **Robert L. Benedetto*** (rlb@math.amherst.edu). *Computing small canonical heights in arithmetic dynamics.*

Let K be a number field, and let ϕ be a morphism from the projective line to itself, defined over K and of degree at least two. It has been conjectured that there is a uniform upper bound for the number of K-rational preperiodic points, and that there is a uniform lower bound for the normalized canonical height of K-rational non-preperiodic points. In this talk, we will discuss some computational evidence for these conjectures, as well as the strategies underlying our computations. (Received September 08, 2011)

1077-11-598 **Michael Coons*** (mcoons@math.uwaterloo.ca). *An irrationality measure for Mahler numbers.*

Let $F(x)\in\mathbb{Z}[[x]]$ be a power series that satisfies a Mahler-type functional equation; that is, there exist positive integers k and d and polynomials $p(x),a_0(x),\ldots,a_d(x)\in\mathbb{Z}[x]$ with $a_0(x)a_d(x)\neq 0$ such that

$$p(x)+\sum_{i=0}^{d}a_i(x)F(x^{k^i})=0.$$

Let ξ be a real number. The *irrationality exponent* $\mu(\xi)$ of ξ is defined as the supremum of the set of real numbers μ such that the inequality $|\xi-p/q|<q^{-\mu}$ has infinitely many solutions $(p,q)\in\mathbb{Z}\times\mathbb{N}$.

In this talk we will outline a proof that $\mu(F(a/b))<\infty$ for all positive integers $b\geq 2$ such that a/b is in the radius of convergence of $F(x)$ and $\log|a|/\log b\in[0,1/2)$; in particular, we show that $F(1/b)$ is not a Liouville number. This generalizes a result of Adamczewski and Cassaigne for automatic numbers.

This is joint work with Jason Bell. (Received September 08, 2011)

1077-11-626 **erica j. Whitaker*** (ewhitaker@math.ohio-state.edu). *Congruence and Noncongruence Subgroups of* $\Gamma(2)$ *via Graphs on Surfaces.*

There is an established way to associate a finite-index subgroup of $\Gamma(2)$ with a bipartite graph on a surface, or, equivalently, a triple of permutations. We will examine this relationship, and find permutations and graphs for groups of the form $\Gamma(2p)$. We will also use graphs to produce infinite families of noncongruence subgroups of every even level. (Received September 08, 2011)

1077-11-640 **Himadri Ganguli*** (hganguli@sfu.ca), Department of Mathematics, Simon Fraser University, 8888 University Drive, Burnaby, BC V3T1V3, Canada. *On the Correlation of completely multiplicative functions.*

Let $f(n)$ be an arithmetic function and $x>0$, then we define the correlation function $C(f,x)=\sum_{n\leq x}f(n)f(n+1)f(n+2)$. In this talk we present an asymptotic formula for $C(f,x)$ in the case when $f(n)$ is a completely multiplicative function and $|f(n)|\leq 1$ for all $n\in\mathbb{N}$. Let $\lambda_y(n)$ denote the truncated Liouville function which equals $+1$ or -1 according n has odd or even number of prime divisors $p\leq y$ counted with multiplicity. It follows from the main theorem that $C(\lambda_y,x)=o(x)$ whenever $y=x^{o(1)}$ and speaks in favour of the Chowla conjecture that $C(\lambda,x)=o(x)$ where λ is the classical liouville function. (Received September 09, 2011)

1077-11-659 **Brandt Kronholm*** (jkronhol@whittier.edu), Brandt Kronholm, Whittier College, 13406 E. Philadelphia St., Whittier, CA 90608-0634. *New Ramanujan Congruence Properties of the Restricted Partition Function* $p(n,m)$ *Modulo Prime Powers.*

Ramanujan-type congruences for the unrestricted partition function $p(n)$ are well known and have been studied in great detail. $p(n,m)$ is the restricted partition function that enumerates the number of partitions of n into exactly m parts.

The close relationship between $p(n)$ and $p(n,m)$ is clear:

$$p(n)=p(n,1)+p(n,2)+\cdots+p(n,n-1)+p(n,n).$$

Let ℓ be any odd prime. The existence of several infinite families of Ramanujan-type congruences for $p(n,\ell)$ have recently been established for all prime power moduli and surprisingly for all n. In this talk we focus our attention not solely on n but on m, the number of parts for several intriguing results.

(Received September 09, 2011)

1077-11-674 **Carl Pomerance***, carl.pomerance@dartmouth.edu. *Elliptic Carmichael numbers.*

(This represents joint work with Aaron Ekstrom and Dinesh Thakur.) One hundred years ago, R. D. Carmichael discovered some composite numbers n that behave like primes with respect to the Fermat congruence; namely, $a^n\equiv a \pmod n$ for every integer a. The least example is $n=561$, and after joint work with W. R. Alford and A. Granville, we now know that there are infinitely many such n. In the 1980's, D. M. Gordon defined an analogue where the Fermat congruence is replaced with $[n+1]P\equiv O \pmod n$, with P an arbitrary rational point on an arbitrary CM elliptic curve with discriminant coprime to n. An example is $n = p(2p + 1)(3p + 2)$, where $p = 468{,}686{,}771{,}783$. We show, modulo a mild conjecture on the least prime in a residue class, that there are infinitely many of these elliptic Carmichael numbers. (Received September 09, 2011)

1077-11-687 **Khang D. Tran*** (khangdtran@gmail.com), 2105 Hazelwood Drive, Apt 304, Urbana, IL 61801. *Connections between discriminants and the root distribution of polynomials with rational generating functions.*

Let $H_m(z)$ be a sequence of polynomials and $D(z, t)$ be the denominator of its generating function $\sum_{m=0}^{\infty} H_m(z)t^m$. We show that in some cases, the roots of $H_m(z)$ are dense as $m \to \infty$ on some fixed arcs whose equations are explicitly given and whose endpoints are the roots of $\mathrm{Disc}_t D(z, t)$. The proofs involve the q-analogue of discriminant, a concept introduced by Mourad Ismail. (Received September 10, 2011)

1077-11-718 **Kristin Lauter** (klauter@microsoft.com) and **Bianca Viray*** (bviray@math.brown.edu). *An arithmetic intersection formula for denominators of Igusa class polynomials.* Preliminary report.

In this talk we will give an explicit formula for the arithmetic intersection number $\mathcal{CM}(K).\mathrm{G}_1$ on the Siegel moduli space of abelian surfaces, under some assumptions on the quartic CM field K. These intersection numbers allow one to compute the denominators of Igusa class polynomials, which has important applications to the construction of genus 2 curves for use in cryptography.

Bruinier and Yang conjectured a formula for intersection numbers on an arithmetic Hilbert modular surface, and, as a consequence, obtain a conjectural formula for $\mathcal{CM}(K).\mathrm{G}_1$ under strong assumptions on the ramification in K. Yang later proved this conjecture under slightly stronger assumptions on the ramification. In this paper, we prove a formula for $\mathcal{CM}(K).\mathrm{G}_1$ for a larger class of primitive quartic CM fields. We use a different method of proof than Yang; namely, we study the embedding problem posed by Goren and the first author by generalizing work of Dorman and Gross–Zagier. (Received September 11, 2011)

1077-11-777 **Ralph Greenberg**, **Karl Rubin**, **Michael Stoll** and **Alice Silverberg*** (asilverb@uci.edu), asilverb@uci.edu. *The rational points on a recalcitrant genus 12 curve.*

We use the method of Chabauty to determine exactly the set of rational points on the genus 12 curve

$$w^7 = (v^3 - 2v^2 - v + 1)/(v^3 - v^2 - 2v + 1).$$

This computation allowed us to show that the images of 7-adic representations of elliptic curves over $\mathbf{Q}$ with a rational subgroup of order 7 are always "as large as possible". The quest for the exact set of rational points took a circuitous route with some interesting twists and turns, and was helped by Bjorn Poonen, Jennifer Balakrishnan, Kiran Kedlaya, Michael Rubinstein, Andrew Sutherland, and Joseph Wetherell. (Received September 15, 2011)

1077-11-781 **George W Grossman*** (gross1gw@cmich.edu), Pearce Hall 217, Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859, and **Yifan Zhang** (zhang5y@cmich.edu), Depatment of Mathematics, Central Michigan University, Mount Pleasant, MI 48859. *Diophantine triples and quadruples.*

In this paper, we give the sufficient and necessary conditions, given integers a, b and c, that there exists integers n, α, β, γ such that $ab+n = \alpha^2$, $ac+n = \beta^2$ and $bc+n = \gamma^2$. The triple (a, b, c) having this property is called a Diophantine triple with property $D\,(n)$. Similarly, this definition can be extended for the quadruple (a, b, c, d). We will also discuss the existence of some special Diophantine triples and quadruples. (Received September 12, 2011)

1077-11-797 **Brendan Hassett**, Department of Mathematics MS 136, Rice University, 6100 S. Main St., Houston, TX 77005, and **Anthony Varilly-Alvarado*** (varilly@rice.edu), Department of Mathematics MS 136, Rice University, 6100 S. Main St., Houston, TX 77005. *Failure of the Hasse principle on general K3 surfaces.*

Transcendental elements of the Brauer group of an algebraic variety, i.e., Brauer classes that remain nontrivial after extending the ground field to an algebraic closure, are quite mysterious from an arithmetic point of view. These classes do not arise for curves or surfaces of negative Kodaira dimension. In 1996, Harari constructed the a 3-fold with a transcendental Brauer-Manin obstruction to the Hasse principle. Until recently, his example was the only one of its kind. We show that transcendental elements of the Brauer group of an algebraic *surface* can obstruct the Hasse principle. We construct a general K3 surface X of degree 2 over $\mathbb{Q}$, together with a two-torsion Brauer class α that is unramified at every finite prime, but ramifies at real points of X. Motivated by Hodge theory, the pair (X, α) is constructed from a double cover of $\mathbb{P}^2 \times \mathbb{P}^2$ ramified over a hypersurface of bi-degree $(2, 2)$. (Received September 12, 2011)

1077-11-858 **Bob Hough*** (`rdhough@math.stanford.edu`), 450 Serra Mall, Stanford, CA 94305.
Resonance method for large character sums.

We discuss adaptation of Soundararajan's 'resonance method' to the study of large character sums, considering

$$\Delta(N,q) = \sup_{\chi\neq\chi_0 \bmod q} |\sum_{n\leq N} \chi(n)|, \qquad (q \text{ large}).$$

The method streamlines and optimizes previous approaches, producing the best known lower bounds for this problem in most ranges of N. (Received September 13, 2011)

1077-11-880 **Terrence R Blackman*** (`tblackman@mec.cuny.edu`), c/o Department of Mathematics, Medgar Evers College, CUNY, 1638 Bedford Ave, Brooklyn, NY 11225. *On the Arithmetic and Geometry of Quaternion Algebras: a new spectral correspondence for Maass waveforms.*

Let $\mathcal{A}$ be an indefinite rational division quaternion algebra with discriminant d equal to pq where p and q are primes such that $p, q > 2$ and let $\mathcal{O}_{pq}$ be a maximal order in $\mathcal{A}$. Further, let $\mathcal{O}_{pq,p^{2r}q^{2s}}, r, s \geq 1$ be an order of index $p^{2r}q^{2s}$ in $\mathcal{O}_{pq}$ with Eichler invariant equal to negative one at p and at q . Finally, let $\mathcal{O}^1_{pq,p^{2r}q^{2s}}$ be the cocompact Fuchsian group given as the group of units of norm one in $\mathcal{O}_{pq,p^{2r}q^{2s}}$. Using the classical the Selberg trace formula, we show that the positive Laplace eigenvalues, including multiplicities, for Maass newforms on $\mathcal{O}^1_{pq,p^{2r}q^{2s}}$ coincides with the Laplace spectrum for Maass newforms defined on the Hecke congruence group $\Gamma_0(M)$ where, M, the level of the congruence group, is equal to $p^{2r+1}q^{2s+1}$, i.e., the discriminant of $\mathcal{O}_{pq,p^{2r}q^{2s}}$. (Received September 13, 2011)

1077-11-881 **David Harvey***, School of Mathematics and Statistics, University of New South Wales, Sydney, NSW 2052, Australia. *Faster deterministic integer factorization.*

The best known deterministic complexity bound for computing the prime factorization of an integer n is $O(M(n^{1/4}\log n))$, where $M(k)$ denotes the cost of multiplying k-bit integers. This result is due to Bostan–Gaudry–Schost, following the Pollard–Strassen approach. We show that this bound can be improved by a factor of $\sqrt{\log\log n}$. This is joint work with Edgar Costa (New York University). (Received September 13, 2011)

1077-11-899 **Jeffrey Beyerl*** (`jbeyerl@clemson.edu`), **Kevin James** and **Hui Xue**. *Divisibility of Eigenforms, and computing a function of the j-invariant.*

A modular form $f(z)$ may be written uniquely as $f(z) = \Delta(z)^a E_4(z)^b E_6(z)^c g(j(z))$ where j is the j-invariant. In this talk I will consider the divisibility of level 1 eigenforms and their relationship to $g(j(z))$. In particular I will give the relationship between the irreducibility of $g(j(z))$ and factorization of a corresponding eigenform. I will also present the computations I performed to show the irreducibility of $g(j(z))$ to higher weights. (Received September 14, 2011)

1077-11-939 **Mark Giesbrecht*** (`mwg@uwaterloo.ca`), Cheriton School of Computer Science, University of Waterloo, Waterloo, ON N2L 3G1, and **Joachim von zur Gathen** (`gathen@bit.uni-bonn.de`), B-IT, University of Bonn, D-53113, Bonn, Germany. *Counting decompositions of additive polynomials.*

We consider the problem of counting decompositions of r-additive (or linearized) polynomials over a finite field $\mathbb{F}_q$, for q a power of a prime power r. The r-additive polynomials in $\mathbb{F}_q[x]$ have the form $f = \sum_{0\leq i\leq d} f_i x^{r^i}$. We count the number of distinct functional decompositions of r-additive polynomials with a right component of degree r:

$$C(f) = \#\{a \in \mathbb{F}_q : \; f = g \circ (x^r + ax)\},$$
$$R(d) = \left\{C(f) : f \in \mathbb{F}_q[x] \text{ monic, squarefree, } r\text{-additive of degree } r^d\right\}.$$

We determine $R(d)$ for all d, and in particular $R(2) = \{0, 1, 2, r+1\}$ and $R(3) = \{0, 1, 2, 3, r+1, r+2, r^2+r+1\}$. For $R(2)$ this is consistent with the work of Bluher (2004), who also considers the inverse problem of finding formulas for the number of polynomials in each class. I.e., for given d find

$$A_i^{(d)} = \#\left\{f \in \mathbb{F}_q[x] \text{ monic, squarefree, } r\text{-additive of degree } r^d,\; C(f) = i\right\}.$$

Bluher gives formulas for $d = 2$. We demonstrate analogous formulae for $d = 3$, and discuss the problem for more general d. We also provide computable constructions and fast algorithms, requiring time polynomial in d and $\log q$. (Received September 14, 2011)

1077-11-961 **Reinier Broker*** (`reinier@math.brown.edu`), Brown University, Box 1917, 151 Thayer Street, Providence, RI 02912, and **Kristin Lauter**. *Evaluating Igusa functions.*

We investigate a new algorithm to evaluate Igusa functions by using Fourier coefficients of Siegel Eisenstein series. We give completely explicit bounds on the size of the Fourier coefficients, and show how to compute the

Fourier coefficients efficiently by using classical modular forms of half-integral weight. (Received September 14, 2011)

1077-11-1050 **Ryan Broderick**, **Lior Fishman** and **Dmitry Kleinbock*** (kleinboc@brandeis.edu), 450 South Street, Waltham, MA 02454, and **Asaf Reich** and **Barak Weiss**. *Intersection property of fractals via Schmidt games.*

We prove that the countable intersection of diffeomorphic images of certain Diophantine sets has full Hausdorff dimension. For example, we show this for the set of badly approximable vectors in $\mathbf{R}^d$. This is done using a new variant of Schmidt's (α, β)-game and showing that our sets are hyperplane absolute winning (HAW). The HAW property passes automatically to games played on certain fractals, thus our sets intersect a large class of fractals (those we call hyperplane-diffuse) in a set of positive dimension. This extends earlier results of Fishman to a more general set-up, with simpler proofs. (Received September 15, 2011)

1077-11-1059 **Jordan Schettler*** (jschettler@math.arizona.edu). *Cyclic p-Extensions of $\mathbb{Z}_p$-Fields.*

Kida and Iwasawa proved number theoretic analogs of the Riemann-Hurwitz formula where the lambda invariant of a $\mathbb{Z}_p$-field plays the role of (twice) a genus of a curve. We can derive special formulas in the case of cyclic p-extensions of $\mathbb{Z}_p$-fields which yield extra information about lambda invariants that cannot be gleaned from the previously known formulas. (Received September 15, 2011)

1077-11-1068 **Eva Kinoshita Belmont** (ebelmont@fas.harvard.edu), **Sarah Trebat-Leder*** (strebat@math.princeton.edu), **Alexandra Musat** (amusat@caltech.edu) and **Holden Lee** (holden1@MIT.EDU). *ℓ-adic Properties of Partition Functions.*

In 2010, Folsom, Kent, and Ono used the theory of modular forms modulo ℓ to give an overarching explanation of many partition congruences. We generalize their work to analyze powers p_r of the partition function as well as Andrews' *spt*-function. By showing that certain generating functions reside in a small space made up of reductions of modular forms, we set up a general framework for congruences for p_r and *spt* on arithmetic progressions of the form $\ell^m n + \delta$ modulo powers of ℓ. Our work gives a conceptual explanation of exceptional congruences of p_r observed by Boylan in 2004, as well as striking congruences of *spt* modulo 5, 7, and 13 recently discovered by Andrews and Garvan. (Received September 16, 2011)

1077-11-1082 **A Johnston*** (jannaston@gmail.com), 2003 Smith Ave, Baltimore, MD 21209. *Exponential Hensel Lifting.*

Traditional Hensel lifting finds roots for polynomials modulo p^n given its roots modulo p, where p is a prime integer. In other words, given $f(x) \in \mathbb{Z}[x]$, $r_1 \in \mathbb{Z}/(p)$ such that $f(r_1) \equiv 0 \bmod p$, and an integer $n > 1$, Hensel lifting finds $r_n \in \mathbb{Z}/(p^n)$ such that $f(r_n) \equiv 0 \bmod p^n$.

This talk describes an exponential version of Hensel lifting. It details a method for finding discrete logarithms modulo p^n given a discrete log modulo p: Given $\gamma, \sigma \in \mathbb{Z}$, $a_1 \in \mathbb{Z}/(p-1)$ such that $\gamma^{a_1} \equiv \sigma \bmod p$, and an integer $n > 1$, exponential Hensel lifting returns a_n such that $\gamma^{a_n} \equiv \sigma \bmod p^n$. (Received September 16, 2011)

1077-11-1104 **Phong Le*** (ple@niagara.edu), Niagara University, Mathematics Department, Lewiston, NY 14109. *On the Dimension of Algebro-Geometric Trace Codes.*

Algebraic-Geometric (AG) codes arise form the evaluation of the elements of an $\mathbb{F}_{q^m}$-vector space of function is a set of $\mathbb{F}_{q^m}$ rational points on a curve X. We shall consider trace codes associated to algebraic-geometric codes. Conditions will be derived where one can determine the exact dimension of such codes. This is a generalization of work done by Van Der Vlugt. (Received September 16, 2011)

1077-11-1155 **James Henry Stankewicz*** (stankewicz@gmail.com). *Twists of Shimura Curves.*

We describe some techniques for determining if Atkin-Lehner twists of Shimura curves (and thus Atkin-Lehner twists of classical modular curves) have rational points. (Received September 16, 2011)

1077-11-1192 **Meghan M De Witt*** (mdewitt1@uco.edu), Edmond, OK. *The Inverse Galois Problem and Minimal Ramification over Function Fields.*

The Inverse Galois Problem is concerned with finding an extension of a given field K having a given Galois group. Here we consider the particular case where the base field is $K = \mathbb{F}_p(t)$. We give a conjectural formula for the minimal number of primes, both finite and infinite, ramified in G-extensions of K, and give theoretical and computational proofs for many cases of this conjecture. (Received September 17, 2011)

1077-11-1200 **Kirsten Eisentraeger***, Department of Mathematics, The Pennsylvania State University, University Park, PA 16802. *Hilbert's Tenth Problem for function fields of positive characteristic.*

Hilbert's Tenth Problem in its original form was to find an algorithm to decide, given a multivariate polynomial equation with integer coefficients, whether it has a solution over the integers. In 1970 Matijasevich, building on work by Davis, Putnam and Robinson, proved that no such algorithm exists, i.e. Hilbert's Tenth Problem is undecidable. Since then, analogues of this problem have been studied by asking the same question for polynomial equations with coefficients and solutions in other commutative rings. In this talk we will discuss some recent results for function fields of positive characteristic, both for transcendence degree one and higher transcendence degree. (Received September 17, 2011)

1077-11-1202 **Kirsten Eisentraeger***, Department of Mathematics, The Pennsylvania State University, University Park, PA 16802. *Turing's work and Hilbert's Tenth Problem.*

In 1900 Hilbert presented his now famous list of 23 open problems. The tenth problem in its original form was to find an algorithm to decide, given a multivariate polynomial equation with integer coefficients, whether it has a solution over the integers. Hilbert's Tenth Problem remained open until 1970 when Matijasevich, building on work by Davis, Putnam and Robinson, proved that no such algorithm exists, i.e. Hilbert's Tenth Problem is undecidable. In this talk we will discuss the work on Hilbert's Tenth Problem and connections to Alan Turing's work. (Received September 17, 2011)

1077-11-1228 **Benjamin Hutz** (`bhutz@gc.cuny.edu`), Ph.D. Program in Mathematics, Graduate Center of CUNY, 365 Fifth Avenue, New York, NY 10016, and **Michael Tepper*** (`mlt16@psu.edu`), Division of Science and Engineering, Penn State Abington, 1600 Woodland Road, Abington, PA 19001. *Multiplier Spectra and the Moduli Space of Degree 3 Morphisms on $\mathbb{P}^1$.*

The moduli space of degree d morphisms on $\mathbb{P}^1$ has been studied a great deal. McMullen showed that there is a finite-to-one correspondence (over $\mathbb{C}$) between classes of morphisms in the moduli space and the multipliers of the periodic points. For degree 2 morphisms Milnor (over $\mathbb{C}$) and Silverman (over $\mathbb{Z}$) showed that the correspondence is an isomorphism. Here we will analyze the two cases: polynomial maps of any degree and rational maps of degree 3. (Received September 18, 2011)

1077-11-1233 **Katherine E Stange*** (`stange@math.stanford.edu`). *Integral points on elliptic curves and explicit valuations of division polynomials.*

Assuming Lang's conjectured lower bound on the heights of non-torsion points on an elliptic curve, we show that there exists an absolute constant C such that for any elliptic curve $E/\mathbb{Q}$ and non-torsion point P in $E(\mathbb{Q})$, there is at most one integral multiple $[n]P$ such that $n > C$. The proof is a modification of a proof of Ingram giving an unconditional but not uniform bound. The new ingredient is a collection of explicit formulae for the sequence of valuations of the division polynomials. For P of non-singular reduction, such sequences are already well described in most cases, but for P of singular reduction, we are led to define a new class of sequences called elliptic troublemaker sequences, which measure the failure of the Néron local height to be quadratic. (Received September 18, 2011)

1077-11-1267 **Joseph H. Silverman** (`joseph_silverman@brown.edu`) and **Katherine E. Stange*** (`stange@math.stanford.edu`). *A dynamical system for elliptic divisibility sequences.*

Consider any integer divisibility sequence $(D_n)_{n\geq 1}$ (i.e integer sequence satisfying $n \mid m \implies D_n \mid D_m$) with the property that every prime number eventually appears as a divisor in the sequence. Define a map $\phi : \mathbb{Z}^{>0} \to \mathbb{Z}^{>0}$ defined by

$$\phi(n) = \min_{k>0}\{D_k \equiv 0 \pmod{n}\}.$$

Consider the dynamical system given by forward iteration of this map. Cycles of this system are called *aliquot cycles*. We consider the case of elliptic divisibility sequences, a class of divisibility sequences associated to elliptic curves. The study of aliquot cycles leads to a characterisation of the set $S(D)$ of indices n satisfying $n|D_n$. In particular, given an index n in $S(D)$, we explain how to construct elements nd in $S(D)$, where d is either a prime divisor of D_n, or d is a product of primes forming an aliquot cycle for D. We draw a connection to the definition of an *amicable pair* for an elliptic curve $E/\mathbb{Q}$: a pair of primes (p, q) of good reduction for E satisfying $\#E(\mathbb{F}_p) = q$ and $\#E(\mathbb{F}_q) = p$. (Received September 18, 2011)

1077-11-1268 **Zev Klagsbrun*** (klagsbru@math.wisc.edu), Dept. of Mathematics, 480 Lincoln Dr., 313 Van Vleck Hall, Madison, WI 53703. *The Distribution of 2-Selmer Ranks of Quadratic Twists of Elliptic Curves.*

Given an elliptic curve E defined over a number field K, we can ask what proportion of quadratic twists of E have 2-Selmer rank r for any non-negative integer r. The Delaunay heuristics combined with work of Dokchitser and Dokchitser suggested a conjecture for this distribution that was verified by work of Heath-Brown, Swinnerton-Dyer, and Kane for elliptic curves over $\mathbb{Q}$ with $E(\mathbb{Q})[2] \simeq \mathbb{Z}/2\mathbb{Z} \times \mathbb{Z}/2\mathbb{Z}$. We present new results for elliptic curves with $E(K)[2] = 0$ and with $E(K)[2] \simeq \mathbb{Z}/2\mathbb{Z}$. I will present joint work of Mazur, Rubin, and myself supporting the conjecture for curves with $E(K)[2] = 0$. Additionally, I will present some new results of my own for curves with $E(K)[2] \simeq \mathbb{Z}/2\mathbb{Z}$, including some surprising results that conflict with the conjecture. (Received September 18, 2011)

1077-11-1289 **Dragos Ghioca** and **Liang-Chung Hsia** (tjtucker@gmail.com), Rochester, New York, and **Thomas J Tucker*** (tjtucker@gmail.com), Department of Mathematics, University of Rochester, Rochester, NY 14627. *Towards a dynamical relative Manin-Mumford conjecture.*

Let f_l be a family of polynomials over the complex numbers, with l varying, subject to certain hypotheses. Let a_l and b_l be two families of points with l varying. We show that if there are infinitely many choices of complex z such that a_z and b_z are both preperiodic for f_z, then a_z and b_z satisfy a very simple relation. This can be interpreted geometrically as a dynamical variant of the relative Manin-Mumford conjecture for families of semiabelian varieties. The techniques here follow work of Baker, DeMarco, Masser, and Zannier. (Received September 18, 2011)

1077-11-1290 **Jing-Jing Huang*** (huang@math.psu.edu), Department of Mathematics, 012 McAllister Building, State College, PA 16802. *Counting the number of solutions to the Erdős-Straus-Schinzel equation and related problems.*

In this talk, we are mainly concerned with the Diophantine equation

$$\frac{a}{n} = \frac{1}{x_1} + \frac{1}{x_2} + \cdots + \frac{1}{x_k}$$

and its number of positive integer solutions $R_k(n;a)$. We begin with the binary case $k = 2$, more precisely, we will investigate the distribution of the function $R_2(n;a)$. By averaging over n, we study the first moment and second moment behaviors of $R_2(n;a)$. For instance, one of our results is

$$\sum_{\substack{n \le N \\ (n,a)=1}} R_2(n;a) = NP_2(\log N;a) + O_a(N \log^5 N),$$

where $P_2(\cdot;a)$ is a quadratic function whose coefficients depend on a. Furthermore, we show that, after normalisation, $R_2(n;a)$ satisfies Gaussian distribution, which is an analog of the Erdős-Kac theorem.

On the other hand, let $E_a(N)$ denote the number of $n \le N$ such that $R_2(n;a) = 0$. We will establish that when $a \ge 3$

$$E_a(N) \sim C(a) \frac{N(\log\log N)^{2^{m-1}-1}}{(\log N)^{1-1/2^m}},$$

with m defined in the talk.

The next project would be to study the ternary case $k = 3$. While the conjectured, by Erdős, Straus and Schinzel, that for fixed $a \ge 4$, we have $R_3(n;a) > 0$ when n is sufficiently large, is still wide open, here we will try to understand the mean value $\sum_{n \le N} R_3(n;a)$ and give some interesting results. (Received September 18, 2011)

1077-11-1295 **Wei Ho***, Columbia University, Dept. of Mathematics, New York, NY 10027. *Some Explicit Moduli Spaces of Elliptic Curves and Generalizations.* Preliminary report.

We give a survey of results and work-in-progress on explicit descriptions of certain moduli spaces related to elliptic curves, abelian varieties, and higher-dimensional Calabi-Yau varieties. In each case, the appropriate geometric objects (over arbitrary base fields) may be parametrized by orbits of representations of algebraic groups. In particular, understanding the rational points of these moduli spaces leads to arithmetic applications. (Received September 19, 2011)

1077-11-1325 **Alexandra Shlapentokh*** (shlapentokha@ecu.edu), Department of Mathematics, East Carolina University, Greenville, NC 27858. *Extensions of a Kim and Roush Result to Algebraic Fields.* Preliminary report.

In 1992, K. Kim and F. Roush showed Diophantine undecidability of any rational function field of odd characteristic over fields of constants algebraic over a finite field and not containing its algebraic closure. In other words, it was shown that over these fields, there is no algorithm to determine whether a polynomial equation in several variables has a solution in the field. In 2000 this result was extended by the author to some algebraic extensions of rational functions fields of odd characteristic, including the ones with a constant field algebraic over a finite field. However, the results covered only the fields where the algebraic closure of a finite field had an extension of degree equal to the characteristic. An analogous result for the even characteristic was proven by K. Eisentraeger in 2003. In this talk we discuss the progress which has been made towards the full generalization of the Kim and Roush result to algebraic extensions, i.e. to any function field of positive characteristic not containing the closure of a finite field. (Received September 19, 2011)

1077-11-1414 **Randy J Heaton***, randy.heaton@gmail.com. *Computing Intersections of Abelian Varieties Associated to Modular Forms.*

We present an algorithm to compute the order of intersection between certain abelian varieties associated to spaces of modular forms. We describe how these orders relate to congruence numbers and the conjecture of Birch and Swinnerton-Dyer. (Received September 19, 2011)

1077-11-1453 **Bogdan Petrenko*** (bpetrenk@brockport.edu), Department of Mathematics, SUNY Brockport, 350 New Campus Drive, Brockport, NY 14420, and **Marcin Mazur**, Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902. *Generalizations of V.I. Arnold's version of Euler's Theorem for matrices.*

In this talk I will explain some extensions of V.I. Arnold's version of Euler's Theorem for matrices that M. Mazur and I have recently obtained. This talk will be based based on the following our joint papers in the Japanese Journal of Mathematics: Vol. 5, Issue 2 (2010) pp. 183-189, and Vol. 6, Issue 1 (2011) pp. 63-64. (Received September 19, 2011)

1077-11-1469 **Jeffrey C . Lagarias*** (lagarias@umich.edu), 530 Church Street, Ann Arbor, MI 48109-1043. *Fractal structures in functions related to number theory.*

Benoit Mandelbrot changed the perception of foreground and background in mathematics and physics, showing the ubiquitous presence of fractal structures in many structural theories. We will discuss some examples coming from functions having connections to number theory: The Takagi function, space-filling curves, and iterating (3x+1)-like maps. (Received September 19, 2011)

1077-11-1516 **Lois Simon*** (simon.lois@gmail.com). *Character sums and hyperelliptic curves associated with subsets of finite fields with square order.*

In this work we will work in finite fields $\mathbb{F}_{q^2}$ where$q = p^n$for some prime$p$. We will work with hyperelliptic curves denotedY_S: $y^2 = f_S(x = \prod_{s\in S}(x-s)$where$S \subset \mathbb{F}_{q^2}$;$X_S$represents the non-singular projective model ofY_S. We utilize the Hasse-Weil bound $|X_S(\mathbb{F}_{q^2}) - (q^2+1)| \leq 2gq$ and$\Lambda(S) = \sum_{b\in\mathbb{F}_{q^2}} \chi(f_S(b)) = |Q_S| - |Q'_S|$, as we try to determine when X_S is maximal, minimal and/or optimal. We say X_S is maximal if the upper Hasse-Weil bound is achieved and if

$$|X_S(\mathbb{F}_{q^2})| = \begin{cases} 1+q^2+q(|S|-1) & \text{if } |S| \text{ is odd,} \\ 1+q^2+q(|S|-2) & \text{if } |S| \text{is even.} \end{cases}$$

We say X_S is minimal if the lower Hasse-Weil bound is reached and if

$$|X_S(\mathbb{F}_{q^2})| = \begin{cases} 1+q^2-q(|S|-1) & \text{if } |S| \text{ is odd,} \\ 1+q^2-q(|S|-2) & \text{if } |S| \text{ is even.} \end{cases}$$

Finally we say X_S is optimal if $\Lambda(S) = q^2 - |S|$. There is an overlap of maximal curves and minimal curves; there is also an overlap between maximal curves and optimal curves. In particular maximal sets, S,and their associated maximal curves X_S are useful in coding theory. (Received September 20, 2011)

1077-11-1566 **Pieter Rozenhart** and **Jonathan Webster*** (jwebster@bates.edu), 3 Andrews Road, Lewiston, ME 04240. *Simple Cubic Function Fields.*

In this talk, we study simple cubic fields in the function field setting, and also generalize the notion of a set of exceptional units to cubic function fields, namely the notion of k-exceptional units. We give a simple proof that the Galois simple cubic function fields are the immediate analog of Shanks simplest cubic number fields. We prove that a unit arising as a root of the polynomial is a fundamental unit. In addition to computing the invariants, including a formula for the regulator, we compute the class numbers of the Galois simple cubic function fields over $\mathbb{F}_5$ and $\mathbb{F}_7$. Finally, as an additional application, we determine all Galois simple cubic function fields with class number one, subject to a mild restriction. (Received September 20, 2011)

1077-11-1573 **Geoffrey Caveney**, **Jean-Louis Nicolas** and **Jonathan Sondow*** (jsondow@alumni.princeton.edu). *Robin's theorem, primes, and a new elementary reformulation of the Riemann Hypothesis.*

Let $\sigma(n)$ denote the sum of the divisors of n, and for $n > 1$ set

$$G(n) := \frac{\sigma(n)}{n \log \log n}.$$

In 1913 Gronwall found that the maximal order of G is $\limsup_{n\to\infty} G(n) = e^{\gamma}$, where γ is Euler's constant. In 1915 Ramanujan proved that if the Riemann Hypothesis (RH) is true, then $G(n) < e^{\gamma}$ for all large n. In 1984 Robin sharpened this by showing that

$$\text{RH} \iff G(n) < e^{\gamma} \quad (n > 5040).$$

In 2011 Geoffrey Caveney, Jean-Louis Nicolas, and I used Robin's theorem to prove that *the RH holds if and only if* 4 *is the only composite number* N *satisfying*

$$G(N) \geq \max\left(G(N/p), G(aN)\right)$$

for all prime factors p *of* N *and all multiples* aN *of* N. An alternate proof of one step depends on two properties of superabundant numbers derived from those of Alaoglu and Erdős in 1944. (Received September 20, 2011)

1077-11-1587 **Helen G. Grundman*** (grundman@brynmawr.edu) and **Laura L. Hall-Seelig**. *Solutions to $xyz = 1$ and $x + y + z = k$ in Integers in Cubic Number Fields.* Preliminary report.

Focusing on algebraic integers in fields of degree three over $\mathbf{Q}$, we consider the problem of finding all solutions to the system of equations

$$xyz = 1 \qquad \text{and} \qquad x + y + z = k$$

for various values of $k \in \mathbf{Z}$. Adapting the methods used by Andrew Bremner for the case where $k = 1$, we translate the problem to one of finding points on a related elliptic curve E_k and solve the problem completely for all k for which $E_k(\mathbf{Q})$ is finite. (Received September 20, 2011)

1077-11-1588 **Helen G. Grundman** and **Laura L. Hall-Seelig*** (hallseeligl@merrimack.edu). *Integer Solutions to $xyz = 1$ and $x + y + z = k$ in Number Fields of Degree at Most Four.* Preliminary report.

For fixed $k \in \mathbf{Z}$, we consider the problem of finding all solutions to the system of equations

$$xyz = 1 \qquad \text{and} \qquad x + y + z = k$$

with x, y, z algebraic integers in fields of degree at most four over $\mathbf{Q}$. Restricting to the values of k for which a related elliptic curve has a finite group of rational points, we find all points on the curve with coordinates in quadratic fields (not necessarily integers) and, as a corollary, solve the problem for degree 2 and these values of k. We then use these results to find solutions to the given equations in integers in quartic fields. (Received September 20, 2011)

1077-11-1592 **Shahed Sharif*** (ssharif@csusm.edu), Dept. of Mathematics, CSU San Marcos, 333 S. Twin Oaks Valley Road, San Marcos, CA 92096. *A descent map for curves with totally degenerate semi-stable reduction.*

Given a suitably nice algebraic curve C defined over a nonarchimedean local field with residue characteristic p, such that C has totally degenerate semi-stable reduction, the reduction of the Jacobian J of C is known to be an extension of a finite group by an arithmetic torus. Using arithmetic on the special fiber of C, we show how to compute the group of rational torsion points on J with prime-to-p order, and determine the rationality of theta characteristics and higher spin structures on C. As an example, we will consider a family of nonhyperelliptic genus 4 curves. (Received September 20, 2011)

1077-11-1609 **Hafedh Herichi** and **Michel L. Lapidus*** (lapidus@math.ucr.edu). *Fractal Strings, the Riemann Hypothesis, Universality and Phase Transitions.*

In the first part of our joint memoir in preparation with Hafedh Herichi, we provide a precise functional analytic framework for studying the spectral operator $a = a_c$, acting on the class of generalized fractal strings of a given dimension c, as introduced semi-heuristically by M. van Frankenhuijsen and the presenter in their 2006 Springer research monograph. After having defined the spectral operator a (and its T-truncations $a - T$) as a suitable meromorphic function of the infinitesimal shift of the real line, we determine its spectrum (and that of $a - T$).

We deduce that the Riemann hypothesis is true if and only if the spectral operator a_c is quasi-invertible (i.e., each truncation $a - T$ is invertible) for every c other than $1/2$. Using results concerning the universality of the Riemann zeta function, we also show that the spectral operator is invertible for $c > 1$, not invertible for $1/2 < c < 1$, and conditionally (i.e., under the Riemann hypothesis), is invertible for $0 < c < 1/2$. Furthermore the spectrum of a_c is bounded for $c > 1$, the entire complex plane $\mathbf{C}$ for $1/2 < c < 1$, and unbounded but conditionally, not all of $\mathbf{C}$, for $0 < c < 1/2$. We therefore establish that several types of phase transitions occur at $c = 1/2$ and at $c = 1$. (Received September 20, 2011)

1077-11-1619 **Andrew Granville*** (`andrew@dms.umontreal.ca`), Département de mathématiques, Université de Montréal, CP 6128 succ. Centre-Ville, Montréal, Quebec H3C 3J7,, Canada. *The latest pretensions.* Preliminary report.

We will discuss some recent developments in the pretentious approach to analytic number theory (Received September 20, 2011)

1077-11-1703 **Benjamin Hutz*** (`bhutz@gc.cuny.edu`), **Robert L Benedetto**, **Dragos Ghioca**, **Par Kurlberg**, **Thomas Scanlon** and **Thomas J Tucker**. *Periods of rational maps modulo primes.*

Let K be a number field, let $\varphi \in K(t)$ be a rational map of degree at least 2, and let $\alpha, \beta \in K$. In [BGHKST] we showed that if α is not in the forward orbit of β, then there is a positive proportion of primes $\mathfrak{p}$ of K such that $\alpha \mod \mathfrak{p}$ is not in the forward orbit of $\beta \mod \mathfrak{p}$. In this talk, we present heuristic and numerical evidence that a higher dimensional analog of this result is unlikely to be true if we replace α by a hypersurface, such as the ramification locus of a morphism $\varphi : \mathbb{P}^n \to \mathbb{P}^n$. This provides evidence that the strategy outlined in [BGKT11] for the cyclic case of the dynamical Mordell-Lang conjecture will not succeed for $n > 4$. (Received September 20, 2011)

1077-11-1705 **Avram M. Gottschlich*** (`avram.gottschlich@dartmouth.edu`), 6188 Kemeny Hall, Dartmouth College, Hanover, NH 03755. *On positive integers n dividing the nth term of an elliptic divisibility sequence.*

Elliptic divisibility sequences are integer sequences related to the denominator of the first coordinate of the n-fold sum of a non-torsion rational point on an elliptic curve. Silverman and Stange recently studied those integers n dividing D_n, where $\{D_n\}$ is an elliptic divisibility sequence. Here we discuss the distribution of these numbers n. (Received September 20, 2011)

1077-11-1733 **Hannah Alpert*** (`hcalpert@math.mit.edu`). *Differences of multiple Fibonacci numbers.*

We show that every integer can be written uniquely as a sum of Fibonacci numbers and their additive inverses, such that every two terms of the same sign differ in index by at least 4 and every two terms of different sign differ in index by at least 3. Furthermore, there is no way to use fewer terms to write a number as a sum of Fibonacci numbers and their additive inverses. This is an analogue of the Zeckendorf representation. (Received September 20, 2011)

1077-11-1736 **Enrique Trevino*** (`etrevin1@swarthmore.edu`), 510 Elm Ave, Swarthmore, PA 19081. *On the maximum number of consecutive integers on which a character is constant.*

Let χ be a non-principal Dirichlet character to the prime modulus p. In 1963, Burgess showed that the maximum number of consecutive integers H for which χ remains constant is $O(p^{1/4} \log p)$. This is the best known asymptotic upper bound on this quantity. Recently, McGown proved an explicit version of Burgess's theorem, namely that $H < 7.06\, p^{1/4} \log p$ for $p \geq 5 \cdot 10^{18}$. By improving an inequality of Burgess on character sums and using some ideas of Norton, we were able to improve the result to $H < 1.55\, p^{1/4} \log p$ whenever $p \geq 2.5 \cdot 10^9$, and $H < 3.64\, p^{1/4} \log p$ for all p. (Received September 20, 2011)

1077-11-1742 **Youness Lamzouri*** (`lamzouri@math.uiuc.edu`), University of Illinois at Urbana-Champaign, Department of Mathematics, Urbana, IL 61801, and **Leo Goldmakher**, Department of Mathematics, University of Toronto, Toronto, On M5S 2E4, Canada. *Large odd order character sums.*

In 1932, Paley showed that there are infinitly many quadratic characters $\chi \bmod q$ whose character sums get as large as $\sqrt{q} \log \log q$. This lower bound is optimal, in view of an upper bound of the same order proved by Montgomery and Vaughan under the assumption of the Generalized Riemann Hypothesis GRH. In this talk, I will show how to obtain omega results for odd order character sums which are best possible, unconditionally. Previously, such bounds were only known under the assumption of the GRH. This is a joint work with Leo Goldmakher. (Received September 20, 2011)

1077-11-1753 **Aaron Levin***, Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Siegel's Theorem and the Shafarevich Conjecture.* Preliminary report.

It is known that in the case of hyperelliptic curves the Shafarevich conjecture can be made effective, i.e., for any number field k and any finite set of places S of k, one can effectively compute the set of isomorphism classes of hyperelliptic curves over k with good reduction outside S. We show that an extension of this result to an effective Shafarevich conjecture for *Jacobians* of hyperelliptic curves of genus g would imply an effective version of Siegel's theorem for integral points on hyperelliptic curves of genus g. (Received September 20, 2011)

1077-11-1757 **Alejandra Alvarado*** (alvaraa@math.purdue.edu), Purdue University, Department of Mathematics, 150 N. University Street, West Lafayette, IN 47907, and **Edray Herbert Goins**. *Arithmetic Progressions in the x-coordinates on Mordell Curves.*

An arithmetic progression (AP) is a sequence of numbers such that the difference between any two consecutive numbers is constant. When we talk about an AP on the curve $y^2 = x^3 + k$, we mean an AP in the x-coordinates. The goal of this talk is to classify length three, four, and five AP's. We show that there exist AP's of length three, four, or five if and only if there there exist rational points on a surface whose fibers are curves of genus zero, one or five, respectively. (Received September 20, 2011)

1077-11-1759 **Bo-Hae Im*** (bohaeim@gmail.com), Dept. of Mathematics, Chung-Ang University, 221 Heukseok-dong, Dongjak-gu, Seoul, Seoul, Seoul 156-756, South Korea, and **Michael Larsen** (larsen@math.indiana.edu), Indiana University, Bloomington, Bloomington, IN. *Infinite rank of elliptic curves over the maximal abelian extension of Q.*

We prove that if E is an elliptic curve defined over a quadratic field K, and the j-invariant of E is not 0 or 1728, then $E(\mathbb{Q}^{ab})$ has infinite rank. Also we prove that if E is an elliptic curve in Legendre form, $y^2 = x(x-1)(x-\lambda)$, where $\mathbb{Q}(\lambda)$ is a cubic field, then $E(K\mathbb{Q}^{ab})$ has infinite rank. (Received September 20, 2011)

1077-11-1766 **Chad Awtrey*** (cawtrey@elon.edu). *Dihedral p-adic fields.*

An important problem in constructive class field theory is to classify all finite extensions of the p-adic numbers by computing important invariants which define each extension. One important invariant is the number of nonisomorphic extensions of a specified degree and Galois group. We consider the case when the degree is a prime q and the Galois group is D_q, the dihedral group of order $2q$. (Received September 20, 2011)

1077-11-1772 **Tim Huber*** (hubertj@utpa.edu), University of Texas - Pan American, Edinburg, TX 78539, and **Richard Charles** and **Andoni Mendoza**. *Symmetric parameterizations for quintic Eisenstein series.*

In his Lost Notebook, Ramanujan gave product expansions for a pair of weight-two Eisenstein series of level five. We demonstrate that Ramanujan's formulas are special cases of more general paramaterizations for quintic Eisenstein series. In particular, the Eisenstein series for the Hecke subgroup of level five are expressible as homogenous polynomials in two parameters closely connected with the Rogers-Ramanujan continued fraction. Moreover, the coefficients of each polynomial are symmetric in absolute value about the middle terms. Corresponding polynomial expansions for for allied series, including Eisenstein series on the full modular group, are also derived. (Received September 20, 2011)

1077-11-1778 **Adam C. McDougall*** (mcdougal@stolaf.edu) and **Nathan Bishop** (bishop@stolaf.edu). *Rational Density.* Preliminary report.

Inspired by the question, "how would one pick a rational number at random?", we use what's known about natural density (asymptotic density of the natural numbers) and its generalizations to define 'rational density' (asymptotic density of the rational numbers).

Directly computing the rational density of a set is quite difficult because it necessarily involves infinite sums of the Euler totient function. Instead, we use a correspondence theorem to compute densities and attain some satisfying results. (Received September 20, 2011)

1077-11-1786 **Robert A Styer*** (robert.styer@villanova.edu), Department of Mathematics and Statistics, 800 Lancaster Avenue, Villanova, PA 19085. *Number of solutions in nonnegative integers x and y to the generalized Pillai equation $\pm ra^x \pm sb^y = c$.* Preliminary report.

We consider N, the number of solutions (x, y, u, v) to the equation $(-1)^u ra^x + (-1)^v sb^y = c$ in nonnegative integers x, y and integers $u, v \in \{0, 1\}$, for given integers $a > 1$, $b > 1$, $c > 0$, $r > 0$ and $s > 0$. There are nine essentially distinct (a, b, c, r, s) with $N \geq 4$. The proof uses linear forms in logarithms to give bounds on a and b of $8 \cdot 10^{14}$, then a combination of LLL basis reduction, bootstrapping, and expansions of the exponents allow us to eliminate the remaining possibilities. We note that $N = 3$ for an infinite number of (a, b, c, r, s). Our work differs from previous work in that we allow x and y to be zero and also allow choices of (u, v) other than $(0, 1)$. This is joint work with Reese Scott. (Received September 20, 2011)

1077-11-1829 **Rachel Pries*** (pries@math.colostate.edu) and **Douglas Ulmer** (ulmer@math.gatech.edu). *Mordell-Weil groups via Artin-Schreier extensions.*

We study the Mordell-Weil groups of Jacobians of curves defined over rational function fields of positive characteristic. Under certain conditions, we show that the rank of the Mordell-Weil group can be arbitrarily large by using Artin-Schreier theory to study the order of vanishing of L-functions. In other situations, we give a formula for the rank in terms of the endomorphism ring of a companion Jacobian. The proof uses an Artin-Schreier variant of Berger's construction of surfaces dominated by a product of curves in towers. (Received September 21, 2011)

1077-11-1833 **Lenny Jones*** (lkjone@ship.edu), Department of Mathematics, Shippensburg University, Shippensburg, PA 17257. *Polynomial Cunningham Chains.*

A sequence of prime numbers $p_1, p_2, p_3, \ldots$, such that $p_i = 2p_{i-1} + 1$ for all i, is called a *Cunningham chain.* If k is the smallest positive integer such that $2p_k + 1$ is composite, then we say the chain has length k. It is conjectured that there are infinitely many Cunningham chains of length k for every positive integer k. A sequence of polynomials $f_1(x), f_2(x), \ldots$ in $\mathbb{Z}[x]$, such that $f_1(x)$ has positive leading coefficient, each $f_i(x)$ is irreducible in $\mathbb{Q}[x]$, and $f_i(x) = xf_{i-1}(x) + 1$ for all i, is defined to be a *polynomial Cunningham chain.* If k is the least positive integer such that $xf_k(x) + 1$ is reducible in $\mathbb{Q}[x]$, then we say the chain has length k. We prove that there are infinitely many polynomial Cunningham chains of length k for every positive integer k, and that there are infinitely many polynomial Cunningham chains of infinite length. (Received September 21, 2011)

1077-11-1854 **Jared S Weinstein*** (jsweinst@bu.edu), Jared Weinstein, Dept. of Mathematics and Statistics, Boston University, Boston, MA 02115. *A variety with many points over a finite field.*

This is joint work with Mitya Boyarchenko. We construct a special hypersurface X over a finite field, which has the property of "maximality", meaning that it has the maximum number of rational points relative to its topology. Our variety is derived from a certain unipotent algebraic group, in an analogous manner as Deligne-Lusztig varieties are derived from reductive algebraic groups. As a consequence, the cohomology of X can be shown to realize a piece of the local Langlands correspondence for certain wild Weil parameters of low conductor. (Received September 21, 2011)

1077-11-1861 **David Zureick-Brown*** (david.zureick.brown@gmail.com), 628 W. College Ave., Decatur, GA 30030. *Rigid cohomology for algebraic stacks.*

Rigid cohomology is one flavor of Weil cohomology. This entails for instance that one can associate to a scheme X over $\mathbb{F}_p$ a collection $H^i(X)$ of finite dimensional $\mathbb{Q}_p$-vector spaces (and variants with supports in a closed subscheme or compact support), which enjoy lots and lots of nice properties (e.g. functoriality, excision, Gysin, duality, a trace formula – basically everything one needs to give a proof of the Weil conjectures).

Classically, the construction of rigid cohomology is a bit complicated and requires many choices, so that proving things like functoriality (or even that it is well defined) are theorems in their own right. An important recent advance is the construction by le Stum of an 'Overconvergent site' which computes the rigid cohomology of X. This site involves no choices and so it trivially well defined, and many things (like functoriality) become transparent.

In this talk I'll explain a bit about classical rigid cohomology and the overconvergent site (beginning with an exposition of characteristic 0 analogues), and explain some new work generalizing rigid cohomology to algebraic stacks (as well as why one would want to do such a thing). (Received September 21, 2011)

1077-11-1884 **Fedor A Bogomolov*** (bogomolo@cims.nyu.edu), 2 Washington Square Village 16 R, New York, NY 10012. *Elliptic division and unramified correspondence.*

Every elliptic curve E over k(let us $chark \neq 2$) defines a subset $P_{E,tors}$ in a projective line corresponding to the the image of torsion points of E if we consider the quotient of E by involution and define the subset of two-torsion points as the set of invariant points under involution. The set $P_{E,tors}$ considered modulo projective automorphisms pf P^1 characterizes the curve E. Consider the following enlargement of $P_{E,tors}$.Take any four points from $P_{E,tors}$ and add all the images of corresponding elliptic curve. Then consider the new set and repeat this operation infinitely many times. Theorem The resulting set for a curve E defined over a number field is equal to the subset $P^1(K)$ where K depends on the initial curve E. This result is applied to the construction of unramified correspondences between curves defined over number fields. (Received September 21, 2011)

1077-11-1915 **Avraham Bourla*** (avraham.bourla@trincoll.edu), Department of Mathematics, Trinity College, 300 Summit st., Hartford, CT 06106. *Recovering the sequence of approximation coefficients from a pair of successive pairs.*

Let $\{a_n\}_1^\infty$ be the sequence of digits for the regular continued fraction expansion of an irrational number r and let $\{\theta_n\}_0^\infty$ be its sequence of approximation coefficients (SAC) from Diophantine approximation. We will show that for all irrational numbers and $n \geq 1$, there is an integer valued function on two variables, whose value for both (θ_{n-1}, θ_n) and (θ_{n+1}, θ_n) is a_{n+1}. In tandem with a theorem due to Jurkat and Peyerimhoff, this will prove that there is a real valued function f on two variables such that $\theta_{n+1} = f(\theta_{n-1}, \theta_n)$ and $\theta_{n-1} = f(\theta_{n+1}, \theta_n)$, revealing elegant symmetrical structure. In particular, the entire SAC can be recovered from a single pair of successive terms. (Received September 21, 2011)

1077-11-1970 **Robert P Boyer*** (rboyer@math.drexel.edu), Department of Mathematics, Drexel University, Philadelphia, PA 19104. *Asymptotics for polynomials from integer partitions.*

Let $F_n(z)$ be the polynomial $\sum_{k=1}^n p_k(n) z^k$ where $p_k(n)$ denote the number of partitions of n with exactly k parts. For real z, the asymptotics of these polynomials was developed by E.M. Wright in 1932. In joint work with W.M.Y. Goh and with D.T. Parry, we gave two approaches to finding the asymptotics of these polynomials with the motivation of describing the limiting behavior of their zeros. In this talk, we will compare these two approaches. (Received September 21, 2011)

1077-11-2012 **Nils Bruin*** (nbruin@sfu.ca), Department of Mathematics, Simon Fraser University, Burnaby, BC V5A 1S6, Canada. *Imaginary quadratic class numbers and Sha for congruent number curves.* Preliminary report.

We consider two number theoretic problems that have their roots in classical questions. For primes p we ask what is

(1) the power of 2 dividing the class number of $\mathbb{Q}(\sqrt{-p})$,

(2) the power of 2 dividing the order of $\mathrm{Sha}(E_p)$,

where E_p is the congruent number curve given by the equation $y^2 = x^3 - p^2 x$.

It is already known that partial answers to these questions are governed by the splitting of p in some fixed octic number field. We give an easily computed criterion that provides a next step in the classification of primes p according to questions (1) and (2). As a simple example, the criterion allows us to show that $10^{200} + 16737$ is not a congruent prime. (Received September 21, 2011)

1077-11-2028 **Robert M. Guralnick** and **Beth Malmskog*** (emalmskog@wesleyan.edu), Department of Mathematics, Wesleyan University, Middletown, CT 06457, and **Rachel Pries**. *Automorphism groups of a family of maximal curves.*

The Hasse Weil bound restricts the number of points of a curve which are defined over a finite field; if the number of points meets this bound, the curve is called maximal. Giulietti and Korchmaros introduced a curve $\mathcal{C}_3$ which is maximal over $\mathbb{F}_{q^6}$ and determined its automorphism group. Garcia, Guneri, and Stichtenoth generalized this construction to a family of curves $\mathcal{C}_n$, indexed by an odd integer $n \geq 3$, such that $\mathcal{C}_n$ is maximal over $\mathbb{F}_{q^{2n}}$. In joint work with Rachel Pries and Robert Guralnick, the speaker determined the automorphism group $\mathrm{Aut}(\mathcal{C}_n)$ when $n > 3$; in contrast with the case $n = 3$, it fixes the point at infinity on $\mathcal{C}_n$. This talk will discuss the result and the outline of our proof. (Received September 21, 2011)

1077-11-2088 **David Michael Zureick-Brown*** (david.zureick.brown@gmail.com), 628 W. College Ave., Decatur, GA 30030, and **Jordan Ellenberg** and **Bryden Cais**. *Cohen-Lenstra heuristics and Random Dieudonné Modules.*

Knowledge of the distribution of class groups is elusive – it is not even known if there are infinitely many number fields with trivial class group. Cohen and Lenstra's heuristic models the p-parts of class groups by random finite abelian p-groups, correctly predicting many strange experimental observations.

While proof of the Cohen-Lenstra conjectures remains inaccessible, the function field analogue – distribution of class groups of quadratic extensions of $\mathbb{F}_p(t)$ – is more tractable. Friedman and Washington modeled the l-power part (with $l \neq p$) of such class groups as random matrices and derived heuristics which agree with experiment. Achter later refined these heuristics, and many cases have been proved (Achter, Ellenberg and Venkatesh).

When $l = p$, the l-power torsion of abelian varieties, and thus the random matrix model, goes haywire. I will explain the correct linear algebraic model – Dieudoneé modules. Our main result is an analogue of the Cohen-Lenstra/Friedman-Washington heuristics – a theorem about the distributions of class numbers of Dieudoneé modules (and other invariants particular to $l = p$). Finally, I'll present experimental evidence supporting our heuristics and explain the connection with rational points on varieties. (Received September 21, 2011)

1077-11-2093 **Lola Thompson*** (lauren.a.thompson@dartmouth.edu). *On the divisors of $x^n - 1$.*
In this talk, we will examine two central questions concerning the divisors of the polynomial $x^n - 1$: "For a given integer n, how large can the coefficients of divisors of $x^n - 1$ be?" and "How often does $x^n - 1$ have a divisor of every degree between 1 and n?" We will discuss how sieve methods and other techniques from multiplicative number theory can be used in order to answer these questions. (Received September 21, 2011)

1077-11-2109 **Jason Bell** and **Kevin Doerksen*** (kdoerkse@gmail.com). *On the prime divisors in zero orbits of families of commuting polynomials.* Preliminary report.
Let $(b_n) = (b_1, b_2, \dots)$ be a sequence of integers. A primitive prime divisor of the k-th term is a prime which divides b_k but does not divide any previous term in the sequence.

We consider a generalized notion of primitive prime divisors as it applies to families of commutative polynomials. Let $\Phi = \{\varphi_1, \dots, \varphi_k\}$ be a finite set of integer polynomials which are commutative with respect to composition. An element β is said to be in the forward orbit of 0 if there are integers $n_1, \dots, n_k$ such that

$$\beta = \varphi_1^{n_1}\varphi_2^{n_2}\dots\varphi_k^{n_k}(0),$$

We say that p is a primitive divisor of β if $p \mid \beta$ and p satisfies the following condition: if $p \mid \gamma$ for some $\gamma = \varphi_1^{\ell_1}\varphi_2^{\ell_2}\dots\varphi_k^{\ell_k}(0)$ where $\ell_i \leq n_i$ for all $i \leq k$ then in fact $\ell_j = n_j$ for all $j \leq k$.

In this talk, we consider families of commutative polynomials which all have zero linear term. We give an effective bound on the number of terms in the forward orbit of 0 which do not have primitive prime divisors. (Received September 21, 2011)

1077-11-2117 **Samuel S. Gross*** (ssgross@math.sc.edu) and **Andrew F. Vincent** (vincenta@math.sc.edu). *On the factorization of $f(n)$ for $f(x)$ in $\mathbb{Z}[x]$.*
Let S be a finite set of rational primes. For a non-zero integer n, define $[n]_S = \prod_{p \in S} |n|_p^{-1}$, where $|n|_p$ is the usual p-adic norm of n. In 1984, Stewart applied Baker's theorem to prove non-trivial, computationally effective upper bounds for $[n(n+1)...(n+k)]_S$ for any integer $k > 0$. Effective upper bounds have also been given by Bennett, Filaseta, and Trifonov for $[n(n+1)]_S$ and $[n^2+7]_S$, where $S = \{2, 3\}$ and $S = \{2\}$, respectively. We extend Stewart's theorem to prove effective upper bounds for $[f(n)]_S$ for an arbitrary $f(x)$ in $\mathbb{Z}[x]$ having at least two distinct roots. (Received September 21, 2011)

1077-11-2125 **Nils Bruin** and **Kevin Doerksen*** (kdoerkse@gmail.com). *Genus 2 curves with $(4,4)$-split Jacobians.*
Split Jacobians are special. For genus 2 curves, they can be recognized from the fact that C is a degree n cover of an elliptic curve for some integer n. One can classify split Jacobians of genus 2 curves by these n. If $\psi : C \longrightarrow E$ is a degree n cover then we say the Jacobian of C is (n, n) split.

In the talk, we consider the case $n = 4$. We classify all genus 2 curves whose Jacobians admit a polarized $(4, 4)$-isogeny to a product of elliptic curves. In fact our result applies to the more general setting of principally-polarized abelian surfaces, and not just those surfaces which are Jacobians of some genus 2 curve. (Received September 21, 2011)

1077-11-2129 **Michael Baiocchi**, **Krishna Dasaratha**, **Laure Flapan*** (laure.flapan@yale.edu), **Thomas Garrity**, **Chansoo Lee**, **Cornelia Mihaila**, **Nicholas Neumann-Chun**, **Sarah Peluse** and **Matthew Stoffregen**. *Multidimensional Continued Fraction Pell Equations.* Preliminary report.
It is classical that there are infinitely many integer solutions x and y to Pell's equation $x^2 - dy^2 = 1$, whenever d is not a perfect square. The solutions stem from the continued fraction expansion of $\sqrt{d}$. We have recently developed a large family of generalizations of continued fractions. This family includes as special cases many well-known multidimensional continued fraction algorithms such as the Brun Algorithm, the Fully Subtractive Algorithm, the Triangle Map, the Güting Map, and the Mönkemeyer Map. For each type of multidimensional continued fraction in this family we construct a three-variable analogue to the Pell equation. We show that these Pell analogues share many of the characteristics of the original Pell equation and we provide a constructive method for using these multidimensional continued fraction Pell equations to produce units in a number field. We then extend these results to multidimensional continued fractions in higher dimensions. (Received September 21, 2011)

1077-11-2165 **Nathan L Walters*** (walters.nathan.l@gmail.com). *Extending the Polya-Carlson Theorem: When Uniform Limits of Rational Functions are Rational.*

The original Polya-Carlson theorem is an early result in the theory of capacity, giving a condition on a power series with integer coefficients which is sufficient to show that it is the Taylor expansion of a rational function. This talk will address a generalization of the theorem to algebraic curves, as well as allowing more general coefficients in the power series. In the course of the exposition, we will draw from such areas of math as capacity theory on curves, local fields and adeles, the product formula, covering spaces, and dual bases. (Received September 21, 2011)

1077-11-2166 **Dimitris Koukoulopoulos*** (koukoulo@crm.umontreal.ca), Centre de recherche mathematics, Universite de Montreal, Montreal, Quebec H3C 3J7, Canada. *When is a multiplicative function small on average?*

Let f be a multiplicative function. The main problem we will be concerned with in this talk is understanding when f is small on average. Halász showed that, unless f 'pretends to be' n^{it} for some small t, this is true and gave quantitative estimates on the rate of decay of the partial sums of f. The estimate provided by Halász's theorem is in general tight but there are functions f for which it is far from the truth. A natural question that arises is to classify the functions f whose partial sums are significantly smaller than what one might predict by Halász's theorem. More precisely, if $\sum_{n\le x} f(n) \ll x(\log x)^{-A}$ for some big A, then what can we say about f? If f is real valued, we show that either $\sum_{p\le x}(1+f(p)) \ll x(\log x)^{-A/2+O(1)}$ or $\sum_{p\le x} f(p) \ll x(\log x)^{-A/2+O(1)}$, depending on whether the Dirichlet series corresponding to f vanishes at the point 1 or not. In other words, f looks very much like the Mobius function or its prime values are small on average. We also give an analogous result for the general case of a complex valued f. Finally, we show how these methods can be used to give a new proof of the prime number theorem in arithmetic progressions. (Received September 21, 2011)

1077-11-2192 **Douglas Ulmer*** (douglas.ulmer@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *On the arithmetic of the Legendre curve in a tower of function fields.* Preliminary report.

Let p be an odd prime number, f a positive integer, $d = p^f + 1$, $K = \mathbf{F}_p(t)$, and $K_d = \mathbf{F}_{p^{2f}}(u)$ where $u^d = t$. The arithmetic of the Legendre curve

$$y^2 = x(x+1)(x+t)$$

in the tower of fields K_d is very rich. For example, the point

$$P = (u, u(u+1)^{d/2}) \in E(K_d)$$

and its conjugates over K generate a subgroup $V_d \subset E(K_d)$ of finite index and rank $d-2$. It also turns out that the Tate-Shafarevich group $\mathrm{Sha}(E/K_d)$ is a finite p-group and we have

$$[E(K_d) : V_d]^2 = |\mathrm{Sha}(E/K_d)|.$$

In this talk we will discuss explicit calculations of the quotient $\frac{E(K_d)}{V_d}$ and $\mathrm{Sha}(E/K_d)$ as modules over $\mathbf{Z}_p[\mathrm{Gal}(K_d/K)]$ and explain why they satisfy a Gras-type conjecture. (Received September 21, 2011)

1077-11-2204 **Jake Levinson*** (jakelev@umich.edu) and **Steven J Miller**. *The n-level density of zeroes of quadratic Dirichlet L-functions.*

The statistical distributions of zeros of L-functions have wide-ranging applications in number theory and geometry. L-functions have been studied in connection with random matrix theory, which provides easier methods of computing these distributions. One statistic, the n-level density of low-lying zeros for a family of L-functions, measures the distribution of zeros near the central point $s = 1/2$. According to the Density Conjecture of Katz and Sarnak, this statistic depends on a classical compact group associated to the family. We extend previous work by Gao, who computed the n-level densities of quadratic Dirichlet L-functions, and showed equality with random matrix theory up to $n = 3$, for test functions of suitably restricted support. We develop a method to streamline the comparison with the prediction from random matrix theory. The key step is to find a 'canonical' form for several Fourier Transform identities, which allows us to verify them via combinatorial arguments. Our main result is to confirm up to $n = 6$ that, for test functions of suitable support, the density is that of the Symplectic Gaussian Ensemble. (Received September 21, 2011)

1077-11-2205 **Paul Cubre*** (cubrpj11@wfu.edu) and **Jeremy Rouse** (rouseja@wfu.edu). *The Z-densities of the Fibonacci sequence.*

Paul S. Bruckman and Peter G. Anderson made a conjecture about the Z-densities of the Fibonacci sequence, F_n, based on computational results. For a prime p, $Z(p)$ is the "Fibonacci entry-point of n" or the smallest positive integer n such that $p \mid F_n$, $M(m,x)$ is the number of primes $p \le x$ such that $m \mid Z(p)$, and $\pi(x)$ is the number of primes less than x. We may define the"Z density of m" to be $\zeta(m) = \lim_{x\to\infty} M(m,x)/\pi(x)$. We will prove the conjecture of Bruckman and Anderson by connecting $Z(p)$ with the order of the point $\alpha = (3/2, 1/2)$ in $G(\mathbb{F}_p) = \{(x, y) \in \mathbb{F}_p \mid x^2 - 5y^2 = 1\}$ and using the Chebotarev density theorem to find the limit. (Received September 21, 2011)

1077-11-2214 **Jonathan W Bober*** (jwbober@gmail.com) and **Leo Goldmakher** (lgoldmak@math.toronto.edu). *The distribution of character sums.*

I will discuss experiments and results concerning the distribution of character sums over long intervals. In particular I will focus on the frequency with which character sums are large and the location where the maximum occurs. (Received September 21, 2011)

1077-11-2242 **Ralph Morrison*** (morrison@math.berkeley.edu), 1810 Bonita Ave, Apartment B, Berkeley, CA 94709, and **Steven J. Miller**. *An Elliptic Curve Test for the L-Functions Ratios Conjecture.*

The Ratios Conjecture gives a heuristic method for predicting the behavior of zeros of L-functions near the central point, and has shown remarkable success whenever applied. Aside from pointing us towards the correct answer, this method highlights features often obscured in direct computation. While predictions are all well and good, at the end of the day we need to verify these heuristics, both for rigorous use of the results and to strengthen the evidence for the Ratios Conjecture. We present our analysis of the Ratios predictions for quadratic twists of elliptic curve L-functions along with our derivation of the actual distributions, and show that they agree up to a power-savings error term. Apart from strengthening the Ratios Conjecture, this result is key in determining effective matrix size for modeling zeros for this family. (Received September 21, 2011)

1077-11-2298 **Dae San Kim*** (dskim@sogang.ac.kr), Department of Mathematics, Sogang University, Sinsu 1, Mapo-gu, Seoul, 121-742, South Korea. *Some identities involving Bernoulli and Euler numbers.*

The aim of this talk is to derive some interesting identities involving Bernoulli and Euler numbers. We obtain those by using some polynomial identities and bosonic and fermionic p-adic integrals. (Received September 22, 2011)

1077-11-2307 **Alon Levy*** (levy@math.brown.edu). *Bounding the Height of a Postcritically Finite Map.* (Joint with P. Ingram and R. Jones)

Postcritically finite (PCF) maps - that is, rational maps whose critical points all have finite forward orbit - have special arithmetic and geometric properties, and should be regarded as a special case, much like elliptic curves with complex multiplication. Over $\mathbb{C}$, we know from Thurston's rigidity theorem that away from the Lattes curve, there are countably many PCF maps, so the PCF maps are in a precise sense sparse over $\mathbb{C}$. In this work, we prove a sparseness result over number fields: the heights of the multipliers of a PCF map are bounded in terms of the degree of the map, so that away from the Lattes curve there are only finitely many of a given degree defined over a given number field. The proof method has some other interesting corollaries, for example about attracting cycles over non-archimedean fields. (Received September 22, 2011)

1077-11-2313 **Kalyani K. Madhu*** (kmadhu@brockport.edu). *Prime Divisors of Certain Polynomial Orbits.*

Let f be a polynomial map over the rational numbers. We say a prime p divides the f-orbit of a point $a \in \mathbb{Q}$ if the p-adic valuation $v_p(f^n(a)) > 0$ for some n. Jones showed that, for certain families of quadratic polynomials over $\mathbb{Z}$, the set of prime divisors of any orbit has natural density zero.

We give a similar result regarding maps of the form $f(x) = x^m + c$ with some restrictions on $c \in \mathbb{Q}$. Let E_m be the set of primes congruent to 1 modulo m. Then the set of primes of E_m that divide the f-orbit of a fixed point a has natural density zero. In order to obtain this result, we show that maps of the form $f(x) = x^m + c$ are eventually stable. That is, there is $N \in \mathbb{N}$ such that $f^N(x) = \prod_{i=1}^{s} g_i(x)$, and $g_i \circ f^n(x)$ is irreducible for all $n \in \mathbb{Z}, n \geq 0$.

(Received September 22, 2011)

1077-11-2325 **Sarah Peluse*** (peluse@uchicago.edu), **Krishna Dasaratha**, **Laure Flapan**, **Tom Garrity**, **Chansoo Lee**, **Cornelia Mihaila**, **Nicholas Neumann-Chun** and **Matt Stoffregen**. *A Family of Algorithms Yielding a Solution to the Hermite Problem.* Preliminary report.

It's well-known that a real number's continued fraction expansion is eventually periodic if and only if it is a quadratic irrational. In 1848, Charles Hermite asked Carl Jacobi for a way to represent real numbers as sequences of non-negative integers such that a number's algebraic properties are revealed by the periodicity of its sequence. Specifically, Hermite wanted an algorithm that returns an eventually periodic sequence of integers if and only if its input is a cubic irrational. Many algorithms, known as multidimensional continued fractions, have been proposed since then, including the Jacobi-Perron algorithm, the Mönkemeyer algorithm, and the Güting algorithm. Many of these algorithms have the property that an eventually periodic sequence implies cubic irrationality, but none have been proven to have the converse property. Building on the triangle map, we have combined three different multidimensional continued fractions to create a family of algorithms that solve the Hermite problem. (Received September 22, 2011)

1077-11-2341 **Machiel van Frankenhuijsen*** (vanframa@uvu.edu), Utah Valley University, Department of Mathematics, 800 West University Parkway, Orem, UT 84058. *Complex Dimensions of Cantor Strings and the Riemann Zeros.*

After giving an overview of the idea of complex dimension, as conceived by Michel Lapidus and developed with collaborators, I will discuss the special class of Cantor strings. In this class, the spectral operator is invertible, thus yielding that the zeros of the Riemann zeta function do not lie in a vertical arithmetic progression. In closing, I will discuss how a strengthening of this theorem to uniformly finite vertical progressions would yield a zero free region of the Riemann zeta function. (Received September 22, 2011)

1077-11-2349 **Jennifer Paulhus*** (paulhusj@grinnell.edu), Grinnell College, Department of Mathematics and Statistics, Grinnell, IA 50112. *Decomposing Jacobian Varieties of Curves.*

Jacobian varieties which have many elliptic curves as factors in their decompositions have interesting applications to rank and torsion questions. Given a curve X with automorphism group G, idempotent relations in the group ring $\mathbb{Q}[G]$ lead to decompositions of the Jacobian of X. In this talk we briefly explain the techniques involved and some recent results obtained from these techniques. We are particularly interested in hyperelliptic curves whose Jacobians have many elliptic curve factors. We will also discuss how data from a computer program of Breuer's provides some insight for families of higher genus curves. (Received September 22, 2011)

1077-11-2354 **Barry R Smith*** (barsmith@lvc.edu). *A congruence modulo $\mathbb{Z}$ for values at zero of partial zeta functions for totally real cubic fields.* Preliminary report.

In 1974, Coates and Sinnott published a remarkable congruence modulo $\mathbb{Z}$ between two rational numbers: the value at zero of a ray class zeta function of a real quadratic field and a number constructed from arithmetic data of the field. They used this congruence to construct p-adic zeta functions associated with the field. We will present a generalization of the Coates-Sinnott congruence to totally real cubic fields. (Received September 22, 2011)

1077-11-2430 **Abhinav Kumar*** (abhinav@math.mit.edu) and **Tetsuji Shioda**. *Rational elliptic surfaces with Mordell-Weil lattice E_8 and multiplicative reduction.*

Oguiso and Shioda described the possible Mordell-Weil lattices that could arise for rational elliptic surfaces over $\overline{\mathbb{Q}}$ (equivalently, the Mordell-Weil group of an elliptic curve over a rational function field in one variable). The study of specific Mordell-Weil lattices has connections to invariant theory and inverse Galois theory (for instance, of some Weyl groups of root lattices), and Shioda has used these techniques to construct "excellent" families of rational elliptic surfaces with additive reduction and Mordell-Weil lattice E_8, E_7, E_6, D_4 etc, and also for multiplicative reduction and Mordell-Weil lattice E_6.

We describe joint work with Shioda which deals with the multiplicative reduction case with Mordell-Weil lattice E_8 or E_7. The parameters of the "excellent" families are related to the fundamental multiplicative invariants of the corresponding Weyl groups. We use our results to produce examples of elliptic surfaces for which the splitting field has large Galois group, and also examples for which it has trivial Galois group (all sections defined over $\mathbb{Q}$). (Received September 22, 2011)

1077-11-2445 **C S Franze*** (franz1cs@cmich.edu), Central Michigan University, Department of Mathematics Pearce 214, Mount Pleasant, MI 48859. *A Weighted Selberg Sieve.* Preliminary report.

The best known bounds concerning almost primes in polynomial sequences come from a weighted form of the Diamond, Halberstam, Richert (DHR) sieve. However, it is known that if the sieve dimension κ is sufficiently large, then Selberg's lower bound sieve is superior to the DHR sieve. Therefore, a weighted form of Selberg's sieve should be capable of improving these bounds. This is indeed the case, at least in some instances. I will present the new bounds and compare the two weighted sieves. (Received September 22, 2011)

1077-11-2451 **Pete L. Clark*** (plclark@gmail.com). *Euclidean quadratic forms and ADC forms.*

Let R be a domain with fraction field K. A quadratic form defined over R is called an **ADC form** if every element of R which is K-represented by the form is also R-represented by the form. A classical result of Aubry, Davenport and Cassels asserts that quadratic forms over Z which satisfy a certain Euclidean property are ADC forms.

In this talk we present results about Euclidean forms and ADC forms over local and global rings. (Received September 22, 2011)

1077-11-2462 **Derek Garton*** (garton@math.wisc.edu). *The Cohen-Lenstra heuristics, roots of unity, and random matrices.* Preliminary report.

It is well known (in certain circles) that some of the conjectures that follow from the Cohen-Lenstra heuristics for number fields appear to be false when there are pth roots of unity in the base field. Recently, Malle even formulated an alternate conjecture based on extensive (and convincing) numerical data. However, the reason for his conjecture remains mysterious to many. Fortunately, in the setting of function fields of curves over finite fields, much more is known about the Cohen-Lenstra heuristics. For example, Achter recently proved that a Cohen-Lenstra-type heuristic is in fact true in this setting (with the unfortunate caveat that the size of the base field must be allowed to increase). Moreover, the presence of pth roots of unity is now just a simple congruence condition on the characteristic of the finite field. It is thus possible to study the “failure” of the Cohen-Lenstra heuristics by studying statistics of certain “random” elements in a group of symplectic similitudes with multiplier satisfying a certain congruence condition. I have computed some of these statistics, and my results match Malle’s conjecture, giving non-numerical justification for his conjecture. (Received September 22, 2011)

1077-11-2469 **Krishna Dasaratha**, **Laure Flapan**, **Chansoo Lee*** (cl4@williams.edu), **Cornelia Mihailia**, **Nicholas G Neumann-Chun**, **Sarah Peluse**, **Matt Stoffregen** and **Thomas A Garrity**. *A Generalized Family of Multidimensional Continued Fractions and its Correspondence to Existing Algorithms.* Preliminary report.

Classical representations of a real number as sequence of integers include its decimal expansion and its continued fraction expansion. Periodicity of the decimal expansion means the real is rational while periodicity of the continued fraction expansion means that the real is a quadratic irrational. In 1848, Hermite asked for a method to represent a real number as a sequence of integers so that periodicity corresponds to periodicity. Attempts to solve this problem (which is still open) are called multi-dimensional continued fractions. We have constructed a family of multidimensional continued fractions by repeatedly subdividing triangles while permuting their vertices after each subdivision. We show that our construction can produce many well-known existing algorithms, including the Brun Algorithm, the Fully Subtractive Algorithm, the triangle map, the Guting Map, and the Monkemeyer Map, allowing us to put all of these seemingly distinct methods into one unified contexts. This has implications ranging from understanding cubic number fields to discovering natural generalizations of Pell’s equations to finding fascinating combinatorial analogues of the classical Stern diatomic sequence. (Received September 22, 2011)

1077-11-2476 **Ryan C Daileda*** (rdaileda@trinity.edu), Department of Mathematics, One Trinity Place, San Antonio, TX 78212-7200, and **Nathan C Jones** (ncjones@olemiss.edu), Department of Mathematics, Hume Hall 305, P. O. Box 1848, University, MS 38677-1848. *Making imprimitive characters behave primitively.*

Given a Dirichlet character χ mod q, it is traditional to extend χ to all of $\mathbb{Z}/q\mathbb{Z}$ by declaring that $\chi(n) = 0$ when $(n, q) \neq 1$. When χ is primitive (i.e. not induced by a Dirichlet character mod d for some proper divisor d of q), this extension endows the associated Gauss sum and L-function with properties that are lost when χ is imprimitve. In this talk we will introduce a modification to the traditional extension of imprimitive characters which causes them to behave primitively, in the sense that the relevant properties of the Gauss sum and L-function take on the form usually only associated to primitive characters. (Received September 22, 2011)

1077-11-2499 **Krishna Dasaratha*** (dasaratha@college.harvard.edu), 476 Quincy House Mail Center, Cambridge, MA 02138, and **Thomas Garrity**, **Laure Flapan**, **Chansoo Lee**, **Cornelia Mihaila**, **Nicholas Neumann-Chun**, **Sarah Peluse** and **Matthew Stoffregen**. *Unique Sequences for Multidimensional Continued Fractions.* Preliminary report.

Many generalizations of continued fractions assign sequences of integers to pairs of real numbers by partitioning a triangle with linear maps. Such algorithms include the Mönkemeyer map, the triangle map, the Brun Algorithm, the Fully Subtractive Algorithm, and the Güting map. These multidimensional continued fractions need not map pairs of real numbers to integer sequences injectively. The Mönkemeyer map is topologically convergent, meaning distinct points in $\mathbb{R}^2$ map to distinct sequences, but several useful algorithms are not. This talk will present general criteria for when a sequence determines a unique point with respect to any of these algorithms. The most important result relates the set of points with a given sequence to the vertices of the new triangle after each partition. These criteria are particularly relevant for periodic sequences. If a periodic sequence determines a unique point (x, y) with respect to such a multidimensional continued fraction algorithm, then x and y are contained in a number field of degree at most three. We classify periodic sequences for a family of multidimensional continued fractions recently constructed by the authors. (Received September 22, 2011)

1077-11-2550 **Michael E. Zieve*** (zieve@umich.edu). *Recent results in arithmetic dynamics.* Preliminary report.

I will present several recent results in arithmetic dynamics. Topics will include primitive prime divisors in dynamical sequences; the extent to which polynomial maps from a number field to itself can fail to be one-to-one; and the numbers of integral, rational, and complex points in backwards orbits and grand orbits of rational functions. (Received September 22, 2011)

1077-11-2569 **Noam D. Elkies*** (elkies@math.harvard.edu). *Families of marked elliptic curves, with some applications.*

We outline an approach to constructing families of elliptic curves marked with a given configuration of integral points in their Mordell-Weil groups. Some of the resulting parametrizations have already appeared in various contexts, ranging from classical formulas for modular curves $\mathrm{X}_1(N)$ and the elliptic curves they parametrize, to recent results of Bhargava and others on average ranks of elliptic curves. We give some other motivations and applications, such as: elliptic curves (and surfaces) with a point (or section) of nonzero height that has many integral multiples; rational functions of low degree on $\mathrm{X}_1(N)$ for large N; and elliptic curves of low conductor or discriminant and moderately large rank in a given family, such as all elliptic curves over $\mathbf{Q}$ or $\mathbf{Q}(\sqrt{5})$, or curves with a 2- or 3-torsion point, or of j-invariant 0 or 1728. (Received September 22, 2011)

1077-11-2610 **Susan Hammond Marshall*** (smarshal@monmouth.edu) and **Alexander R. Perlis**. *Integer Embeddings of Heronian Tetrahedra.*

A triangle is said to be Heronian if all three of its sides have integer length and its area is also an integer. It was proved in 2001 that every Heronian triangle has an integer embedding in the plane. In this talk, we will prove the 3-dimensional analogue: every Heronian tetrahedron has an integer embedding in $\mathbb{R}^3$, where a tetrahedron is said to be Heronian if all of its edges have integer length, all of the triangles making up its faces have integer area and its volume is an integer. This result is a corollary of the following more general result, which we prove using the arithmetic of quaternions: Let $M \subset \mathbf{Q}^3$ be a finite set of points such that the distance between any two points is an integer. Then there exists a Euclidean motion T so that $TM \subset \mathbb{Z}^3$. (Received September 22, 2011)

1077-11-2614 **Krishna Dasaratha**, **Laure Flapan**, **Thomas Garrity**, **Chansoo Lee**, **Cornelia Mihaila*** (cmihaila@wellesley.edu), **Nicholas Neumann-Chun**, **Sarah Peluse** and **Matt Stoffregen**. *A Generalized Family of Multidimensional Continued Fractions?* Preliminary report.

Classical representations of a real number as sequence of integers include its decimal expansion and its continued fraction expansion. Periodicity of the decimal expansion means the real number is rational while periodicity of the continued fraction expansion means that the number is a quadratic irrational. In 1848, Hermite asked for a method to represent a real number as a sequence of integers so that periodicity corresponds to the degree of the number field it lies in. Attempts to solve this problem (which is still open) are called multi-dimensional continued fractions. We have developed a family of 216 multi-dimensional continued fractions, which include any number of previously known multi-dimensional continued fractions. We will discuss how this family is quite natural and how periodicity for each of these multi-dimensional continued fractions gives us information about cubic irrationals. (Received September 22, 2011)

1077-11-2635 **Jeffery Breeding*** (jbreedi1@slu.edu), Department of Mathematics & Computer Science, Saint Louis University, 220 North Grand Boulevard, Saint Louis, MO 63103. *Bounds for dimensions of degree 2 newforms.* Preliminary report.

Dimensions of spaces of Siegel cusp forms of degree 2 over principal congruence subgroups $\Gamma(p)$ of Sp(4, $\mathbb{Z}$) have been computed by several people using the Selberg trace formula. These cusp forms can be associated to cuspidal automorphic representations of GSp(4, $\mathbb{A}$), where $\mathbb{A}$ is the adele ring of $\mathbb{Q}$. The dimensions of $\Gamma(p)$–fixed vectors at the local components of the representation contribute to the dimension formulas for spaces of cusp forms. By finding the possible dimensions for these spaces, we can compute bounds for dimensions of spaces of newforms. (Received September 22, 2011)

1077-11-2743 **Amanda Kovacs*** (Akovacs09@lions.molloy.edu), 402 N Woodward Drive, Massapequa, NY 11758. *The n-House Problem.*

A famous problem published in the English magazine "Strand" in 1914 asked for the number of houses that has the property that the sum of the addresses below it is equal to the sum of the addresses above it. The addresses are numbered consecutively, and the total number of houses is between 50 and 500. When this problem was presented to Ramanujan by Mahalanobis, Ramanujan asked him to write down a continued fraction, which was the general solution to the problem. We extend the "house problem" by solving for two houses, where the three sums (sum of the addresses below the first house, sum of the addresses between the first and second houses, sum of the addresses above the second house) are all equal. We then look at the more generalized problem, in which the two houses are replaced with n houses. (Received September 22, 2011)

1077-11-2923 **Jorge Dioses***, Department of Mathematics, Oklahoma State University, Stillwater, OK 74074. *Relations between class numbers of binary cubic forms with different splitting types over a place in an imaginary quadratic field.*

This study was motivated by a theorem of Jin Nakagawa. The theorem gives a precise relation between the class numbers of forms of positive discriminant and those of forms of negative discriminant. The forms of positive discriminant are those that factor into three real factors, while the ones with negative discriminant have an irreducible quadratic factor over $\mathbb{R}$. In essence, Nakagawa's theorem says there is a relation between the classes of one splitting type over $\mathbb{R}$ with the other splitting type.

One natural problem suggested by Nakagawa's theorem is to explore whether or not such a relation is true over more general global fields or for splitting types over other primes. This paper generalizes this result to an imaginary quadratic fields. In that case, we can define two Dirichlet series: one for the lattice of binary cubic forms over the ring of integers and another one for its dual. The coefficients in both cases are class numbers. The final result shows that these two series are basically the same, up to a simple constant factor consisting of a power of 3. The proof relies on class field theory. (Received September 23, 2011)

1077-11-2966 **Taiyu Li*** (arith.tyli@gmail.com), School of Mathematics, Shandong University, 27 Shanda Nanlu, Jinan, Shandong 250100. *The quadratic Waring-Goldbach problem and related topics* Preliminary report.

In this short talk, we will give a brief introduction of the history of the additive problems involvingsquares of primes. These include joint work of the presenter with A.V. Kumchev on sums of "almost equal" squares ofprimes as well as recent work of the author on exceptional sets for sums of squares of primes and a kth power ofprime. (Received October 18, 2011)

12 ► Field theory and polynomials

1077-12-128 **Benjamin L Weiss*** (blweiss@umich.edu), Benjamin Weiss, 1272 Beacon St. Apt 8, Brookline, MA 02446. *Diophantine Equations With Two Separated Variables.*

We classify pairs of polynomials $G, H \in \mathbb{C}[T]$ such that $G(X) = H(Y)$ defines an irreducible curve of genus zero, excepting the cases where $G(X)$ or $H(Y)$ is a power of a smaller degree polynomial. As a consequence, we obtain results about pairs of polynomials $G, H \in \mathbb{Q}[T]$ for which the equation $G(X) = H(Y)$ has infinitely many rational solutions.

We'll briefly discuss the previous results applied to this classification. These include Riemann's existence theorem for covers of punctured spheres; the Riemann-Hurwitz formula; Fried's result classifying factors of $G(X) - H(Y)$ in terms of the decompositions of $G(X)$ and $H(Y)$; the classification of Cassou-Nogues and Couveignes for indecomposable polynomials $G(X)$ and $H(Y)$ with $G(X) - H(Y)$ reducible. (Received July 28, 2011)

1077-12-289 **Daniel C Smith*** (smithdc@umail.iu.edu). *Measuring Security.*

A great many of the cryptanalyses of modern multivariate post-quantum cryptosystems have relied in some form on the existence of a large and easily detectable differential symmetry or invariant. In response to this trend, we propose an effectively computable measure of security against differential attacks which can be derived to instill confidence in future post-quantum schemes. As an exercise, we demonstrate the utility of this measurement by showing the dichotomy in measure among unbroken and definitively insecure cryptographic primitives. (Received August 18, 2011)

1077-12-299 **Seiji Nishioka*** (nishioka@gem.aoyama.ac.jp), 5-10-1 Fuchinobe, Chuo-ku, Sagamihara-shi, Kanagawa 252-5258, Japan. *Solvability of difference Riccati equations.*

I will talk about my result on solvability of difference Riccati equations in the sense of Franke's generalized Liouvillian extension. I use valuation rings to characterize Franke's extension. The result is the following. If a difference Riccati equation which never turns out to be linear by iterations has a solution in some Franke's extension, then one of the iterated Riccati equations has an algebraic solution. I supposed that the coefficient field is an inversive difference field. Applying this result, one conclude unsolvability of the q-Airy equation and the q-Bessel equation with a parameter of rational number when q is a transcendental number. (Received August 19, 2011)

1077-12-530 **V. Ravi Srinivasan*** (srinivasan@cua.edu), 2920 montauk court, falls church, VA 22042. *Classification of Algebraic Subgroups of Lower Order Unipotent Algebraic Groups.* Preliminary report.

Let F be a differential field of characteristic zero and C be its field of Constants. Let $\mathcal{U}(n, C)$ be the group of all upper triangular matrices with 1's on the main diagonal. It is well-known that under certain conditions on F, Picard-Vessiot extensions exist for the group $\mathcal{U}(n, C)$. In this talk we will look into one such construction of a Picard-Vessiot extension and use its structure and the Galois correspondence to classify the algebraic subgroups of $\mathcal{U}(n, C)$ for smaller n. (Received September 06, 2011)

1077-12-596 **Dmitry Trushin*** (trushindima@yandex.ru), The Hebrew University of Jerusalem, Einstein Institute of Mathematics, Manchester, Edmond J. Safra Campus, Givat Ram, 91904 Jerusalem, Israel. *The ring of global sections of a differential scheme.*

If we study differential equations by methods of algebraic geometry, the notion of a differential scheme appears. However, there are some anomalies, which do not occur in the non-differential case. For example, the ring of global sections does not necessarily coincide with the initial ring. Jerald Kovacic developed theory of differential schemes and posed the problem: whether the differential spectrum of the ring of global sections coincides with the differential spectrum of the initial ring? I am going to present a solution to the question in some important cases and discuss related problems. (Received September 08, 2011)

1077-12-600 **Michael Wibmer*** (michael.wibmer@matha.rwth-aachen.de). *Galois theory of strongly normal differential and difference extensions.*

Jerald Kovacic developed a scheme-theoretic approach to the Galois theory of strongly normal differential extensions. We will present an analogous approach for difference equations. (Received September 08, 2011)

1077-12-833 **Michael F Singer*** (singer@math.ncsu.edu), Department of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695. *Linear Algebraic Groups as Paramterized Picard-Vessiot Galois Groups.*

I will discuss the inverse problem: which linear differential algebraic groups can occur as PPV-Galois groups over k(x) where k is a differentially closed field with respect to some parametric derivations and x' = 1, a' =0 for all a in k. I will show that a linear algebraic group (considered as a linear differential algebraic group) is a PPV-Galois group over this field if and only if its identity component has no one dimensional quotient as an algebraic group. (Received September 22, 2011)

1077-12-932 **Yuri Burda*** (yburda@math.toronto.edu). *Topological Methods in Klein's Resolvent Problem.*

Klein's resolvent problem asks whether using a rational substitution $y = R(z, a_1, \ldots, a_n)$ the equation

$$z^n + a_1 z^{n-1} + \ldots + a_n = 0$$

can be transformed into an algebraic equation on y depending on a small number k of parameters.

Many tools have been applied to achieve progress in this problem: low-dimensional algebraic geometry (n=5: Kronecker, Klein, n=6: Serre, n=7: Duncan), valuation theory (Buhler, Reichstein), Galois cohomology (Serre).

Arnold suggested in the 70's to approach the problem by studying the complexity of the covering realized by the multi-valued function z over the space of its parameters.

Developing this idea we propose a topological method based on the notion of Parshin neighborhood of a flag and topological results on coverings over tori. With this method we prove a bound $k \geq \lfloor n/2 \rfloor$ in the original problem and obtain estimates in similar questions. We prove for instance that for a generic algebraic function depending on k parameters of degree at least 2k the number of parameters can't be reduced at all. (Received September 14, 2011)

1077-12-1073 **Edgar Martìnez-Moro**, **Hakan Özadam**, **Ferruh Özbudak** and **Steve Szabo*** (steve.szabo@eku.edu). *A Class of Multidimensional Repeated-root Cyclic Codes.*

We study a particular class of multidimensional repeated-root cyclic codes over a finite field. We show that these codes are products of one dimensional cyclic codes whose lengths are powers of p. We obtain the Hamming distance for such codes. Using the Hasse derrivative, we obtain a parity check matrix as well. Finally, we genaralize the so-called weight-retaining property to multivariables. (Received September 16, 2011)

1077-12-1171 **Zbigniew Hajto*** (zbigniew.hajto@uj.edu.pl), Faculty of Mathematics and Computer Science, Jagiellonian University, ul. Lojasiewicza 6, 30-348 Krakow, Poland, and **Teresa Crespo** and **Elzbieta Sowa**. *Real Picard-Vessiot theory.*

For a given linear differential equation defined over a real differential field with real closed field of constants, we prove that there exists a Picard-Vessiot extension which moreover is a real field. For such a Picard-Vessiot extension, we present a Galois correspondence theorem. (Received September 17, 2011)

1077-12-2676 **Carlos E Arreche*** (carreche@gc.cuny.edu), Department of Mathematics, CUNY Graduate Center, 365 Fifth Ave., Room 4208, New York, NY 10016-4309. *Generalizing Kovacic's algorithm to second order homogeneous linear differential equations with parameters.* Preliminary report.

In 1986 Jerry Kovacic developed an algorithm for solving second order linear homogeneous differential equations with coefficients in $C(x)$, where C is an algebraically closed field of characteristic zero, using the classification of the algebraic subgroups of $\mathrm{SL}_2(C)$, since the differential Galois group associated to such an equation is realizable as an algebraic subgroup of $\mathrm{SL}_2(C)$ after a possible change of variables.

In this talk we will discuss how to generalize Kovacic's algorithm to compute the differential Galois group associated to a second order linear homogeneous differential equation with parameters. In this case the differential Galois group is realizable as a differential algebraic subgroup of SL_2, again after a change of variables. In this work we rely on William Sit's classification of the differential algebraic subgroups of SL_2 as well as the representation theory of linear differential algebraic groups. (Received September 22, 2011)

1077-12-2891 **Alice Medvedev*** (alice@math.berkeley.edu) and **Thomas W Scanlon**. *Ritt's Theorem and refinements.*

Almost a century ago, Ritt proved that composition of polynomials in characteristic zero is well-behaved: each polynomial "factors" uniquely into indecomposable factors, up to compositional units and permutations of factors. This talk is about the refinements of Ritt's theorem that we needed for the classification of plane curves invariant under coordinate-wise polynomial dynamical systems. In particular, I will describe bounds and normal forms for the possible sequences of permutations of factors. (Received September 22, 2011)

13 ► Commutative rings and algebras

1077-13-125 **Brian L Miller*** (brian.l.miller@ttu.edu). *Integration and Primary Decomposition.*

We provide an algorithm to compute the logarithmic part of an integral in which the integrand lies in a tower of transcendental elementary extensions followed by an algebraic extension. Computing the logarithmic part of an integral in a transcendental elementary has been given by Bronstein. However, computing the logarithmic part in an algebraic extension has remained difficult. We offer an algorithm that utilizes primary decomposition and Gröbner bases. We are also able to give an explicit bound for the termination of the algorithm. (Received July 28, 2011)

1077-13-205 **Bernadette M Boyle*** (bboyle2@nd.edu), University of Notre Dame, 255 Hurley Hall, Notre Dame, IN 46556. *On the Unimodality of Pure O-Sequences.* Preliminary report.

We will discuss some properties of pure O-sequences, or the Hilbert functions of Artinian level monomial algebras, particularly to see when they are unimodal. Due to Macaulay's theorem, one knows that algebras in two variables are unimodal. Furthermore, it has been shown that monomial Artinian level algebras of type two in three variables have the Weak Lefschetz Property (in characteristic zero), and thus are unimodal. On the other hand, for any $r > 2$, there exists a monomial Artinian level algebra in r variables whose Hilbert function fails unimodality with an arbitrary number of peaks. This poster will show the unimodality of the Hilbert function in two of the smallest open cases, namely that of monomial Artinian level algebras of type three in three variables and type two in four variables. Since the Weak Lefschetz Property does not necessarily hold for such algebras, we give a new approach for each case. Furthermore, we will discuss how the socle degree affects the unimodality of pure O-sequences. (Received August 11, 2011)

1077-13-339 **Jesse Elliott*** (`jesse.elliott@csuci.edu`), 305 Channel Islands Drive, Camarillo, CA 93012. *Factoring formal power series over principal ideal domains.*

We provide an irreducibility test and factoring algorithm (with some qualificiations) for formal power series in the unique factorization domain $R[[X]]$, where R is any principal ideal domain. Our main tool is a generalization of the p-adic Weierstrass preparation theorem to the context of complete filtered commutative rings. (Received August 24, 2011)

1077-13-409 **Harlan Kadish*** (`hmkadish@math.tamu.edu`), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843-3368. *An Application of Quasi-Inverse Rings.*

Let V be a representation of a linear algebraic group G. The invariant polynomial functions on V almost always fail to separate the orbits of G. Nevertheless, there is an algorithm to compute a finite set of separating invariant functions by introducing a new quasi-inverse operation on k[V]: the quasi-inverse of f is 1/f where defined and zero elsewhere. The algorithm and the length of the functions as straight line programs have polynomial bounds in the parameters of the representation. One then considers (1) the structure of commutative rings R that have quasi-inverse operations and (2) the applications thereof to equivalence relations on Spec(R). (Received August 29, 2011)

1077-13-419 **Alexandru Buium*** (`buium@math.unm.edu`), 1 University of New Mexico, Albuquerque, NM 87131. *The Lie groupoid of the integers.*

An object can be constructed that can be viewed as an arithmetic analogue, for the ring of integers, of the Lie groupoid of a curve. This object is defined as the infinite p-jet space of the Witt ring of the integers and its rather non-trivial structure can be analysed. (Received August 30, 2011)

1077-13-535 **M Axtell** (`axte2004@stthomas.edu`), St. Paul, MN 55105, **N Baeth*** (`baeth@ucmo.edu`), W.C. Morris 213, Warrensburg, MO 64093, and **J Stickles** (`jstickles@millikin.edu`), Decatur, IL 62522. *Cut Structures in Zero-divisor Graphs.*

Zero-divisor graphs and, more recently, compressed zero-divisor graphs are well-represented in the commutative ring literature. In this talk we consider various cut structures — sets of edges or vertices whose removal disconnects the graph — in both compressed and non-compressed zero-divisor graphs. In doing so, we connect these graph-theoretic concepts with algebraic notions and provide realization theorems for zero-divisor graphs over commutative rings with identity. (Received September 06, 2011)

1077-13-536 **Richard Erwin Hasenauer*** (`richard.hasenauer@ndsu.edu`), NDSU Mathematics Department #2750, PO Box 6050, Fargo, ND 58108-6050. *Normsets of almost Dedekind domains and atomicity.*

Let D be an almost Dedekind domain. Hence for each maximal ideal M, we have D_M being a Noetherian valuation domain. Using these local valuations we create a global norm. The set of these norms, called the normset, is used to classify which almost Dedekind domains are atomic. We also introduce the idea of a legitimate domain, and as a corollary show that a glad domain is atomic if and only if it is a semilocal Dedekind domain (hence a semilocal PID). (Received September 06, 2011)

1077-13-537 **Andy R Magid*** (`amagid@ou.edu`), Department of Mathematics, University of Oklahoma, 601 Elm Room 423, Norman, OK 73019. *Differential Modules over a Differential Ring.* Preliminary report.

Let R be a commutative differential ring which is an algebra over a differential field F, the latter of characteristic 0 and with algebraically closed field of constants. We consider the category of differential R modules every element of which satisfies a linear homogeneous differential equation over F. We study in particular simple differential R modules and injective differential R modules, especially in the case that R itself is differentially simple. We further consider the R module properties of differential R modules in this case. (Received September 06, 2011)

1077-13-583 **Eddy Campbell** and **Jianjun Chuai*** (`jchuai@unb.ca`), Department of Mathematics and Statistics, University of New Brunswick, Fredericton, NB E3B 5A3, Canada. *Finding generators for the vanishing ideal of a finite set of points.*

Let k be a field of characteristic $p > 0$ and let W be a finite additive subgroup of k^n. Further, let $I(W) \subset k[x_1, x_2, \ldots, x_n]$ be the vanishing ideal of W. Then $I(W)$ is generated by n elements. Using Invariant Theory, we give an algorithm for finding these generators. Our result also shows that these generators are even linear combinations of powers of the variables. (Received September 07, 2011)

1077-13-637 **Dennis Moore*** (d.k.moore@uky.edu), Department of Mathematics, 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506, and **Uwe Nagel** (uwe.nagel@uky.edu). *Algorithms for strongly stable ideals.* Preliminary report.

Strongly stable ideals arise naturally in algebraic geometry, commutative algebra, and combinatorics. We present three algorithms for generating saturated strongly stable ideals: all such ideals with a given Hilbert polynomial, a particular ideal for each Hilbert function associated to a given Hilbert polynomial, and all such ideals with a given Hilbert function. The first algorithm is prompted by combinatorial approaches to studying the Hilbert scheme, and the second algorithm can be used to study strongly stable ideals having maximal total Betti numbers for a fixed Hilbert polynomial. We have implemented these algorithms in the computer algebra system *Macaulay2*. (Received September 09, 2011)

1077-13-730 **James Freitag*** (jfreitag@uic.edu), University of Illinois at Chicago, 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60607-7045. *Differential algebraic groups as superstable groups.*

We will discuss differential algebraic groups from the point of view of model theory. After defining almost simple differential algebraic groups (in the sense of Cassidy and Singer), we will prove that almost simple differential algebraic groups are either commutative or perfect. (Received September 11, 2011)

1077-13-804 **Eero Hyry**, Finland, and **Maryam Akhavin*** (m.akhavin@gmail.com), Department of Mathematics and Statistics, Univ of Tampere, 33014. *A note on generalized Gorenstein complexes.*

We present a generalization of Gorenstein complexes (as defined by Grothendieck) in the context of relative homological algebra. Utilizing the notion of a canonical module of a complex — which we define at the beginning of our paper — we prove that there exists an equivalence between the category of generalized Gorenstein complexes and the category of modules of the G-class. We then obtain that a complex is a generalized Gorenstein complex if and only if it is Cohen-Macaulay and the corresponding Cousin complex consists of Gorenstein injective modules. (Received September 13, 2011)

1077-13-861 **Alina A Florescu*** (alina-florescu@uiowa.edu), University of Iowa, Department of Mathematics, 14 MacLean Hall, Iowa City, IA 52242. *Generalized Factorization in the Integers.* Preliminary report.

D. D. Anderson and A. Frazier introduced a general theory of factorization in *On a general theory of factorization in integral domains*, Rocky Mountain J. Math. vol. 41, no. 3 (2011), 663-705.

Let D be an integral domain and τ a relation on $D^{\#}$, the set of nonzero nonunits of D. A *(reduced) τ-factorization* of $a \in D^{\#}$ is $a = ua_1 \dots a_n$ where u is a unit $(u = 1)$ and whenever $i \neq j$, $a_i \tau a_j$. Then $a \in D^{\#}$ is a *(reduced) τ-atom* if any (reduced) τ-factorization of a has length 1. Also, a is *τ-prime* if $a|ua_1 \dots a_n$, a τ-factorization, implies $a|a_i$ for some i. We are interested in the relation τ_n on $\mathbb{Z}^{\#}$ defined by $a\tau_n b \iff a \equiv b \bmod n$. We consider τ_n- and reduced τ_n-factorizations in $\mathbb{Z}$. (Received September 14, 2011)

1077-13-964 **K. Alan Loper** (lopera@math.ohio-state.edu) and **Nicholas J. Werner*** (nw89@evansville.edu), Department of Mathematics, University of Evansville, 1800 Lincoln Ave, Evansville, IN 47722. *A Generalization of Integer-valued Polynomials Rings.*

The classical ring of integer-valued polynomials $\mathrm{Int}(\mathbb{Z})$ consists of the polynomials in $\mathbb{Q}[x]$ that map $\mathbb{Z}$ into $\mathbb{Z}$. In this talk, we consider a generalization of integer-valued polynomials where the polynomials act on $\mathbb{Z}$-algebras such as a ring of algebraic integers or the ring of $n \times n$ matrices with entries in $\mathbb{Z}$. Specifically, given a $\mathbb{Z}$-algebra A, we define $\mathrm{Int}_A(\mathbb{Z})$ to be the set of polynomials in $\mathbb{Q}[x]$ that map A into A; then, $\mathrm{Int}_A(\mathbb{Z})$ is usually a proper subring of $\mathrm{Int}(\mathbb{Z})$. The principal question we consider is whether or not $\mathrm{Int}_A(\mathbb{Z})$ is a Prüfer domain. We will demonstrate that when A is a finite-dimensional $\mathbb{Z}$-algebra, $\mathrm{Int}_A(\mathbb{Z})$ need not be a Prüfer domain, but the integral closure of $\mathrm{Int}_A(\mathbb{Z})$ is always a Prüfer domain. (Received September 14, 2011)

1077-13-1231 **William F. Keigher*** (keigher@rutgers.edu) and **V. Ravi Srinivasan**. *Automorphisms of Hurwitz series.*

In this talk we will consider the notions of a Hurwitz automorphism and a comorphism involving the ring of Hurwitz series over a ring A. A Hurwitz automorphism is the analog of a Seidenberg automorphism of the power series ring $A[[t]]$ when the characteristic of the underlying ring is not necessarily zero. We will show that the set of all Hurwitz automorphisms, comorphisms, and derivations of the underlying ring A are naturally isomorphic to one another. (Received September 18, 2011)

1077-13-1577 **Andrei Zelevinsky*** (andrei@neu.edu), Department of Mathematics, Northeastern University, 360 Huntington Avenue, Boston, MA 02115. *Triangular bases in acyclic quantum cluster algebras.* Preliminary report.

In a joint work in progress with Arkady Berenstein, we introduce a new approach to the problem of constructing a "natural" linear basis in an acyclic quantum cluster algebra. This approach is based on a suitable modification of Lusztig's lemma. Thus it is close in spirit to the well known-constructions of the Kazhdan-Lusztig basis in a Hecke algebra and of Lusztig's canonical basis for quantum groups. (Received September 20, 2011)

1077-13-1918 **Jared L Painter*** (jlpainter@uta.edu), 411 S. Nedderman Drive, 478 Pickard Hall, Arlington, TX 76019-0408. *On the Algebra Structure of Tor for Trivariate Monomial Ideals.* Preliminary report.

In this talk we explore the algebra structure of $A = \mathrm{Tor}^R(\Bbbk, R/I)$, where $R = \Bbbk[x, y, z]$ is a trivariate polynomial ring over a field $\Bbbk$ and I is a monomial ideal primary to the homogeneous maximal ideal $\mathfrak{m}$ of R. Recently, L. Avramov classified the behavior of the Bass numbers of embedding codepth 3 commutative local rings. His classification relied on a corresponding classification of their respective Tor algebras, which is comprised of 5 categories. We will determine which of the 5 categories of Tor algebras can be realized by monomial ideals. In addition we will identify classes of monomial ideals I so that A will have the desired algebra structure. (Received September 21, 2011)

1077-13-2017 **Neil Epstein*** (nepstein@uni-osnabrueck.de), Univesität Osnabrück, Institut für Mathematik, 49076 Osnabrück, Germany, and **Javid Validashti**. *Hilbert-Kunz multiplicities of products of ideals.* Preliminary report.

The Hilbert-Kunz multiplicity has long been used in prime characteristic singularity theory and in order to determine when two ideals have the same tight closure. In this work, we develop inequalities relating the Hilbert-Kunz multiplicities of a pair of ideals to that of their product. In doing so, we obtain surprising connections with the tight closure of ideals, the class of parameter ideals, and low-dimensional cases. (Received September 21, 2011)

1077-13-2280 **Lourdes Juan*** (lourdes.juan@ttu.edu), Lubbock, TX 79409. *Generic Differential Galois Extensions.*

Let $\mathcal{C}$ be an algebraically closed field of characteristic zero, regarded as a differential field with the trivial derivation, and let G be an algebraic subgroup of $GL_n(\mathcal{C})$. The notion of generic differential Galois extension for G has been introduced and studied by the presenter and co-authors in a series of papers. In this talk we will discuss the existence and properties of such extensions. (Received September 22, 2011)

1077-13-2424 **Daniel R Moseley*** (dmoseley@uoregon.edu). *Group Actions on Arrangement Complements.*

The symmetric group acts on the configuration space of n points in $\mathbb{R}^3$ and the induced action on cohomology is isomorphic to the regular representation. We will give a neat proof of this fact and generalize this result to other arrangement complements. (Received September 22, 2011)

1077-13-2622 **Amanda R. Curtis*** (arcurtis@math.ucsb.edu), **Alexander J. Diesl** (adiesl@wellesley.edu) and **Jane C. Rieck** (rieck@math.wisc.edu). *Classifying annihilator-ideal graphs of finite commutative rings- Part I.* Preliminary report.

The ideal annihilator graph $\tilde{\Gamma}(R)$ of a ring R, created by M. Behboodi and Z. Rakeei, is defined as follows: vertices are nonzero ideals with nonzero annihilators, and an edge exists between two vertices if the product of the corresponding ideals multiply to zero. We pursue the question of whether or not a graph isomorphism $\tilde{\Gamma}(R) \cong \tilde{\Gamma}(S)$ requires the rings R and S have isomorphic ideal lattices, for finite rings. We prove such a theorem holds (with one small exception) for finite PIRs. (Received September 22, 2011)

1077-13-2650 **Brian Johnson*** (s-bjohns67@math.unl.edu), 203 Avery Hall, University of Nebraska - Lincoln, Lincoln, NE 68588-0130. *Prime avoidance avoidance.* Preliminary report.

Prime avoidance is a fundamental result in the theory of commutative rings, but in the graded setting (even just $\mathbb{Z}$-graded), the theorem is false for homogeneous elements. On our way to developing a general theory of commutative rings graded by arbitrary abelian groups, we note a few alternate proofs of results usually making use of prime avoidance. (Received September 22, 2011)

1077-13-2728 **Amanda R Curtis**, **Alexander J Diesl** and **Jane C Rieck*** (`rieck@math.wisc.edu`). *Classifying Annihilator-Ideal Graphs for Finite Commutative Rings: Part Two.*

The ideal annihilator graph $\tilde{\Gamma}(R)$ of a ring R, created by M. Behboodi and Z. Rakeei, is defined as follows: vertices are nonzero ideals with nonzero annihilators, and an edge exists between two vertices if the product of the corresponding ideals multiply to zero. We consider which types of graphs on 6 or fewer vertices can be realized as graphs of finite commutative rings, as well as questions relating $\tilde{\Gamma}(R)$ to $\Gamma_E(R)$ for finite rings. (Received September 22, 2011)

1077-13-2789 **Bonnie Smith*** (`bonnie.smith@uky.edu`). *The Core of a Strongly Stable Ideal.*

A reduction of an ideal I is an ideal $J \subseteq I$ such that $JI^r = I^{r+1}$ for some r. Reductions are very similar to, but often simpler than, the ideal I. They are a key tool in Commutative Algebra, used to study algebraically the "blow-up" of a curve or other variety. An ideal I has infinitely many reductions, and their intersection is called the core of I. Though natural to study, the core of an ideal is difficult to compute. We consider a certain family of ideals which have a graph-theoretical interpretation. Using the combinatorial object to which such an ideal corresponds, we are able to compute its core. (Received September 22, 2011)

14 ► Algebraic geometry

1077-14-10 **Edward Frenkel*** (`frenkel@math.berkeley.edu`), Department of Mathematics, University of California, Berkeley, CA 94720. *Langlands Program, Trace Formulas, and their Geometrization.*

The Langlands Program relates Galois representations and automorphic representations of reductive algebraic groups defined over number fields and the fields of functions on curves over finite fields. The trace formula is a powerful tool in the study of this connection. After giving an introduction to the Langlands Program and its geometric version, which applies to curves over finite fields as well as over the complex field, I will outline a conjectural framework of "geometric trace formulas" in the case that the curve is defined over the complex field. It exploits a categorical formulation of the geometric Langlands correspondence. The talk is based on my joint work with Robert Langlands and Ngo Bao Chau (arXiv:1003.4578, arXiv:1004.5323). (Received September 18, 2011)

1077-14-11 **Edward Frenkel*** (`frenkel@math.berkeley.edu`). *Langlands Program, Trace Formulas, and their Geometrization, II.*

I will talk about the Langlands functoriality conjecture and an approach to proving it using the trace formula following my joint work with Robert Langlands and Ngo Bao Chau (arXiv:1003.4578, arXiv:1004.5323). (Received September 19, 2011)

1077-14-12 **Edward Frenkel*** (`frenkel@math.berkeley.edu`). *Langlands Program, Trace Formulas, and their Geometrization, III.*

I will discuss the "geometric trace formulas" and their interpretation in the framework of the categorical version of the Langlands correspondence. The talk is based on my joint work with Robert Langlands and Ngo Bao Chau (arXiv:1003.4578, arXiv:1004.5323). (Received September 19, 2011)

1077-14-28 **Allen Knutson*** (`allenk@math.cornell.edu`), NY. *A stratification of the space of all k-planes in $\mathbb{C}^n$.*

The space of all k-dimensional linear subspaces of $\mathbb{C}^n$ forms a manifold called the **Grassmannian**. To describe a V in it, pick a basis, and put the resulting $k \times n$ matrix in reduced row-echelon form. Based on the k locations of the pivot columns, we can break the Grassmannian into $\binom{n}{k}$ pieces. But we actually want to refine that:

(1) Consider the $k \times n$ *real* matrices, such that every $k \times k$ determinant, or **Plücker coordinate**, is nonnegative. Lusztig defined a stratification in which the boundary of each stratum is a union of others.

(2) There is a natural deformation of the Plücker coordinate ring to a noncommutative one. Very few ideals survive this; the column-scaling-invariant ones that do define a list of closed subsets.

(3) If we use subspaces of $(\mathbb{F}_p)^n$ instead, the map $r \mapsto r^p$ on the Plücker ring enjoys $(a+b)^p = a^p + b^p$ (the **Freshman's Dream**). One can define a good "pth root" map ϕ, and ask which ideals I are preserved by ϕ.

Amazingly, these three very different sources all give the same stratification. I will describe the strata, and how to naturally index them by juggling patterns of length n with k balls. (Received September 19, 2011)

1077-14-35 **Raman Sanyal** and **Bernd Sturmfels*** (bernd@math.berkeley.edu), Department of Mathematics, University of California, Berkeley, CA 94720, and **Cynthia Vinzant**. *The Entropic Discriminant.*

The entropic discriminant describes the complex branch locus of the polar map of an arrangement of real hyperplanes. It is the non-negative polynomial which vanishes when the equations defining the analytic center of a linear program have a complex double root. We study the geometry of the entropic discriminant, and we determine its degree in terms of matroid invariants. (Received June 21, 2011)

1077-14-42 **Gaetan Borot**, **Bertrand Eynard**, **Motohico Mulase** and **Brad Safnuk*** (brad.safnuk@cmich.edu), Mathematics Department, Central Michigan University, Mt. Pleasant, MI 48859. *A matrix model for simple Hurwitz numbers and topological recursion.*

We introduce a new matrix model representation for the generating function of simple Hurwitz numbers. We calculate the spectral curve of the model and the associated symplectic invariants developed by Eynard and Orantin. As an application, we prove the conjecture proposed by Bouchard and Mariño, relating Hurwitz numbers to the symplectic invariants of the Lambert curve $x = ye^{-y}$. (Received July 01, 2011)

1077-14-175 **T. Shaska*** (shaska@oakland.edu), **L. Beshaj** and **V. Hoxha**. *Interesting families of algebraic curves.*

Algebraic curves covering elliptic curves have been studied extensively in algebraic geometry or number theory. There is some interest lately on such families of curves from the cryptography viewpoint in constructing attacks in elliptic curve cryptography as well as the number theory viewpoint of constructing curves with many rational points, etc. We will discuss some families of such curves for genus $g \leq 5$, their automorphisms, and possible applications. Invariants of superelliptic curves which are covers of elliptic curves are introduced and their half-integer rational theta-nulls are discussed. (Received August 07, 2011)

1077-14-197 **Megan Patnott***, mpatnott@nd.edu. *Hilbert Functions and Graded Betti Numbers of Arithmetically Gorenstein Points on General Surfaces in $\mathbb{P}^3$.* Preliminary report.

We show the existence of arithmetically Gorenstein sets of points with certain Hilbert functions and graded Betti numbers on surfaces of several degrees in $\mathbb{P}^3$. We also discuss a connection between these sets of points and rank two arithmetically Cohen-Macaulay indecomposable vector bundles on the surfaces. (Received August 11, 2011)

1077-14-312 **Caitlin A Lownes***, clownes@mit.edu. *Fraction of Nonnegative Polynomials that are Sums of Squares.*

Polynomials that are sums of squares (SOS) can be efficiently optimized via semidefinite programming. In this paper, we investigate when a nonnegative polynomial $p \in \mathbb{R}[x_1, \ldots, x_n]$ is SOS. For nonnegative polynomials of fixed degree, previous results by Blekherman show that, as $n \to \infty$, the fraction of nonnegative polynomials that are SOS approaches zero. However, these bounds are loose, and this fraction is unknown for most polynomials of low degree in few variables. Our research focuses on estimating this fraction for nonnegative bivariate polynomials of degree at most four in each variable. The fraction of nonnegative polynomials that are SOS can be estimated as the ratio of volumes of two naturally definable convex bodies of dimension 24. To avoid computing these volumes directly, we implemented a version of Smith's rapidly mixing hit and run technique for uniform sampling from a convex body. (Received August 19, 2011)

1077-14-386 **Yuri Zarhin*** (zarhin@math.psu.edu), Pennsylvania State University, Department of Mathematics, University Park, PA 16802. *Abelian varieties with homotheties.* Preliminary report.

We introduce a positive characteristic analogue of complex abelian varieties with semisimple Hodge groups. Namely, we call an abelian variety X that is defined over a finitely generated field of prime characteristic *an abelian variety with homotheties*, AVH if the center of the corresponding ℓ-adic Lie algebra (attached to the Galois action on the ℓ-adic Tate module of X) consists of scalars. E.g., X is an AVH if the center of its endomorphism algebra (over an algebraic closure of the ground field) is a (direct sum of) totally real number field(s). Another example of AVH is provided by abelian varieties that have a good supersingular reduction somewhere. Notice that the class of AVH's is closed under the operations of taking an abelian subvariety, a product and an isogenous variety.

We discuss various properties of AVH's, including independence on ℓ and analogues of the Tate conjecture on homomorphisms over infinite cyclotomic extensions of the ground field. (Received August 28, 2011)

1077-14-435 **Arsen Elkin*** (arsen.elkin@gmail.com), Mathematics Institute, University of Warwick, Coventry, CV81EF, England, and **Rachel Pries**. *De Rham cohomology of Artin-Schreier curves in characteristic two.*

We discuss explicit computation of the de Rham cohomology of hyperelliptic curves defined over algebraically closed fields of characteristic two and its application to determination of the Ekedahl-Oort stratification of the moduli space of such curves. (Received September 01, 2011)

1077-14-511 **Raymond T Hoobler*** (rhoobler@ccny.cuny.edu). *Cohomology of Differential Schemes.* Preliminary report.

We complete the work of Kovacic and others by defining and establishing the basic properties of DiffSpec and differential schemes. We then introduce the Δ -flat topology and show that it agrees with Kolchin's constrained cohomology for a Δ field K. We finish by explaining and generalizing Kolchin's result that $H^*(K_{cnstrd}, \Delta G) = H^*(K_{Gal}, G)$ for a Δ field K and an ordinary linear algebraic group G where ΔG is the differential group scheme obtained by adding the differential operators Δ to G. (Received September 17, 2011)

1077-14-654 **Samuel Grushevsky*** (sam@math.sunysb.edu), Mathematics Department, Stony Brook University, Stony Brook, NY 11794-3651. *Calogero-Moser curves and the geometry of the moduli space of curves.*

Using ideas motivated by the Whitham perturbation theory of soliton equations, we use meromorphic differentials with real periods to construct foliations of the moduli space of Riemann surfaces (algebraic curves). By studying the local and global geometry of these foliations, we obtain various results on the geometry of the moduli space, and make further conjectures. In particular we obtain direct elementary proofs of Diaz' bound for the dimension of complete subvarieties, and prove vanishing of some tautological homology classes. Our construction can also be viewed as certain perturbations of Calogero-Moser spectral curves.

Joint work with Igor Krichever. (Received September 09, 2011)

1077-14-671 **Sara Gharahbeigi*** (sarabeigi.math@gmail.com), Department of Mathematics, One Brooking Drive, St Louis, MO 63130. *Maximal rank conjecture for rational curves on hypersurfaces.*

We will show the maximal rank conjecture(via a geometric approach) for general rational curves on general hypersurfaces(of degree less than the dimension of the ambient projective space). As a result we get that such curves, have the least possible regularity index. (Received September 09, 2011)

1077-14-747 **Olivier Haution*** (olivier.haution@gmail.com). *Degree formula for the Euler characteristic.*

Given a rational map between smooth projective varieties, this formula gives a restriction on the gcd of the degrees of closed points on the varieties in terms of integers invariant under field extensions : the dimensions of the varieties, their Euler characteristics, and the degree of the map. It can be used to establish incompressibility properties of varieties. It was stated and proved by Kirill Zainoulline under some assumptions on the characteristic of the base field. We discuss a simpler approach which additionally works over any field. (Received September 12, 2011)

1077-14-792 **Omar Leon Sanchez*** (oleonsan@uwaterloo.ca), 545 Belmont Ave West, Unit 406, Kitchener, Ontario N2M 5G7, Canada. *Prolongations and differentially closed fields.*

Given two disjoint sets of commuting derivations Δ_1 and Δ_2 and a Δ_2-algebraic variety V. One can construct the Δ_1/Δ_2-prolongation of V, which is a torsor of the Δ_2-tangent bundle of V containing $(a, \delta_1 a, \dots, \delta_r a)$ for each $a \in V$ and where $\Delta_1 = \{\delta_1, \dots, \delta_r\}$.

In the spirit of the Pierce-Pillay axioms for ordinary differentially closed fields. We give a geometric characterization, indeed a first-order axiomatization, of partial differentially closed fields in terms of differential algebraic varieties and the appropriate prolongations. (Received September 12, 2011)

1077-14-885 **Fei YE*** (fye@macs.biu.ac.il), Department of mathematics, Bar-Ilan University, 52900 Ramat Gan, Israel. *Connectedness of moduli spaces of line arrangements.*

A Zariski pair of arrangements consists of two arrangements whose combinatorial data are same but the topology of their complements are different. In this talk, I will show that there is no Zariski pair of arrangements of 9 lines. I will also show that the fundamental groups of two arrangements of 10 lines known as a (weak) Zariski pair (see "Topologyand combinatorics of real line arrangements") are isomorphic. (Received September 14, 2011)

1077-14-960 **Reinier Broker*** (reinier@math.brown.edu), Brown University, Box 1917, 151 Thayer Street, Providence, RI 02912, and **Kristin Lauter** and **Marco Streng**. *Abelian surfaces with extra endomorphims.*

For elliptic curves, the modular polynomial $\Phi_p(X,Y)$ parametrizes elliptic curves together with a p-isogeny. The polynomial $\Phi_p(X,X)$ parametrizes elliptic curves together with an endomorphism of degree p. Kronecker discovered already that the irreducible factors of $\Phi_p(X,X)$ are Hilbert class polynomials. In this talk we will consider abelian surfaces with extra endomorphisms. We will show which factors occur when you factor the 2-dimensional analogue of the modular polymial $\Phi_p(X,X)$. In the case $p=2$, everything can be explicitly computed and we will give a complete classification of abelian surfaces admitting a $(2,2)$-endomorphism. (Received September 14, 2011)

1077-14-1010 **Caroline Junkins*** (cjunk084@uottawa.ca), Department of Mathematics and Statistics, University of Ottawa, 585 King Edward, ON K1N 6N5. *The J-invariant and Tits indices for groups of type E_6.*

A connection between the indices of the Tits algebras of a split linear algebraic group G and the degree one parameters of its motivic J-invariant was introduced by Quéguiner-Mathieu, Semenov and Zainoulline through use of the second Chern class map in the Riemann-Roch theorem without denominators. We extend their result to higher Chern class maps and provide applications to groups of inner type E_6. (Received September 15, 2011)

1077-14-1139 **Sho Tanimoto*** (tanimoto@cims.nyu.edu), Courant Institute of Mathematical Sciences, New York University, New York, NY. *Manin's Conjecture and Balanced line bundles.*

Manin's conjecture relates the asymptotic of the counting function of rational points of bounded height on Fano varieties to certain global geometric invariants. In this talk I will discuss some geometric issues arising from Manin's Conjecture and introduce the notion of balanced line bundles. This is joint work with Brendan Hassett and Yuri Tschinkel. (Received September 16, 2011)

1077-14-1226 **Aravind Asok** (asok@usc.edu) and **Christian Haesemeyer*** (chh@math.ucla.edu). *Rational points and $\mathbb{A}^1$-homotopy theory.*

We discuss how rational points and zero cycles of degree one are detected homologically in $\mathbb{A}^1$-homotopy theory, and how this might be used to address the question whether a variety that admits a zero cycle of degree one will have a rational point. (Received September 18, 2011)

1077-14-1246 **Jeffrey D Achter*** (achter@math.colostate.edu), Department of Mathematics, Colorado State University, Fort Collins, CO 80523-1874. *Arithmetic Torelli maps for cubic surfaces and threefolds.* Preliminary report.

It has long been known that to a complex cubic surface or threefold one can canonically associate a principally polarized abelian variety. I'll explain a construction which works for cubics over an arithmetic base. This answers, away from the prime 2, an old question of Deligne and a recent question of Kudla and Rapoport. (Received September 18, 2011)

1077-14-1368 **Kirill Zainoulline*** (kirill@uottawa.ca), Department of Mathematics and Statistics, University of Ottawa, 585 King Edward, Ottawa, Ontario K1N6N5, Canada. *The gamma filtration on projective homogeneous varieties.*

We study the Grothendieck gamma-filtration on the variety X of Borel subgroups of a linear algebraic group G. It is well-known that its first subsequent quotient gives the Picard group of X which can be identified with the weight lattice of the respective Lie algebra L. One of our results says that the second subsequent quotient is uniquely determined by the Dynkin index of L. Based on the computation of the Grothendieck group K_0 of X we provide a uniform low bound for the torsion of the graded ring associated to the filtration. We discuss various applications to the theory of cohomological invariants and G-torsors. (Received September 19, 2011)

1077-14-1374 **Tomer M. Schlank*** (tomer.schlank@gmail.com) and **Yonatan Harpaz** (harpazy@gmail.com). *Homotopy Obstructions to Rational Points - I.*

In 1969 Artin and Mazur defined the étale homotopy type $\acute{E}t(X)$ of a scheme X as a way to homotopically realize the étale topos of X. In this talk we will consider the relative situation $X \to S$ and define a relative version $\acute{E}t_{/S}(X)$ of this notion. We call it the **relative homotopy type of** X **over** S.

It turns out that the relative homotopy type can be especially useful in studying the sections of the map $X \to S$. In particular this notion can be used in order to obtain homotopy-theoretic obstructions to the existence of a section.

In the special case where $S = Spec(K)$ is the spectrum of a field K, the set of sections are just the set of K-rational points $X(K)$. In that case the obstructions we obtain are a direct generalization of Grothendieck's section obstruction. If furthermore K is a **global field** then these obstructions can be used to described various known arithmetic obstructions, such as the regular and étale Brauer-Manin obstructions. This point of view can be used to show new properties of these obstructions. (Received September 21, 2011)

1077-14-1375 **Yonatan Harpaz*** (harpazy@gmail.com) and **Tomer M. Schlank** (tomer.schlank@gmail.com). *Homotopy Obstructions to Rational Points - II.*

In 1969 Artin and Mazur defined the étale homotopy type $\acute{E}t(X)$ of a scheme X as a way to homotopically realize the étale topos of X. In this talk we will consider the relative situation $X \to S$ and define a relative version $\acute{E}t_{/S}(X)$ of this notion. We call it the **relative homotopy type of** X **over** S.

It turns out that the relative homotopy type can be especially useful in studying the sections of the map $X \to S$. In particular this notion can be used in order to obtain homotopy-theoretic obstructions to the existence of a section.

In the special case where $S = Spec(K)$ is the spectrum of a field K, the set of sections are just the set of K-rational points $X(K)$. In that case the obstructions we obtain are a direct generalization of Grothendieck's section obstruction. If furthermore K is a **global field** then these obstructions can be used to described various known arithmetic obstructions, such as the regular and étale Brauer-Manin obstructions. This point of view can be used to show new properties of these obstructions. (Received September 19, 2011)

1077-14-1430 **Victor I Piercey***, University of Arizona, Department of Mathematics, 617 N. Santa Rita Ave., Tucson, AZ 85721. *Resolving Collinearity Among Four Points in the Complex Projective Plane.* Preliminary report.

In 1954, Semple considered Schubert's space of triangles in $\mathbb{P}^2$ and described a smooth compactification with a modular interpretation. In this talk, I will describe a smooth compactification of the space of 4 points in general linear position in $\mathbb{P}^2$ and its relations to Semple's compactification.

The goal of this research program is to find a modular resolution of singularities for the configuration of n points in $\mathbb{P}^2$. By a theorem of Mnëv, this family of varieties exhibits every possible singularity. (Received September 19, 2011)

1077-14-1612 **Drew Lewis*** (andrew@math.wustl.edu), Washington University in St. Louis, Campus Box 1146, One Brookings Drive, St. Louis, MO 63130. *Affine fibrations and Vénéreau-type polynomials.*

The Vénéreau polynomials $f_n = y + x^n(xz + y(yu + z^2))$ $(n \geq 1)$ are well known examples of polynomials with many coordinate-like properties, including that they are coordinates when x is inverted, or upon going modulo x. f_n is known to be a $\mathbb{C}[x]$-coordinate for $n \geq 2$, but the question remains open for $n = 1$.

We show that many polynomials with this coordinate-like property are in fact coordinates over $\mathbb{C}[x]$. In the case of $\mathbb{C}^{[4]}$, the additional assumption that a polynomial becomes a coordinate of a tame automorphism upon inverting x is sufficient to guarantee it is a $\mathbb{C}[x]$-coordinate. As corollaries, we obtain that Vénéreau-type polynomials are all 1-stable $\mathbb{C}[x]$-coordinates, and characterize them as the simplest potential counterexamples to the Dolgachev-Weisfeiler conjecture. (Received September 20, 2011)

1077-14-1616 **Adrian Iovita*** (iovita@mathstat.concordia.ca), Department of Mathematics, Concordia University, 1455 de Maisonneuve West Blvd., Montreal, QC H3G 1M8, Canada. *A p-adic criterion for good reduction of curves over a p-adic field.*

Let X be a smooth, proper curve over a finite extension K of $\mathbb{Q}_p$ and let us suppose that X has a K-rational point x. Let π denote the (etale) unipotent (geometric) fundamental group attached to the pair X, x and for every natural number n let $\pi[n]$ denote the quotient of π by its natural n-th step filtration. Then $\pi[n]$ is a finite dimensional $\mathbb{Q}_p$-vector space with a continuous action by G_K, the absolute Galois group of K.

Together with Fabrizio Andreatta and Minhyong Kim we have proved: X has good reduction over $\mathcal{O}_K$ if and only if $\pi[n]$ is a crystalline G_K-representation for all n. (Received September 20, 2011)

1077-14-1631 **James C Price*** (jprice@uafortsmith.edu), 5210 Grand Avenue, P.O. Box 3649, Fort Smith, AR 72913-3649. *An obstruction in extending Abhyankar's results for the Jacobian conjecture.*

In this talk we will briefly discuss the issues in trying to extend Abhyankar's results for the Jacobian conjecture to weighted homogenous polynomials of positive weight. In particular, we will construct a series of weighted homogeneous polynomial pairs of positive weight that behave the same way under the Jacobian as their negatively weighted counterparts, but they will not possess the same pairwise properties. (Received September 20, 2011)

1077-14-1663 **Michael A. Burr*** (mburr1@fordham.edu), Mathematics Department, 441 E Fordham Rd., Bronx, NY 10458. *Asymptotic Purity for Very General Hypersurfaces of Products of Projective Spaces.*

For a complex irreducible projective variety, the asymptotic cohomological functions were introduced by Küronya and Demailly to measure the growth rate of the cohomology of high tensor powers of an invertible sheaf. These functions have proven to be useful in understanding the positivity of divisors as well as other geometric properties of the variety. In this talk I will define a strong vanishing property, called asymptotic purity, and prove that very general hypersurfaces of $\mathbb{P}^n \times \mathbb{P}^n$ of bidegree (k,k) have this property. These examples provide evidence for the truth of a conjecture of Bogomolov concerning asymptotic purity. (Received September 20, 2011)

1077-14-1735 **Linhui Shen*** (linhui.shen@yale.edu). *Stasheff polytopes and the coordinate ring of the cluster $\mathcal{X}$-variety of type A_n.*

We define Stasheff polytopes in the space of tropical points of cluster $\mathcal{A}$-varieties. We study the supports of products of elements of canonical bases for cluster $\mathcal{X}$-varieties. We prove that, for the cluster $\mathcal{X}$-variety of type A_n, such supports are Stasheff polytopes. (Received September 20, 2011)

1077-14-1788 **Ellen J Goldstein*** (ellen.goldstein@northwestern.edu). *Nilpotent Orbit Closures in the Symplectic and Orthogonal Groups.* Preliminary report.

For an algebraically closed field K of arbitrary characteristic, consider a linear algebraic group G over K and $\overline{\mathcal{O}_X}$, the (Zariski) closure of the adjoint orbit of an element X of the Lie algebra $\mathfrak{g}$. $\overline{\mathcal{O}_X}$ is a subvariety of $\mathfrak{g}$ and it is an ongoing problem to determine under what circumstances $\overline{\mathcal{O}_X}$ is normal. For G the orthogonal or symplectic group, Kraft and Procesi showed that $\overline{\mathcal{O}_X}$ is a normal variety for certain nilpotent $X \in \mathfrak{g}$ when $\operatorname{char} K = 0$. We begin to generalize their result for $\operatorname{char} K = p \neq 2$, concluding that an orbit closure $\overline{\mathcal{O}_X}$ of a nilpotent element $X \in \mathfrak{g}$ is normal if and only if it is non-singular in all orbits $\mathcal{O}$ of codimension 2 contained in the boundary of $\overline{\mathcal{O}_X}$. In particular, if $\overline{\mathcal{O}_X} \setminus \mathcal{O}_X$ does not contain any orbits of codimension 2, then $\overline{\mathcal{O}_X}$ is normal. (Received September 20, 2011)

1077-14-1858 **Joseph Rabinoff*** (rabinoff@math.harvard.edu), Department of Mathematics, One Oxford Street, Cambridge, MA 02138. *Far beyond Newton polygons.*

The theorem of the Newton polygon allows one to calculate the number of zeros with given valuation of a polynomial or power series in one variable over a non-Archimedean field. We will explain in what sense a lifting theorem for the intersection of tropicalizations of complementary-dimensional subschemes of a torus is a useful generalization of the theorem of the Newton polygon to higher dimensions. This lifting theorem also gives an effective version of Bernshtein's theorem in the case of a trivial valuation.

Joint with Brian Osserman. (Received September 21, 2011)

1077-14-1896 **Justin D. Peachey*** (jpeache@clemson.edu). *Codes from separable linearized polynomials and associated Riemann-Roch spaces.*

Consider the extended norm-trace function field $\mathbb{F}_{q^r}(x,y)/\mathbb{F}_{q^r}$ defined by

$$x^u = L(y),$$

where $L(y)$ is a separable linearized polynomial which splits over $\mathbb{F}_{q^r}$. The norm-trace function field and the Hermitian function field are special cases of this function field. Our work yields explicit bases for certain Riemann-Roch spaces of the extended norm-trace function field. In this talk, we apply these bases to the construction and analysis of related algebraic geometry codes and to the determination of associated Weierstrass semigroups. These bases and codes give rise to explicit small-bias sets. We also consider an analogue of the Weierstrass semigroup for a finite graph and explore the similarities between it and the classical Weierstrass semigroup. (Received September 21, 2011)

1077-14-1944 **Danko Adrovic*** (adrovic@math.uic.edu), Dep. of Mathematics, Statistics and Comp. Sc., 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60607-7045, and **Jan Verschelde** (jan@math.uic.edu), Dep. of Mathematics, Statistics and Comp. Sc., 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60607-7045. *Polyhedral Methods for Space Curves and Two Dimensional Surfaces Exploiting Symmetry.*

We present a polyhedral algorithm to manipulate algebraic solution sets of dimension one and two. Using facet normals to Newton polytopes as pretropisms, we focus on the first two terms of a Puiseux series expansion. The leading powers of the series are computed via the tropical prevariety. This polyhedral algorithm is well suited for exploitation of symmetry, when it arises in systems of polynomials. Initial form systems with pretropisms in the same group orbit are solved only once, allowing for a systematic filtration of redundant data. Computations with cddlib and Sage are illustrated on cyclic n-roots polynomial systems. (Received September 21, 2011)

1077-14-1989 **Erik A Insko*** (erik-insko@uiowa.edu) and **Alexander Yong**. *Patch Ideals and Peterson Varieties.*

Patch ideals encode neighborhoods of a variety in GL_n/B. For Peterson varieties we determine generators for these ideals and show they are complete intersections, and thus Cohen-Macaulay and Gorenstein. We combinatorially describe the singular locus of the Peterson variety; give an explicit equivariant K-theory localization formula; and extend some results of B. Kostant and of D. Peterson to intersections of Peterson varieties with Schubert varieties. Similarly, we use patch ideals to briefly analyze other examples of torus-invariant subvarieties of GL_n/B, including Richardson varieties and Springer fibers. (Received September 21, 2011)

1077-14-2004 **Shilin Yu*** (yu@math.psu.edu), 432 McAllister Building, Dept. of Mathematics, Pennsylvania State University, State College, PA 16802. *Dolbeault dgas and L_∞-algebroids associated to subvarieties.*

In this talk, I will discuss the construction of a natural "Dolbeault dga" associated to any closed embedding $i : X \hookrightarrow Y$ of complex manifolds, which encodes the holomorphic structure of the formal neighborhood of X in Y. By a theorem of M. Kapranov and M. Kontsevich, the Dolbeault dga of the diagonal embedding $\Delta : X \to X \times X$ is isomorphic to the Chevalley-Eilenberg complex of an L_∞-structure on the shifted tangent bundle $TX[-1]$, whose brackets can be written down explicitly using Atiyah class. I will sketch an alternative proof from a new point of view and generalize it to the case of an arbitrary embedding, in which the shifted normal bundle $N[-1]$ admits a structure of L_∞-algebroid with an ∞-anchor map $\alpha : N[-1] \to TX$. Two applications of this L_∞-algebroid will be mentioned: 1) it governs the infinitesimal deformations of X within Y; 2) its universal enveloping algebra is an A_∞-algebra whose cohomology is the graded associative algebra $\mathrm{Ext}^\bullet_Y(i_*\mathcal{O}_X, i_*\mathcal{O}_X)$ with the Yoneda product. (Received September 21, 2011)

1077-14-2153 **Ronald van Luijk*** (rvl@math.leidenuniv.nl) and **Cecilia Salgado**. *Density of rational points on Del Pezzo surfaces of degree one.*

The Segre-Manin Theorem implies that if a Del Pezzo surface S of degree at least three, defined over $\mathbb{Q}$, has a rational point, then the rational points are Zariski dense in S. A result of Manin yields the same for degree two, as long as the initial point avoids a specific subset. Similar results for Del Pezzo surfaces of degree one are meager: they either depend on conjectures, or they are restricted to small families of surfaces.

Every Del Pezzo surface of degree one has a natural elliptic fibration. Ulas showed for a family of isotrivial Del Pezzo surfaces of degree one that there is a genus-one multisection of the fibration of infinite order; if this multisection contains infinitely many rational points, then the set of rational points on the surface is dense.

We will generalize Ulas' technique by showing that for every Del Pezzo surface S of degree one and any point P on it (other than the unique base point of the elliptic fibration), there is a genus-at-most-one multisection going through P. For sufficiently general P, the existence of infinitely many rational points on the multisection implies that the set of rational points is dense on S. (Received September 21, 2011)

1077-14-2263 **Xia Liao*** (xl07c@fsu.edu), FSU Mathematics, 208 Love Building, 1017 Academic Way, Tallahassee, FL 32306-4510. *Chern classes of sheaves of logarithmic differentials.*

Let D be a cartier divisor in a nonsingular complete variety. In this paper we compare the Chern-Schwartz-Macpherson class of the complement of D and the chern class of the sheaf of logarithmic derivatives along D. When D is a reduced divisor in a surface, we show that these classes agree with each other if and only if the milnor number and tjurina number of the singularity of D are the same. (Received September 22, 2011)

1077-14-2378 **Alan Koch*** (akoch@agnesscott.edu), Department of Mathematics, 141 E. College Ave., Decatur, GA 30030. *Cyclic Breuil modules and Hopf orders in characteristic p.* Preliminary report.

Let k be a perfect field of characteristic $p > 0$. We use the theory of Breuil modules over regular local rings to describe a class of Hopf algebras over the discrete valuation ring $k[[t]]$. We relate these to Hopf algebras over the residue field k and the field of fractions $k((t))$. (Received September 22, 2011)

1077-14-2479 **Eleanor S Farrington*** (efarrington@maritime.edu), 101 Academy Dr, Buzzards Bay, MA 02155. *The Arithmetic-Geometric Mean of genus 1 with Applications to genus 2 and 3.* Preliminary report.

The relation between elliptic curves and the arithmetic-geometric mean was discovered by Lagrange and Gauss as a method of calculating elliptic integrals. This classical approach is limited to cases where the elliptic curve is given by a cubic equation with three real roots. We define an arithmetic-geometric mean for all elliptic curves over $\mathbb{C}$ and detail the choices implicit in the classical construction. With this full understanding of the genus 1 case, we will consider its applications to computing the arithmetic-geometric mean of genus 2 and 3 curves with split Jacobians. (Received September 22, 2011)

1077-14-2524 **Robert Edward Campbell*** (rcampbel@math.uci.edu). *Realizing Cubic Hypersurfaces in $\mathbb{P}^3$.*

There has been much work on classification of cubic surfaces in $\mathbb{P}^3$ over finite fields. The problem has been reduced to considering automorphisms of a certain combinatorial structure that arises from lines on this surface. However, it is still unknown whether each automorphism of the structure (there are known to be 25 types of these) can be realized geometrically by an actual cubic hypersurface. We present an approach allowing to construct some examples, based on the classification of automorphisms of complex cubic surfaces by I Dolgachev. (Received September 22, 2011)

1077-14-2724 **Jia Wan*** (wan2235@vandals.uidaho.edu), 514 Taylor Apt.6, Moscow, ID 83843. *On the Secant Defectivity of Classically Studied Varieties.*

Consider an irreducible, non-degenerate projective variety X. The k-th secant variety of X is the Zariski closure of the union of the linear spaces spanned by all k tuple points on X. The study of this object is centered around finding related invariants, such as dimension. Although it can be traced back to Bezout's work in the 18th century, scientists have shown more interest in this topic at the turn of the 20th century, since the problem is strongly connected to questions in representation theory, coding theory, algebraic complexity theory, and combinatorics. In recent years, many efforts have been made to develop techniques to describe secant varieties for some well known varieties. In 1995, work by J. Alexander and A. Hirschowitz completed a project that was underway for over 100 years and confirmed the conjecture that finished the Waring's problem. However, the problem is still unsolved in its generality. Indeed, we are still far away from completing the classification of all the defective secant varieties, even for some specific varieties. In this talk, I will explain the techniques involved in classifying defective secant varieties of some classically studied varieties, as well as conjectures, open problems and some recent improvements we have achieved in this area. (Received September 22, 2011)

1077-14-2726 **Anupam Bhatnagar*** (anupam.nyc@gmail.com). *Projective varieties covered by trivial families.*

Let k be an algebraically closed field of characteristic zero, C a connected smooth projective curve defined over k. Let X, Y be integral projective schemes over C and $g : X \to Y$ a morphism defined over C such that $g^{\#} : \mathcal{O}_Y \to g_*\mathcal{O}_X$ is an isomorphism. If $X \to C$ is a trivial family, then the generic fiber of the family $Y \to C$ is isotrivial. (Received September 22, 2011)

1077-14-2727 **Jon Yaggie*** (jyaggi2@uic.edu). *Variety of Finitely Generated k-algebra Homomorphisms.*

Let k be an algebraically closed field. Let A and B be arbitrary commutative (unitary) k-algebras. Assume $V \subset A$ and $W \subset B$ are finite dimensional k-linear subspaces. Denote the subalgebras of A and B generated by V and W as $A(V)$ and $B(W)$. Then the set $Hom(A, B, V, W)$ of k-algebra homomorphisms $f : A(V) \to B(W)$ such that $f(V) \subset W$ is an affine k-variety in a natural way. The structure of the proof of this claim suggests an algorithm could be developed to allow software to calculate the affine variety $Hom(A, B, V, W)$. The goal of my research is to develop software capable of doing this calculation and use this software to compute some classical algebras (e.g. group algebras, monomial algebras etc). Time permitting I will discuss specific applications of these algebraic sets. (Received September 22, 2011)

1077-14-2792 **Julianna S Tymoczko*** (julianna-tymoczko@uiowa.edu), Math and Stats Department, Clark Science Center, Smith College, 44 College Lane, Northampton, MA 01063. *Regular nilpotent Hessenberg varieties.*

Regular nilpotent Hessenberg varieties are a family of subvarieties of the flag variety with important applications in representation theory, quantum cohomology, algebraic geometry, combinatorics, and other fields. We will discuss a paving by affines of the regular nilpotent Hessenberg varieties of arbitrary Lie type (which gives a natural cohomology basis), and a geometric proof that their homology injects into that of the flag variety. Time permitting, we will also discuss some representations that arise. Some of this work is joint with Erik Insko (University of Iowa). (Received September 22, 2011)

15 ► Linear and multilinear algebra; matrix theory

1077-15-66 **Gary Greaves** and **Graeme Taylor*** (magdt@bristol.ac.uk). *Lehmer's conjecture for Hermitian matrices over the Eisenstein and Gaussian integers.* Preliminary report.

We solve Lehmer's problem for a class of polynomials arising from Hermitian matrices over the Eisenstein and Gaussian integers: any such polynomial has Mahler measure at least $\lambda_0 = 1.17628\ldots$. To do so, we classify (via graphs) all such matrices with Mahler measure at most 1.3. (Received July 16, 2011)

1077-15-100 **Sivaram K. Narayan*** (sivaram.narayan@cmich.edu), Department of Mathematics, Pearce Hall 218, Central Michigan University, Mount Pleasant, MI 48859. *Lower Bounds for Minimum Semi-definite Rank from Orthogonal Removal and Chordal Supergraphs.*

The minimum semi-definite rank (msr) of a graph is the minimum rank among positive semi-definite matrices with the given graph. The OS-number is a useful lower bound for msr, which arises by considering ordered vertex sets with some connectivity properties. In this talk we discuss two new interpretations of the OS-number. We first show that OS-number is also equal to the maximum number of vertices which can be orthogonally removed from a graph under certain non-degeneracy conditions. Our second interpretation of the OS-number is as the maximum possible rank of chordal supergraphs who exhibit a notion of connectivity we call isolation-preserving. These interpretations not only give insight into the OS-number, but also allow us to prove some new results. For example we show that $msr(G) = |G| - 2$ if and only if $OS(G) = |G| - 2$. (Received July 26, 2011)

1077-15-109 **Chennah Heroor*** (chennah@mit.edu), **Troy Klingler** (kling1te@cmich.edu), **Anthony Pochini** (pochi1as@cmich.edu) and **Gretchen Schillemat** (geschillemat@gmail.com). *Bounds for the Minimum Semi-Definite Rank of Circulant Graphs.* Preliminary report.

The minimum rank of a graph is the smallest possible rank of any real symmetric matrix associated to the given graph. The real (complex) minimum semi-definite rank of a graph is the minimum rank among symmetric (Hermitian) positive semi-definite matrices associated to the given graph. A circulant graph, $G = Circ(n, S)$, is a graph with n vertices in which the i^{th} vertex is adjacent to the $(i+j)^{th}$ and $(i-j)^{th}$ vertices for each j in S which is a subset of {1, . . . , n}. The zero forcing set of a graph G is a subset of vertices Z, which are all colored black with the vertices in $G - Z$ colored white, where the derived coloring of G using a color change rule is all black. We are interested in the zero forcing number, denoted $Z(G)$, which is the minimum $|Z|$ over all zero forcing sets for a graph G. A positive semi-definite zero forcing number $Z_+(G)$ is defined using a different color change rule. In this talk, we will present results on $Z(G)$ and $Z_+(G)$ of certain classes of circulant graphs including $Circ(n, \{1, t\})$ and $Circ(n, \{a, a+1, a+2, \ldots, t\})$. These graph parameters provide bounds on the minimum rank and minimum semidefinite rank of these graphs. (Received July 27, 2011)

1077-15-118 **Martin S. Copenhaver*** (copenhaver@gatech.edu), **Cortney Logan** (clogan@students.stonehill.edu), **Kyanne Mayfield** (mayfield13@up.edu) and **Jonathan Sheperd** (jsheperd@nd.edu). *Diagram vectors of frames and the tight frame scaling problem.*

A frame is a redundant spanning set. A tight frame is a generalization of an orthonormal basis. A notion of digram vectors associated to frames in $\mathbb{R}^2$ has yielded many results about tight frames in $\mathbb{R}^2$. We provide a generalized notion of diagram vectors which allows for significant developments in the theory of tight frames in finite dimensions. In particular, we completely answer the *tight frame scaling problem* - that is, given a set of unit vectors $\{f_i\}_{i=1}^k$ in a finite dimensional Hilbert space $\mathcal{H}_n$, when do there exist positive scalars $c_1, \ldots, c_k$ so that $\{c_i f_i\}_{i=1}^k$ is a tight frame? When such scalings do exist, we provide a means of determining coefficients using a specific formulation for $\mathbb{R}^2$ as well as a general approach for $\mathcal{H}_n$ using techniques from computational geometry. (Received July 28, 2011)

1077-15-137 **Natalie Campbell** and **Kevin N. Vander Meulen*** (kvanderm@redeemer.ca), Department of Mathematics, Redeemer University College, 777 Garner Road, Ancaster, Ontario L9K 1J4, Canada, and **Adam van Tuyl**. *Nilpotent and spectrally arbitrary matrix patterns over $\mathbb{C}$.*

A zero-nonzero matrix pattern $\mathcal{A}$ is said to be potentially nilpotent over a field $\mathbb{F}$ if there exists a nilpotent matrix with entries in $\mathbb{F}$ having zero-nonzero pattern $\mathcal{A}$. We present classes of patterns which are potentially nilpotent over a field $\mathbb{F}$ if and only if $\mathbb{F}$ contains certain roots of unity. We then introduce some sparse patterns of order $n \geq 4$ which are spectrally arbitrary over $\mathbb{C}$ but not over $\mathbb{R}$. (A pattern $\mathbb{A}$ of order n is said to be a spectrally arbitrary pattern over $\mathbb{F}$ if for every degree n monic polynomial p with coefficients in $\mathbb{F}$, there is a matrix with pattern $\mathcal{A}$ whose characteristic polynomial equals p.) We employ a slight modification of the nilpotent-Jacobian method. (Received July 30, 2011)

1077-15-294 **Suren Jayasuriya*** (smj20@pitt.edu) and **Pedro Perez** (perez_pedro@columbusstate.edu). *Finite-Dimensional Frame Theory over Arbitrary Fields.* Preliminary report.

Frame theory has become of great importance in the past three decades, forming the theoretical basis behind signal processing and sampling theory. In 2009, Bodmann et al. investigated frames over $\mathbb{Z}_2$ in "Frame Theory for Binary Vector Spaces". Motivated by their work, we develop frame theory for finite-dimensional vector spaces over arbitrary fields $\mathbb{F}$ that may have a degenerate bilinear form. We introduce an analysis frame as a frame for a vector space such that the analysis operator $\Theta : V \to \mathbb{F}^k$ defined by $\Theta(x) = (\langle x, x_1\rangle, \langle x, x_2\rangle, \ldots, \langle x, x_k\rangle)^T$ is injective. We establish equivalent results on vector spaces that admit an analysis frame, called analysis spaces, including a reconstruction formula, Riesz Representation theorem, and existence of a dual frame pair. Defining a zero inner product subspace $ZIP(V) := \{x \in V | \langle x, y\rangle = 0 \ \ \forall y \in V\}$, we prove that every finite-dimensional vector space can be decomposed into an analysis space and its zero inner product subspace. This work was completed during the summer of 2011 at the Math REU program at Texas A & M University under the direction of Dr. David Larson. (Received August 18, 2011)

1077-15-368 **Mohammad Javaheri*** (mjavaheri@siena.edu), 515 Loudon Road, Siena College, School of Science, Loudonville, NY 12211. *Dense 2-generator subsemigroups of* 2×2 *matrices.*

We present a pair of 2×2 matrices (in both real and complex cases) such that the semigroup generated by the pair is dense in the set of all 2×2 matrices. (Received August 29, 2011)

1077-15-493 **Richard A Brualdi*** (brualdi@math.wisc.edu), **Jia-yu Shao**, **Shi-Cai Gong**, **Chang-Qing Xu** and **Guang-Hui Xu**. *On the Extremal Energy of Integral Weighted Graphs.*

Let $\mathcal{T}(n, m)$ and $\mathcal{F}(n, m)$ denote the classes of weighted trees and forests, respectively, of order n with the positive integral weights and the fixed total weight sum m, respectively. In this paper, we determine the minimum energies for both the classes $\mathcal{T}(n, m)$ and $\mathcal{F}(n, m)$. We also determine the maximum energy for the class $\mathcal{F}(n, m)$. In all cases, we characterize the weighted graphs whose energies reach these extremal values. We also solve the similar maximum energy and minimum energy problems for the classes of (0,1) weighted trees and forests. (Received September 05, 2011)

1077-15-496 **In-Jae Kim*** (in-jae.kim@mnsu.edu), 273 Wissink Hall, Mankato, MN 56001, and **Bryan L Shader** (bshader@uwyo.edu), University of Wyoming, 1000 E. University Ave., Laramie, WY 82071. *Unordered multiplicity lists of a class of binary trees.*

Associated with a given graph G on n vertices $1, 2, \ldots, n$, is the set $S(G)$ of all $n \times n$ real symmetric matrices $A = [a_{ij}]$ whose off-diagonal entries are placed according to the edges of G, i.e., for $i \neq j$, $a_{ij} \neq 0$ if and only if vertices i and j are adjacent. In this talk we present spectral properties of matrices in $S(G)$ for a class of binary trees G. We first show that a matrix A in $S(G)$ has no eigenvalues of multiplicity 4 or more, at most one eigenvalue of multiplicity 3, and at least three simple eigenvalues. We then completely determine the unordered multiplicity lists of these binary trees. As a consequence, it is shown that the minimum number of distinct eigenvalues of a matrix in $S(G)$ is one more than the diameter of G. (Received September 05, 2011)

1077-15-908 **Pauline van den Driessche*** (pvdd@math.uvic.ca). *Refined Inertia of Sign Pattern Matrices.* Preliminary report.

The refined inertia of a real $n \times n$ matrix $A = [a_{ij}]$ is the ordered 4-tuple of nonnegative integers $(n_+, n_-, n_z, 2n_p)$ where n_+ (resp. n_-) is the number of eigenvalues with positive (resp. negative) real part, and n_z (resp. $2n_p$) is the number of zero eigenvalues (resp. nonzero pure imaginary eigenvalues) of A. Associated with A is the $n \times n$ sign pattern matrix $\mathcal{S}_n = [s_{ij}]$ with $s_{ij} = sign(a_{ij})$, which in turn defines a sign pattern class $Q(\mathcal{S}_n)$ of matrices and an associated signed directed graph. A sign pattern $\mathcal{S}_n$ has refined inertia $(n_+, n_-, n_z, 2n_p)$ if there exists $A \in Q(\mathcal{S}_n)$ with this refined inertia. This talk discusses sign patterns that require or allow certain refined inertias, including those related to bifurcations in ordinary differential equation systems. (Received September 14, 2011)

1077-15-950 **Shaun M Fallat*** (sfallat@math.uregina.ca), Department of Mathematics and Statistics, University of Regina, Regina, Sask. s4s0a2, Canada. *Bipartiteness and the Signless Laplacian Matrix of a Graph.*

For the Laplacian matrix, L, of a graph G, Fiedler observed long ago that the smallest positive eigenvalue of L, $\alpha(G)$, is zero if and only if G is disconnected and that $\alpha(G) \leq \nu(G) \leq \epsilon(G)$ where $\nu(G), \epsilon(G)$ are, respectively, the vertex connectivity, and the edge connectivity of the graph G.

For the signless Laplacian matrix, Q, it is known that the smallest eigenvalue, $\lambda_b(G)$, is zero if and only if G is bipartite.

We establish the inequalities, $\lambda_b(G) \leq \nu_b(G) \leq \epsilon_b(G)$, where $\nu_b(G)$ and $\epsilon_b(G)$ denote the fewest number of vertices (resp. edges) whose deletion yields a bipartite graph. We also derive a number of useful relationships between the eigenvalues of Q and other parameters associated with G. (Received September 14, 2011)

1077-15-1048 **Minerva Catral*** (catralm@xavier.edu), Department of Mathematics & Computer Science, Xavier University, 3800 Victory Parkway, Cincinnati, OH 45207, and **Dale Olesky** and **Pauline van den Driessche**. *Drazin and Group Inverses of Matrices with Bipartite Digraphs.*

We consider block matrices whose digraphs are bipartite and present a simple block formula for their Drazin inverse. This form is used to derive a graph-theoretic description of the entries of the group inverse of some examples of such matrices. An open question about group inverses of matrices having more general bipartite digraphs is posed and a summary of cases for which its answer is known is given. (Received September 15, 2011)

1077-15-1076 **Nasser Dastrange*** (dastrange@bvu.edu), Buena Vista University, 610, West Fourth Street, Storm Lake, IA 50588. *On the eigenvalues and eigenvectors of the adjacency matrices of the complete graphs and complete bipartite graphs.* Preliminary report.

In this paper we use MATLAB software to compute the eigenvalues and the corresponding eigenvectors of the adjacency matrices of the complete graphs and complete bipartite graphs.

Furthermore, recent research, some interesting properties, and several examples will be presented to illustrate the topic. (Received September 16, 2011)

1077-15-1387 **Travis A. Peters*** (tpeters@iastate.edu). *Positive Semidefinite Zero Forcing.* Preliminary report.

The zero forcing number $Z(G)$ is used to study the maximum nullity/minimum rank of the family of symmetric matrices described by a simple, undirected graph G. We study the positive semidefinite zero forcing number $Z_+(G)$ and some of its properties. Given a graph G with some vertices S colored black and the remaining vertices colored white, the positive semidefinite color change rule is: If $W_1, W_2, ..., W_k$ are the sets of vertices of the k components of $G - S$, $w \in W_i$, $u \in S$, and w is the only white neighbor of u in the subgraph of G induced by $W_i \cup S$, then change the color of w to black. The positive semidefinite zero forcing number is the smallest number of vertices needed to be initially colored black so that repeated applications of the positive semidefinite color change rule will result in all vertices being black. The positive semidefinite zero forcing number is a variant of the (standard) zero forcing number, which uses the same definition except with a different color change rule: If u is black and w is the only white neighbor of u, then change the color of w to black. (Received September 19, 2011)

1077-15-1548 **Jason J Molitierno*** (molitiernoj@sacredheart.edu), Department of Mathematics, Sacred Heart University, 5151 Park Avenue, Fairfield, CT 06825-1000. *The algebraic connectivity of graphs as a function of genus.*

The Laplacian matrix for a graph on n vertices labeled $1, \dots, n$ is the $n \times n$ matrix whose i^{th} diagonal entry is the degree of vertex i, and the off diagonal entries (i, j) are -1 if vertices i and j are adjacent and 0 otherwise. Laplacian matrices are positive semidefinite, hence we can order the eigenvalues as $\lambda_1 \leq \lambda_2 \leq \dots \lambda_n$. Since the row sums of the Laplacian matrix are each zero, it follows that $\lambda_1 = 0$ since the vector of all ones is a corresponding eigenvector. The eigenvalue λ_2 is a measure of how connected the graph is and is known as the algebraic connectivity. For example, the algebraic connectivity is zero if and only if the graph is disconnected. Moreover, if edges are added to an existing graph, the algebraic connectivity monotonically increases. In this talk, we investigate the algebraic connectivity of graphs in terms of their topological properties. We find upper bounds on the algebraic connectivities of graphs in terms of their genus. We also determine the conditions of when the upper bounds can and cannot be achieved. (Received September 20, 2011)

1077-15-1806 **Yang Liu*** (yliu15@wm.edu), Department of Mathematics, College of William and Mary, P.O. Box 8795, Williamsburg, VA 23187. *Lower Rank Approximation: A Generalization of Schmidt-Mirsky Theorem and Algorithms.*

We study the optimal approximation of linear operators, especially, the linear operator on ℓ_p-space. Considering the generalized singular values, we prove an extension of Schmidt-Mirsky theorem. The results can be applied to matrix completion and sparse matrix recovery. (Received September 21, 2011)

1077-15-2067 **Dominic Kramer*** (kramerd@iastate.edu). *Identifying a Basis in a Frame.*

Given a frame, we present a convex optimization problem that identifies a subset of the frame that is a basis with some nice properties. In particular, if the frame is a union of two orthonormal bases, we show that the solution to the optimization problem identifies these bases. This is joint work with Eric Weber and Mark Lammers. (Received September 22, 2011)

1077-15-2213 **Leslie Hogben**, Ames, IA , and **Jillian McLeod*** (jillian.e.mcleod@uscga.edu), New London, CT 06322. *Partition Regular Matrices from a Linear Algebraic Perspective.*

In 1933 Richard Rado wrote a treatise on finite (kernel) partition regular matrices (PR matrices), in which he completely characterized such matrices using his famous *columns condition*. These matrices most often appear in the context of finite Ramsey theory where they can be used to reinterpret typical Ramsey-type statements such as Shur's Theorem, van der Waerden's Theorem, and the Finite Sums Theorem. Much attention has been given to the combinatorial understanding of what it means for a matrix to be PR. The columns condition provides an equivalent and distinctly linear algebraic interpretation, but the linear algebra of PR matrices appears to be less studied in the literature. In this talk I will discuss some of the linear algebraic properties of PR matrices along with some new results related to the oriented vertex-edge incidence matrix of a strongly connected graph- which, it turns out, is always a PR matrix.

(Received September 21, 2011)

1077-15-2225 **Joseph Kolibal*** (Joseph.Kolibal@usm.edu), Department of Mathematics, The University of Southern Mississippi, Box 5045, Hattiesburg, MS 39406, and **Eowyn Cenek**. *A fast iterative Toeplitz solver.* Preliminary report.

We introduce an efficient iterative solver suitable for inverting or finding solutions to some large dense or full matrices that typically arise in a variety of engineering and signal processing problems, and provide suitable criteria for convergence as well as examining methods to assure the convergence of the iteration. In particular, in solving $Ax = b$, we show that for diagonally dominant Toeplitz matrices that we can solve for x using $O(2^k n \log n)$ operations, for a small integer k. If the Toeplitz matrix is not diagonally dominant, but does have an extended dominant diagonal, we can still solve the problem using $O(2^k n \log n)$ operations. While the method is computationally efficient, there are a number of computational issues which require attention, including the need for extended precision arithmetic to achieve accurate results due to the potential large growth in numerical errors when applying the method. (Received September 21, 2011)

1077-15-2250 **Joshua Ide*** (ji1574@ship.edu) and **Lenny Jones**. *Enumerating Invariant Subspaces of $\mathbb{R}^n$.*

Let T be a linear operator defined over $\mathbb{R}^n$. In this talk, we explore for what positive integers m does there exist exactly m T-invariant subspaces of $\mathbb{R}^n$. (Received September 21, 2011)

1077-15-2574 **Ulrica Wilson*** (uwilson@morehouse.edu), Morehouse College, Atlanta, GA 30314, and **Leslie Hogben**, Iowa State University, Ames, IA 50011. *Eventually r-cyclic matrices.*

An eventual property of a matrix $M \in \mathbb{C}^{n\times n}$ is a property that holds for all powers $M^k, k \geq k_0$, for some positive integer k_0. Eventually positive and eventually nonnegative matrices have been studied extensively since their introduction by Friedland in 1978. A matrix is strongly eventually nonnegative if it is eventually nonnegative and it has a power that is both irreducible and nonnegative. In 2010, Hogben introduced and used eventually r-cyclic matrices to establish an algorithm to determine whether a matrix is strongly eventually nonnegative. We studied eventual properties of matrices from a unified perspective and established properties of the eigenstructure of eventually r-cyclic matrices. (Received September 22, 2011)

1077-15-2602 **Edward D. Hanson*** (hanson@math.wisc.edu), Department of Mathematics, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706-1388. *A characterization of Leonard pairs using the parameters $\{a_i\}_{i=0}^d$.*

Let V denote a vector space with finite positive dimension. We consider an ordered pair of linear transformations $A : V \to V$ and $A^* : V \to V$ that satisfy (i) and (ii) below:

(1) There exists a basis for V with respect to which the matrix representing A is irreducible tridiagonal and the matrix representing A^* is diagonal.

(2) There exists a basis for V with respect to which the matrix representing A^* is irreducible tridiagonal and the matrix representing A is diagonal.

We call such a pair a *Leonard pair* on V. Arlene Pascasio recently obtained a characterization of the Q-polynomial distance-regular graphs using the intersection numbers a_i. In this talk, we extend her results to a linear algebraic level and obtain a characterization of Leonard pairs. Pascasio's argument appears to rely on the underlying combinatorial assumptions, so we take a different approach that is algebraic in nature. (Received September 22, 2011)

1077-15-2757 **Wayne Barrett*** (wayne@math.byu.edu), Department of Mathematics, Brigham Young University, Provo, UT 84602. *The Inverse Inertia Problem for Graphs.*

Let G be a graph on n vertices and let $S(G)$ be the set of all real symmetric $n \times n$ matrices whose nonzero off-diagonal entries occur in exactly the positions corresponding to the edges of G. The inverse eigenvalue problem for G is:

(IEPG) Given a graph G on n vertices and real numbers $\lambda_1, \lambda_2, \ldots, \lambda_n$, is there a matrix in $S(G)$ with eigenvalues equal to $\lambda_1, \lambda_2, \ldots, \lambda_n$?

The major progress on the (IEPG) has been made for trees; it is an open problem for most other graphs.

A simplification of the (IEPG) is the inverse inertia problem. The *partial inertia* of a real symmetric matrix A is the pair $(\pi(A), \nu(A))$, where $\pi(A)$ is the number of positive eigenvalues of A, and $\nu(A)$ is the number of negative eigenvalues. The inertia set of a graph G is the set of all partial inertias of matrices in $S(G)$.

We give an overview of a number of techniques that have been used for determining the inertia sets of graphs including clique and star covers, the graph operations of edges subdivision/deletion and joins, separating sets, and Colin de Verdière parameters. These suffice to determine the inertia sets of the 1,252 graphs on 7 or fewer vertices. (Received September 22, 2011)

1077-15-2809 **Louis Deaett*** (Louis.Deaett@quinnipiac.edu). *The minimum semidefinite rank of the Heawood graph is 10.*

The Heawood graph is the unique (3,5)-cage graph, and the point-line incidence graph of the Fano plane. Consider an assignment to each vertex of this graph of a vector in $\mathbb{C}^n$ such that two vectors are orthogonal if and only if the vertices to which they are assigned are not adjacent. In joint work with H. Tracy Hall, we show that the smallest n for which this is possible is $n = 10$. That is, the minimum semidefinite rank of the Heawood graph is equal to 10. (Received September 22, 2011)

1077-15-2873 **Troy V Banks*** (tvbanks@salisbury.edu), Department of Math and Computer Science, Salisbury University, 1101 Camden Ave, Salisbury, MD 21801. *On the structure of certain class of Toeplitz-like Kernels.*

We study the structure of a certain class of Toeplitz-like positive definite kernels on the free semigroup on N generators. We explore some possible applications to multiscale processes and to learning with kernels. Associated classes of orthogonal polynomials are also investigated. (Received September 22, 2011)

1077-15-2917 **Ileana Ionascu*** (ionascui@philau.edu). *Variations of orbit reflexivity for matrices.*

The presentation will give the characterizations of orbit reflexivity and of some more newly defined variations of it, as C-orbit reflexivity and null-orbit reflexivity for matrices seen as operators on finite dimnensional spaces. (Received September 23, 2011)

1077-15-2926 **Walid Sharabati*** (sharabati@gmail.com), Lafayette, IN 47905. *Clustering edges and vertices using fuzzy logic, case study: news documents.*

In this paper, we first present the inner product method to compute a similarity measure for edges and vertices using covariate information associated with vertices and edges based on the external structure of the network. The vector of covariates associated with vertices is utilized to predict missing edges. We then discuss the interchangeability and duality between vertices and edges in a graph, and ultimately, to compute a similarity measure for vertices using the line graph transformation. Then we introduce a fuzzy logic algorithm to cluster vertices. Finally, we apply the two methods on news documents and compare results. (Received September 23, 2011)

16 ► Associative rings and algebras

1077-16-576 **Andrea Jedwab** and **M. Susan Montgomery***, Dept of Mathematics, KAP 104, USC, 3620 S. Vermont Ave, Los Angeles, CA 90089-2532. *Brauer characters and Frobenius-Schur indicators for bismash products.* Preliminary report.

For a finite group G, Brauer characters give a way of studying irreducible representations in characteristic p, by "lifting" information to characteristic 0. We extend the notion of Brauer characters and some basic properties to the case of a bismash product $H = k^G \# kF$ of groups F, G. For example, we show that the determinant of the Cartan matrix is a power of p. We then prove the analog of a theorem of J. Thompson (1986) on Frobenius-Schur indicators:

THEOREM: *Let k be an algebraically closed field of odd characteristic. Let $H_{\mathbb{C}} = \mathbb{C}^G \# \mathbb{C}F$ be a bismash product over $\mathbb{C}$ and $H_k = k^G \# kF$ the corresponding bismash product over k.*

Then if all irreducible $H_{\mathbb{C}}$-modules have Schur indicator $+1$ (respectively ± 1), the same is true for all irreducible H_k-modules.

Using the theorem and our previous work with Jedwab over $\mathbb{C}$ we show that if k is as above and $H_k = k^{C_n} \# kS_{n-1}$ is the bismash product constructed from the standard factorization of the symmetric group $S_n = S_{n-1}C_n$, then every irreducible representation of H_k has indicator $+1$, that is H_k is totally orthogonal. (Received September 07, 2011)

1077-16-1188 **David E. Radford*** (radford@uic.edu). *On the algebra of a class of finite-dimensional objects which accounts for some invariants of 1-1 tangles, knots, and links.* Preliminary report.

There are generalizations of quasitriangular and coquasitriangular Hopf algebras, namely quantum algebras and coalgebras and their specializations, which produce regular isotopy invariants of 1-1 tangles, knots, and links, classical or virtual. We investigate the class of these objects from the point of view of duality, their representations, and various constructions, including products. The nature of the invariants arising from constructions is explored. (Received September 17, 2011)

1077-16-1326 **Shlomo Gelaki*** (gelaki@math.technion.ac.il). *On Symmetric Tensor Categories.*

I will present some new results concerning symmetric tensor categories, which answer questions and conjectures of J.P. Serre. (Received September 19, 2011)

1077-16-1382 **Manizheh Nafari*** (manizheh@uta.edu), Department of Mathematics, University of Texas at Arlington, P.O.Box 19408, Arlington, TX 76019, and **Michaela Vancliff** (vancliff@uta.edu), Department of Mathematics, University of Texas at Arlington, P.O.Box 19408, Arlington, TX 76019. *Graded Skew Clifford Algebras that are Twists of Graded Clifford Algebras.*

We prove that if A is a regular graded skew Clifford algebra and is a twist of a regular graded Clifford algebra B by an automorphism, then the subalgebra of A generated by a certain normalizing sequence of homogeneous degree-two elements is a twist of a polynomial ring by an automorphism, and is a skew polynomial ring. We also present an example that demonstrates that this can fail when A is not a twist of B. (Received September 19, 2011)

1077-16-1476 **Mark Kleiner*** (mkleiner@syr.edu), Department of Mathematics, Syracuse University, Syracuse, NY 13244-1150, and **Markus Reitenbach**, Department of Mathematics and Statistics, Colorado Mesa University, Grand Junction, CO 81501. *Functorial approach to differentiation algorithms for representations of partially ordered sets.*

Adjoint functors and projectivization in representation theory of partially ordered sets are used to generalize the algorithms of differentiation by a maximal and by a minimal point. Conceptual explanations are given for the combinatorial construction of the derived set and for the differentiation functor. (Received September 19, 2011)

1077-16-1502 **Alexander V. Odesskii** (aodesski@brocku.ca), St. Catharines, Ontario L2S 3A1, Canada, **Vladimir N. Rubtsov*** (volodya@univ-angers.fr), 2, boulevard Lavoisier, Faculté des Sciences, Département de Mathématiques, LAREMA, 49000 Angers, France, and **Sokolov V. Vladimir**, Kosygina st., 2, Moscow, 119334, Russia. *Non-abelian quadratic Poisson brackets: From noncommutative ODE to noncommutative Algebraic Geometry and back.* Preliminary report.

We study some general non-abelian quadratic Poisson brackets. The study was motivated by some top-like integrable systems on associative algebras. We give and interpret the compatibility condition of linear and quadratic non-abelian Poisson structures using Hochshild cohomology of infinitesimal associative bialgebras. We give a full classification of such structures in the case of the free associative algebra with 2 generators. Relations with double Poisson structure of M. Van den Bergh and H_0-structures of W. Crawley-Boevey are discussed. (Received September 20, 2011)

1077-16-1787 **Siu-Hung Ng*** (rng@iastate.edu), Mathematics Department, Iowa State University, Ames, IA 50011. *Congruence property and Galois symmetry of modular categories.*

The natural representation of SL(2,$\mathbb{Z}$) associated to a RCFT has been conjectured, by Eholzer, to be t-rational and have a congruence kernel. It is further conjectured by Coste and Gannon a Galois symmetry of this representation. Some of these conjectures have been proved mathematically in the context of modular categories via the machinery called generalized Frobenius-Schur indicators. In this talk, I will report recent progress of these conjectures for modular categories. (Received September 20, 2011)

1077-16-1796 **Jeanette Shakalli*** (shakalli@math.tamu.edu). *Deformations of an Algebra.* Preliminary report.

Roughly speaking, the purpose of deformation theory is to organize objects of some type, in our case algebras, into continuous families and then determine how the objects within each family are related. Given an algebra, finding all its deformations is, if at all possible, quite a challenging problem. For this reason, several specializations of this question have been proposed. For instance, authors, such as Guccione et al and Witherspoon, concentrate their efforts in the study of deformations of an algebra arising from an action of a Hopf algebra.

Recently, we have obtained a general construction of a deformation of a smash product algebra, which is derived from an action of a particular Hopf algebra. This Hopf algebra is generated by skew-primitive and group-like elements, and depends on a complex parameter. The smash product algebra is defined on the quantum symmetric algebra of a finite-dimensional complex vector space and a group. In this work, we will present an application of this result, which has enabled us to find a deformation of such a smash product algebra which is, to the best of our knowledge, the first known example of a deformation in which the new relations in the deformed algebra involve elements of the vector space. (Received September 21, 2011)

1077-16-1984 **Shannon Talbott*** (shannon-talbott@uiowa.edu). *Stable Endomorphism Rings.*

Quivers, which are directed graphs, provide a combinatorial framework for the study of representations of algebras. Let k be an algebraically closed field. A representation of a quiver over k is given by a family of k-vector spaces, one for each vertex of the quiver, and a family of k-linear transformations, one for each arrow of the quiver. A k-linear combination of non-zero paths of the quiver (of length greater than 1) which begin and end at the same vertex is called a relation of the quiver. We look at a special class of algebras which are defined by certain quivers and relations and for which all representations are given combinatorially. We consider special modules M, called string modules. We show, using examples, how their endomorphism ring $End(M)$ can be determined as well as their stable endomorphism ring $\underline{End}(M)$ which is the quotient of $End(M)$ by the ideal of those endomorphisms of M that factor through a projective module. (Received September 21, 2011)

1077-16-2186 **Christopher L Phan***, Department of Mathematics, Bucknell University, Lewisburg, PA 17837. *Delayed Koszul Duality.* Preliminary report.

It's a classic result that the Yoneda algebra $E(A) = Ext_A(k,k)$ of a Koszul algebra A is another quadratic algebra, which is again Koszul; indeed, $E(E(A)) \simeq A$. Green, et. al., have also proven a similar property for Berger's class of N-Koszul algebras: if A is N-Koszul, then $E(E(E(A))) \simeq E(A)$. We study the condition $E(E(E(A))) \simeq E(A)$ in general, and prove this property is preserved under a number of operations. (Received September 21, 2011)

1077-16-2239 **Christof Geiss*** (christof@matem.unam.mx), Ciudad Universitaria, Mexico, D.F. 04510, **Bernard Leclerc** (bernard.leclerc@unicaen.fr), Caen, France, and **Jan Schroeer** (schroer@math.uni-bonn.de), Bonn, Germany. *Cluster structures on quantum coordinate ring.* Preliminary report.

We show that the quantum coordinate ring of the unipotent subgroup N(w) of a symmetric Kac-Moody group G associated with a Weyl group element w has the structure of a quantum cluster algebra. This quantum cluster structure arises naturally from a subcategory C_w of the module category of the corresponding preprojective algebra. An important ingredient of the proof is a system of quantum determinantal identities which can be viewed as a q-analogue of a T-system. In case G is a simple algebraic group of type A, D, E, we deduce from these results that the quantum coordinate ring of an open cell of a partial flag variety attached to G also has a cluster structure. (Received September 21, 2011)

1077-16-2292 **David Nacin*** (nacind@wpunj.edu), 63 Ferndale Lane, Lincoln Park, NJ 07035. *A Minimal Non-Koszul $A(\Gamma)$.*

We describe the collection of associative non-commutative algebras $A(\Gamma)$ sometimes also known as splitting algebras. This class of algebras is important due to its relationship to factorizations of polynomials with non-commutative coeffcients.

In 2008 a non-Koszul example of an algebra of this type was found. Recent results by Retakh, Serconek and Wilson have produced conditions for numerical Koszulity based upon the homological properties of the graph. We discuss a computer aided proof which gives the minimal example of a layered graph producing an $A(\Gamma)$ which fails to be Koszul. (Received September 22, 2011)

1077-16-2659 **Matt S Davis*** (davis@math.hmc.edu). *Representations of rank two affine Hecke algebras at roots of unity.*

We will describe a method for classifying the irreducible representations of the crystallographic rank two affine Hecke algebras using algebraic and combinatorial methods, for all possible values of q. The focus is on the case when q is a root of unity of small order. The classification is based mostly on weight spaces of modules and the way in the specialization for q affects the distribution of weight spaces among the irreducibles for each central character. (Received September 22, 2011)

1077-16-2707 **Yorck Sommerhäuser*** (sommerh@jaguar1.usouthal.edu), University of South Alabama, Department of Mathematics and Statistics, 411 University Blvd N, Mobile, AL 36688. *Conductors and Exponents.*

It is not difficult to see that the entries of the Verlinde matrix of a semisimple factorizable Hopf algebra are contained in the cyclotomic field determined by its exponent. But as the Drinfel'd double of the symmetric group on three letters demonstrates, this is not necessarily the smallest cyclotomic field that contains these entries. On the other hand, the cyclotomic field determined by the exponent is close to being as small as possible, as we show in the talk: If N is the exponent of the semisimple factorizable Hopf algebra and C is the conductor of the field that is generated by the entries of its Verlinde matrix, then N divides the least common multiple of $2C$ and 24. Here, the conductor of an abelian number field is the order of the root of unity that generates the smallest cyclotomic field containing this abelian field.

The stated result holds more generally for Galois modular data. It follows from work of Y. Zhu and the speaker that modular data coming from semisimple factorizable Hopf algebras are Galois. We note that S.-H. Ng has, in a conference talk in Almeria in July 2011, announced that modular data coming from modular categories also have the Galois property, which would imply that this result can be generalized accordingly. (Received September 22, 2011)

1077-16-2733 **Arkady Berenstein** (arkadiy@math.uoregon.edu) and **Jacob Greenstein*** (jacob.greenstein@ucr.edu). *Topological Hall algebras and exponentials in categories.* Preliminary report.

We define a topological Hall algebra by dropping the exactness. The resulting algebra is a deformation of the completion of the usual Hall algebra with respect to the grading by the Grothendieck group, and its associativity leads to rather non-trivial q-binomial identities. To establish the existence of an integral isomorphism of the topological Hall algebra onto the completion of the Hall algebra, one needs to introduce exponentials of categories and study their factorizations. In particular, this yields non-commutative generating functions for Grassmanians in categories, as well as interesting q-exponential identities. (Received September 22, 2011)

1077-16-2742 **Calin Chindris**, **Piotr Dowbor**, **Ryan Kinser** and **Jerzy Weyman*** (j.weyman@neu.edu). *Semi-invariants and the representation type of Artin algebras.* Preliminary report.

I report on the joint work with Calin Chindris, Piotr Dowbor and Ryan Kinser. We address hte following questions. 1. Suppose an Artin algebra has the property that in every dimension vector every irreducible component has an open orbit. Is A of finite representation type ? 2. Let A be a triangular algebra such that for every irreducible component C of representation spaces of A the ring SI(C) of semiinvariants on C has weight spaces of dimension at most 1. Is A of finite representation type.

We give counterexamples to both statements. (Received September 22, 2011)

1077-16-2764 **Edward Richmond*** (erichmond@math.ubc.ca) and **Arkady Berenstein**. *Littlewood-Richardson coefficients for reflection groups.*

Let G be a simple Lie group or Kac-Moody group and P be a parabolic subgroup of G. One of the goals Schubert calculus is to understand the product structure of the cohomology ring $H^*(G/P)$ with respect to its basis of Schubert classes. If G/P is the Grassmannian, then the structure constants corresponding to the Schubert basis are the classical Littlewood-Richardson coefficients which appear in various topics such as enumerative geometry, algebraic combinatorics and representation theory.

In this talk, I will discuss joint work with A. Berenstein in which we give a combinatorial formula for these coefficients in terms of the Cartan matrix corresponding to G. In particular, our formula implies positivity of the "generalized" Littlewood-Richardson coefficients in the case where the off diagonal Cartan matrix entries are not equal to -1. Moreover, this positivity result is purely algebraic and does not rely on the geometry of the flag variety G/P. (Received September 22, 2011)

1077-16-2846 **Padmini P Veerapen*** (pveerapen@uta.edu), 411 S. Nedderman Drive, 478 Pickard Hall, Arlington, TX 76019-0408, and **Michaela Vancliff**. *Noncommutative Quadratic Forms.* Preliminary report.

To every (commutative) quadratic form is associated a symmetric matrix, and one has the standard notions of rank and determinant function defined on the matrix, and, thus, on the quadratic form. In a recent paper by T. Cassidy & M. Vancliff, the notion of quadratic form is extended to the noncommutative setting. In this talk, we define a notion of rank (μ-rank) on such noncommutative quadratic forms. We use our definition of μ-rank of a noncommutative quadratic form to establish a connection between the points in the zero locus of the relations of a graded skew Clifford algebra A and quadratic forms of μ-rank at most two associated to A. (Received September 22, 2011)

17 ► Nonassociative rings and algebras

1077-17-63 **Rebecca L. Jayne*** (jayne.rebecca@gmail.com), Washington College, 300 Washington Ave., Chestertown, MD 21620, and **Kailash C. Misra** (misra@math.ncsu.edu), Department of Mathematics, North Carolina State University, Box 8205, Raleigh, NC 27606. *Maximal weights and multiplicities of certain $\widehat{sl}(n)$-modules.*

Consider $V(\Lambda)$, the integrable highest weight $\widehat{sl}(n)$-module of highest weight Λ. The maximal weights are those that, when we consider the weight structure of $V(\Lambda)$, form something like a roof; the rest of the weights occur on strings stemming from the maximal weights. It is known that the set of maximal dominant weights of $V(\Lambda)$ is finite. We give explicit descriptions of maximal dominant weights for certain Λ and examine the multiplicities of particular maximal dominant weights. To determine these multiplicities, we use combinatorial objects called extended Young diagrams. We discuss a relationship between multiplicity and avoiding permutations and exhibit this relationship for some low rank cases. (Received July 15, 2011)

1077-17-120 **Peter Fedak**, Harvey Mudd College, Claremont, CA, **Gizem Karaali***, Pomona College, Claremont, CA, **Keith McHugh**, Pomona College, Claremont, CA, **Aaron Pribadi**, Harvey Mudd College, Claremont, CA , and **Sundeep Sampath**, Claremont Graduate University, Claremont, CA. *Constructing Integrable Systems From Graded Classical r-Matrices.* Preliminary report.

We examine methods of constructing integrable systems from solutions of the graded classical Yang-Baxter equation (CYBE). This process is well-understood in the non-graded case; we extend its scope to Lie superalgebras by following the work of Zhang, Gould, and Bracken (1991). In particular, we explicitly describe an approach to go from the r-matrix solutions of the graded CYBE to an integrable classical system on a supermanifold.

We illustrate our method with examples of integrable systems and examine how they relate to their non-graded counterparts. (Received July 28, 2011)

1077-17-390 **Noah Snyder*** (nsnyder@math.columbia.edu), **Christopher Douglas** and **Christopher Schommer-Pries**. 3-*Dimensional Topology and Finite Tensor Categories.*

The Turaev-Viro construction assigns to a spherical fusion category a 3-dimensional topological field theory. We generalize this construction in three ways. First we construct a fully local 0123 extended TFT. Second, we relax the assumption of sphericality on the fusion category; an arbitrary fusion category gives a 3-framed TFT while an additional choice of spherical structure yields an oriented TFT. Third we show that a non-semisimple finite tensor category gives a non-compact fully extended TFT. This correspondence between finite tensor categories and TFTs allows one to translate algebraic statements and arguments into topology and vice-versa. In particular, the generalization of Radford's theorem to finite tensor categories is equivalent to the fact that $\pi_1(\mathrm{SO}_3) \cong \mathbb{Z}/2$. (Received August 28, 2011)

1077-17-453 **James E. Humphreys*** (jeh@math.umass.edu). *Special nilpotent orbits and modular Lie algebra representations.* Preliminary report.

Let $\mathfrak{g}$ be the Lie algebra of a simple algebraic group over an algebraically closed field of good characteristic $p > 0$. The simple modules for its universal enveloping algebra $U(\mathfrak{g})$ are those for finite dimensional reduced enveloping algebras $U_\chi(\mathfrak{g})$ with $\chi \in \mathfrak{g}^*$. The crucial case involves "nilpotent" χ. Given a regular block in $U_\chi(\mathfrak{g})$, it is natural to ask which power of p divides the dimension of each simple module in the block. The Kac–Weisfeiler Conjecture, proved by Premet, ensures that p^d divides all dimensions if the orbit of χ under the adjoint group has dimension $2d$; further work of Premet shows this power is best possible (at least for p "sufficiently large"). On the other hand, a higher power of p is sometimes observed. We discuss evidence that this may occur just when the orbit of χ is *non-special* in Lusztig's sense. (Received September 02, 2011)

1077-17-1214 **Eric Sommers***, Dept of Mathematics and Statistics, LGRT, Amherst, MA 01003. *On a duality for nilpotent orbits.* Preliminary report.

We calculate minimal points in a Cartan subalgebra of a Lie algebra satisfying certain conditions (one involves the associated variety of the corresponding maximal primitive ideal determined by the point in the Cartan). This is related to the interpretation of Lusztig-Spaltenstein duality by Barbasch-Vogan and explains the generalization of this duality by the author, and then further by Achar. (Received September 18, 2011)

1077-17-1432 **linlin Chen*** (linlin.chen@mavs.uta.edu), Department of Mathematics, University of Texas at Arlington, P.O. Box 19408, Arlington, TX 76019-0408, and **Minerva Cordero** (cordero@uta.edu), Department of Mathematics, University of Texas at Arlington, P.O. Box 19408, Arlington, TX 76019-0408. *Equivalent Condition of Primitivity for Semifields.*

For a semifield S of order q^n, we prove that $d \in S$ is a right primitive element if and only if its characteristic polynomial has order $q^n - 1$. With this result, we find that there are 70 right and left primitive elements in Knuth binary semifield of order 2^7. We also show that the image of a right primitive element under an automorphism of S is right primitive and from that it follows Knuth system W has 3 automorphisms. (Received September 19, 2011)

1077-17-1443 **Valerio Toledano Laredo*** (v.toledanolaredo@neu.edu), 360 Huntington Ave, Boston, MA 02115. *Yangians, quantum loop algebras and trigonometric connections.*

I will describe monodromy representations of affine braid groups arising from a flat connection with values in the Yangian of a simple Lie algebra g. These representations are related to those arising from the quantum Weyl group operators of the quantum loop algebra of g. Matching these two classes of representations involves in particular the construction of a functor relating finite-dimensional modules of those two quantum groups.

This is based on joint work with Sachin Gautam. (Received September 19, 2011)

1077-17-1454 **Andrew Douglas*** (afdouglas@gmail.com), Department of Mathematics, CIty University of New York, NYCCT, 300 Jay Street, Brooklyn, NY 11201, **Delaram Kahrobaei**, Department of Mathematics, City University of New York (NYCCT), 300 Jay Street, Brooklyn, NY 11201, and **Joe Repka**. *Abelian extensions of orthogonal Lie algebras in E_6 and E_8.*

We construct abelian extensions of the special orthogonal Lie algebras D_5 and D_7, which we embed into the exceptional Lie algebras E_6 and E_8, respectively. We then examine the finite-dimensional, irreducible representations of E_6 and E_8 restricted to the abelian extensions of D_5 and D_7, respectively, under the embeddings. The irreducible representations of E_6 remain indecomposable upon restriction to $\widetilde{D}_5$. Irreducible representations of E_8 may decompose upon restriction to $\widetilde{D}_7$. Next, we illustrate why the methods used in the article cannot be extended to D_6 and E_7. As a final application, we show that a certain "natural" embedding of D_7 into E_8 cannot be lifted to an extension of D_7 by a 64-dimensional non-abelian algebra. (Received September 19, 2011)

1077-17-1471 **Sam Evens*** (sevens@nd.edu). *The Belkale-Kumar cup product.*

This talk is based on joint work with Bill Graham. I will explain how to interpret the Belkale-Kumar deformed cup product using deformations of Lie algebras. Time permitting, I will also discuss the Kac-Moody case. (Received September 19, 2011)

1077-17-1576 **Qiang Mu*** (qmu520@gmail.com), School of Mathematical Sciences, Harbin Normal University, Harbin, Heilongjia 150080, Peoples Rep of China. *Cartan Type Lie Superalgebra $\widetilde{S}(n)$ over a Field of Positive Characteristic.*

We show that every derivation of Cartan type modular Lie superalgebra $\widetilde{S}(n)$ is inner, and $\widetilde{S}(n)$ has no nonsingular associative form. (Received September 20, 2011)

1077-17-1674 **Julie Beier*** (beier_jc@mercer.edu), Mercer University, Department of Mathematics, 1400 Coleman Avenue, Macon, GA 31201. *Weights and Combinatorics Appearing in Certain Demazure Crystals.*

Crystal bases provide a useful tool for studying the combinatorics of integrable representations of quantum affine algebras. The integrable modules contain certain important subspaces called Demazure modules. We look specifically at the quantum affine algebra $U_q(\widehat{sl}(n))$. The crystal bases for integrable modules of this quantum group can be realized in terms of combinatorial objects called extended Young diagrams. Previously, we used this representation to give an explicit realization of a certain class of Demazure crystals. Here we give this explicit realization, calculate the weights of the elements in this family of Demazure crystals and show the correspondence between the weights and the extended Young diagrams. (Received September 20, 2011)

1077-17-1762 **Jeannette Mun Larsen*** (JeannetteLarsen@my.unt.edu), 2019 Elk Trail, Harker Heights, TX 76548. *Equivalence Classes of Subquotients of Pseudodifferential Operator Modules on the Line.* Preliminary report.

Consider the spaces Ψ of pseudodifferential operators between spaces of tensor densities on the line. These spaces are modules for the Lie algebra of vector fields on the line, and their degree filtration Ψ^K is invariant under this module structure. The question of the equivalence classes of the subquotients Ψ^K / Ψ^{K-L} has been considered by Lecomte and Ovsienko, but only in the case of operators between tensor densities of the same degree. We treat the projectively split case in general. The subquotients at L = 5 are particularly interesting: complete invariants for their equivalence classes are given by pencils of conics and cubics in a certain plane of parameters associated to the tensor densities. (Received September 20, 2011)

1077-17-2259 **Marco A Aldi*** (aldi@brandeis.edu) and **Reimundo Heluani**. *Twisted Nilmanifolds and Dilogarithmic OPEs.*

We describe new representations of certain central extensions of 2-step nilpotent Lie algebra. Our construction resembles that of lattice vertex algebras, but the basic OPEs have dilogarithmic singularities. The geometry of the underlying nilmanifolds reveals the existence of a natural class of intertwiners. (Received September 21, 2011)

1077-17-2633 **Sachin Gautam*** (sachin@math.columbia.edu), Department of Mathematics, Columbia University, 2990 Broadway, New York, NY 10027. *Yangians and quantum loop algebras.*

For a simple Lie algebra $\mathfrak{g}$, the Yangian $Y_\hbar\mathfrak{g}$ and the quantum loop algebra $U_\hbar L\mathfrak{g}$ are deformations of the current algebra $\mathfrak{g}[u]$ and the loop algebra $\mathfrak{g}[z, z^{-1}]$ respectively. These deformations arise as a tool to construct rational and trigonometric solutions of the quantum Yang-Baxter equation.

In this talk I will present an explicit relation between the representation theories of the Yangian and quantum loop algebra associated to a simple Lie algebra $\mathfrak{g}$. The motivation for constructing such a relation lies in an attempt to understand the monodromy of a certain trigonometric connection (constructed by V. Toledano Laredo) which appears naturally in the theory of quantum cohomology for quiver varieties.

This talk is based on a joint work with V. Toledano Laredo (arxiv:1012.3687). (Received September 22, 2011)

1077-17-2711 **Angela M. Brown*** (ambrown@uta.edu). *Some New Results on Albert-Like Semifield Planes.* Preliminary report.

A semifield is a non-associative division ring. In 1958 Albert defined the "twisted fields" which are semifields with elements in $\mathbb{GF}(p^n)$ where p is prime and with multiplication defined by

$$x \circ y = xy^{p^m} - cx^{p^m} y$$

where $1 \leq m < n, c \neq a^{p^m - 1}$ for $a \in \mathbb{GF}(p^n)$. In 1961 Albert further defined the "generalized twisted fields" similarly with a new product

$$x \circ y = xy - cx^{\alpha} y^{\beta}$$

where $\alpha, \beta \in$ Aut $(\mathbb{GF}(p^n)), c \neq x^{\alpha-1} y^{\beta-1}$ and $x, y \in \mathbb{GF}(p^n)$. We are working with a similarly defined product with an additional term. This product is defined as:

$$x \circ y = xy + Ax^{\alpha} y^{\beta} + Bx^{\beta} y^{\alpha}$$

where $\alpha \neq 1, \beta \neq 1, \alpha \neq \beta$ are automorphisms of $\mathbb{GF}(p^n)$ with $p \geq 3, n \geq 4$ and $A, B \in \mathbb{GF}(p^n)$.

These algebraic structures are used to coordinatize projective planes. We will be discussing our results obtained concerning automorphisms on these projective planes, namely those projective planes over the base field $(\mathbb{GF}(3^6))$. (Received September 22, 2011)

18 ► Category theory; homological algebra

1077-18-114 **Ik Jae Lee*** (ijlee@math.ksu.edu), 3103 Heritage Ct. #64, Manhattan, KS 66503. *A new generalization of the Khovanov Homology.* Preliminary report.

In this paper we give a new generalization of the Khovanov homology. The construction begins with a Frobenius-algebra-like object in a category of graded vector-spaces with an anyonic braiding, with most of the relations weaken to hold only up to phase. The construction of Khovanov can be adapted to give a new link homology theory from such data. Both Khovanov's original theory and the odd Khovanov homology of Oszvath, Rassmusen and Szabo arise from special cases of the construction in which the braiding is a symmetry. (Received July 28, 2011)

1077-18-212 **Radmila Sazdanovic*** (radmilas@math.upenn.edu), University of Pennsylvania, DRL 209 33rd South street, Philadelphia, PA 19104-6395, and **Mikhail Khovanov**. *Categorification of the polynomial ring.*

We introduce a categorification of the one-variable polynomial ring Z[x], based on the geometrically defined graded algebra and show how to lift various operations on polynomials to the categorified setting. This construction generalizes to categorification of various orthogonal polynomials, including Chebyshev polynomials and the Hermite polynomials. (Received August 12, 2011)

1077-18-447 **Pavel Etingof***, Department of Mathematics, MIT, 77 Massachusetts Ave., Cambridge, MA 02139, and **Shlomo Gelaki**, Department of Mathematics, Technion - Israel Institute of Technology, Haifa, Israel. *Forms of tensor categories over arbitrary fields.*

We explain how to classify forms of a tensor category over a not necessarily algebraically closed field, and give explicit examples of classification of such forms. We also discuss the problem of categorification of weak fusion rings, and classify categorifications for the simplest families of such rings. This leads to interesting questions in both elementary and advanced number theory, such as the classification of regular polygons constuctible by compass and ruler (i.e., Fermat primes), the Merkurjev-Suslin theorem, and global class field theory. (Received September 01, 2011)

1077-18-893 **Luke Wolcott*** (lwolcott@uw.edu). *Ring maps, derived categories, and the Bousfield Lattice.*

A ring map between commutative rings induces adjoint maps between their derived categories. We investigate how thick and localizing subcategories, and the Bousfield lattice, behave with respect to these maps. This gives new information about the derived categories of several non-Noetherian rings. The work connects to classifications given by Neeman, Thomason, and Balmer, and complements the stratification construction of Benson, Iyengar, and Krause. (Received September 14, 2011)

1077-18-1052 **Piyush Ravindra Shroff*** (pshroff@math.tamu.edu). *Finite generation of the cohomology of quotients of a PBW algebra.*

In this talk I will give a proof of finite generation of the cohomology of quotients of a PBW algebra with the help of cohomology of quotients of quantum symmetric algebras. The proof uses a finite generation lemma of Friedlander and Suslin. (Received September 15, 2011)

1077-18-1570 **Pinhas Grossman**, **David A Jordan*** (djordan@math.utexas.edu) and **Noah Snyder**. *A fibration controlling G-graded extensions of fusion categories.* Preliminary report.

For a fusion category C, the Brauer-Picard 2-group BrPic(C) of invertible $C-C$-bimodules controls, among other things, the possible extensions of C by a finite group G: these are in bijection with homotopy classes of maps [BG,BBrPic(C)], by a theorem of Etingof, Nikshych and Ostrik. This reduces constructing G-extensions of C to computing obstructions lying in various $H^m(G,\pi_n(BBrPic(C)))$.

We study the functor $M: Eq(C) \to BrPic(C)$, which sends a tensor auto-equivalence F of C to the $C-C$-bimodule category M_F, which is C as a left module category, with right action twisted by F. We compute the homotopy fiber of M to be $Inv(C)$, the groupoid of invertible objects of C. We apply the resulting long exact sequence in homotopy groups to solve several extension problems arising in the theory of subfactors. (Received September 20, 2011)

1077-18-1607 **Jonny Comes*** (jcomes@lclark.edu). *Ideals in Deligne's $\underline{\mathrm{Rep}}(GL_\delta)$.*

I will begin this talk with a definition of Deligne's tensor category $\underline{\mathrm{Rep}}(GL_\delta)$ for arbitrary complex δ. I will then describe the indecomposable objects in that category and explain how the category is related to representations of general linear supergroups. Lastly, I will report on recent results concerning the tensor ideals of $\underline{\mathrm{Rep}}(GL_\delta)$. (Received September 21, 2011)

1077-18-1623 **Daniel A. Bravo Vivallo*** (daniel.bravo@maine.edu), University of Southern Maine, Department of Mathematics and Statistics, PO Box 9300, Portland, ME 04104-9300. *The stable derived category of a polynomial ring in two variables modulo the quadratic forms.* Preliminary report.

We define the stable derived category of any ring R as the homotopy category of a model category structure on the category of chain complexes of R-modules. The construction works for any ring R but recovers the stable derived category introduced by Krause in the case that R is Noetherian. A dual construction also using model categories is studied by Jim Gillespie. The model category approach allows us to study this category more transparently and to develop certain computational aspects. In particular, taking R to be the ring of polynomials in two variables over a field modulo the ideal generated by the homogenous polynomials in degree two, we are able to exhibit several non trivial objects of the stable derived category and maps between them, giving us new insights into the stable derived category of this ring. (Received September 20, 2011)

1077-18-1656 **James Gillespie*** (jgillesp@ramapo.edu), Ramapo College of New Jersey, School of Theoretical and Applied Science, 505 Ramapo Valley Road, Mahwah, NJ 07430. *The projective stable derived category of a ring.* Preliminary report.

For any ring R, Daniel Bravo Vivallo introduced the stable derived category of R by putting an appropriate model structure on the category of chain complexes of R-modules. The fibrant objects are the exact chain complexes of injective R-modules. We look at the dual approach. That is, there is a model category structure on chain complexes of R-modules having exact complexes of projective R-modules as the cofibrant objects. We believe the two approaches lead to two different homotopy categories in general. So there is an injective stable derived category of R and a projective stable derived category of R as well as an adjunction between them which comes from a Quillen adjunction between the model structures. But in some cases, such as when R is Gorenstein, this adjunction is in fact a Quillen equivalence between the model structures, which means the associated homotopy categories are equivalent in this case. (Received September 20, 2011)

1077-18-1908 **Romie Banerjee*** (banerjee@math.tifr.res.in), Tata Institute of Fundamental Research, School of Mathematics, Dr. Homi Bhabha Road, Mumbai, 400005, India. *Categories of Modules and their Deformations.*

Using Quillen-Lurie deformation theory formalism we develop an obstruction theory for studying the stable ∞ category of modules over a given geometric ∞ stack, and produce a more general version of the Thomason-Trobaugh localization theorem for triangulated categories. This helps us identify a large class of perfect geometric stacks. Applications include Grothendieck duality. (Received September 21, 2011)

1077-18-2289 **Ryan Cohen Reich*** (ryanr@math.ucla.edu), 1409 Midvale Ave Apt 210, Los Angeles, CA 90024. *Coherence of canonically-defined natural transformations in the derived category of ℓ-adic sheaves.*

The formalism of the ! and $*$ functors with all their adjunctions and natural morphisms is powerful enough that a large proportion of natural transformations appearing in algebraic geometry are constructed solely by combining just these canonical ones. This lends the checking of commutative diagrams a sense of inevitability. We show that this sense is justified: all such diagrams always commute. (Received September 22, 2011)

1077-18-2400 **P. Robert Kotiuga*** (prk@bu.edu), Boston University, ECE Dept., 8 Saint Mary's Street, Boston, MA 02215. *Generalized Cohomology Theories in Engineering Practice.* Preliminary report.

Consider examples and interrelationships through the interrelationships between the generalized cohomology theories illustrated:

- In computational electromagnetics, a simplicial complex is a finite element mesh, and the variational formulation of Hodge theory on manifolds with boundary leads to the use of Whitney forms as a direct variational method.
- Pontryagin's proof of the existence of Seifert surfaces lead to Oriented Bordism Theory. In computational electromagnetics it is the basis for computing "cuts for magnetic scalar potentials".
- Equivariant cohomology identifies "stationary phase approximations" which are exact.
- K-theory is used in materials science(topological insulators, topological superconductors, quantum Hall effect) and communication engineering: The "vector fields on sphere problem", and normed division algebras, are key to MIMO information theory; construction of expander graphs are key to both coding theory and counterexamples to the Baum-Connes conjecture with coefficients.

These (generalized) cohomology theories are related through calculus and PDEs. The one-liner: "there exists a spectral sequence..." sums up the algebra, but also opens a door to a unified view of algorithmic complexity. (Received September 22, 2011)

1077-18-2423 **Emily Peters*** (eep@math.mit.edu). *Tensor categories and the classification of subfactors.*

The classification of subfactors up to index 5 has recently been completed, and progress at indices (slightly) higher than 5 is being made. In this talk, I will explain how to get tensor categories from subfactors, and how these classification results may be interpreted for fusion categories. The index of a subfactor corresponds to an unusual notion of size for a tensor category; studying small-index subfactors means studying tensor categories which have (at least) one non-trivial object of small dimension. I will be describing joint work with Morrison, Penneys and Snyder. (Received September 22, 2011)

1077-18-2785 **André Joyal*** (joyal.andre@uqam.ca), Département de Mathématiques, UQAM, 201 President-Kennedy Avenue, PK-5151, Montréal, Quebec Qc H3C3P8, Canada, and **Matthieu Anel** (mathieu.anel@gmail.com), Mathematics Department, 201 President-Kennedy Avenue, PK-5151, Montréal, Québec Qc H3C 3P8, Canada. *A general bar-cobar duality.* Preliminary report.

We extend Sweedler's theory of algebras and coalgebras to operads and cooperads. We show for that the category of cooperads is symmetric monoidal closed and that the category of operads is enriched over it. This is true generally for operads and cooperads enriched in any symmetric monoidal locally presentable category, and in particular for differential graded operads and cooperads. We then formulate the bar-cobar duality for operads and cooperads in this setting. (Received September 22, 2011)

19 ► K-theory

1077-19-400 **Paul Frank Baum*** (baum@math.psu.edu). *Expanders and K-Theory for Discrete Groups.*

An expander is a sequence $X_1, X_2, X_3, \ldots$ of finite graphs which is efficiently connected. Expanders have various uses in engineering — e.g. in designing and constructing fibre optic networks. A naturally arising question is :"Does there exist a finitely generated group G such that the Cayley graph of G contains a sub-graph which is an expander?" The answer to this question is "YES" provided that "contains" is suitably weakened. The group G is known as the Gromov group and is the only known example of a non-exact group. M. Gromov began the construction of this group and then the construction was completed by several mathematicians. The Gromov group is a counter-example to BCC (Baum-Connes with Coefficients).This talk will give the basic definitions:

expander, K-theory, BC(Baum-Connes), BCC(Baum-Connes with coefficients) — and will indicate why the Gromov group is a counter-example to BCC. All this leads to the tentative conclusion that the natural class of groups for which BCC is true is exact groups. The relevant generalized cohomology theory is K-theory. (Received August 29, 2011)

1077-19-403 **Paul Frank Baum*** (baum@math.psu.edu). *K-homology and index theory : Beyond ellipticity.*

This talk will indicate how K-homology can be used to extend the Atiyah-Singer index formula to a naturally arising class of non-elliptic operators. K-homology is the dual theory to K-theory — i.e. K-homology is the homology theory determined by the Bott K-theory spectrum. For a finite CW complex X, the K-homology of X can be defined via functional analysis and this gives the Kasparov groups $KK^*(C(X), \mathbb{C})$. A definition in the spirit of bordism theory uses K-cycles (M, E, φ) where M is a compact Spin^c manifold without boundary, E is a $\mathbb{C}$ vector bundle on M, and φ is a continuous map from M to X.

$$\varphi\colon M \longrightarrow X$$

Denote the K-cycle version of K-homology by $K_*^{top}(X)$. The BD(Baum-Douglas) isomorphism

$$\mu\colon K_*^{top}(X) \longrightarrow KK^*(C(X), \mathbb{C})$$

provides a framework for extending Atiyah-Singer beyond elliptic operators. The talk will first give the basic definitions, and will then show how the BD framework applies to a naturally arising class of hypoelliptic (but not elliptic) operators on contact manifolds. The above is joint work with Erik van Erp. (Received August 29, 2011)

1077-19-884 **Aderemi Oluyomi Kuku*** (kukua@gram.edu), Department of Mathematics & Computer Science, Grambling state University, Grambling, LA 71245. *Profinite (Continuous) Equivariant Higher Algebraic K-theory for the Action of Algebraic Groups.*

The lecture starts with a preamble on representations of groups G being considered as actions of G on objects of various 'nice' categories; e.g. actions of finite or compact Lie groups G on the category of finite dimensional complex vector spaces; or actions of algebraic groups G on the category of algebraic vector bundles on a G-scheme X. We next note that the actions of G on such categories give rise to the category of G-representations on which one can do K-theory. One motivation for this approach to representation theory is the fact that when G is a finite or compact Lie group, the Grothendiek group of G-representations in the category of finite dimensional complex vector spaces coincide with the Abelian group of generalized characters of G. As such, K-theoy of such equivariant categories belong to the theory of group representations and is aptly described as Equivariant K-theory. So, for an algebraic group G over a field F, we present constructions and computations of equivariant higher K-groups as well as profinite (continuous) equivariant higher K-groups of some G-schemes, including twisted flag varieties, when F is a number field or p-adic field. (Received September 14, 2011)

20 ► *Group theory and generalizations*

1077-20-117 **Jonathan Scott Brown*** (brownjs@for.mat.bham.ac.uk). *Changing highest weight theories for finite W-algebras.*

A highest weight theory for a finite W-algebra $U(\mathfrak{g}, e)$ was developed by Brundan, Goodwin, and Kleshchev. This leads to a strategy for classifying the irreducible finite dimensional $U(\mathfrak{g}, e)$-modules. The highest weight theory depends on the choice of a parabolic subalgebra of $\mathfrak{g}$ leading to different parameterizations of the finite dimensional irreducible $U(\mathfrak{g}, e)$-modules. We explain how to construct an isomorphism preserving bijection between the parameterizing sets for different choices of parabolic subalgebra when $\mathfrak{g}$ is of type A, or when $\mathfrak{g}$ is of types C or D and e is an even multiplicity nilpotent element. (Received July 28, 2011)

1077-20-123 **Robert M Guralnick*** (guralnic@usc.edu), Department of Mathematics, University of Southern California, Los Angeles, CA 90089-2532, and **Jason Fulman**. *Unipotent Classes in Disconnected Algebraic Groups.*

Let G be a normal subgroup of the finite group A with A/G cyclic. There is a variant of Burnside's Lemma about the average number of fixed points in a coset and orbits. We use this to show to count certain types of conjugacy classes of A in a generating coset for A/G. This allows us to give an easy proof of the fact that if A is an algebraic group with connected component G, then there are only finitely many conjugacy classes of unipotent elements in any coset of G given that G has only finitely many unipotent classes. (Received July 28, 2011)

1077-20-218 **Igor A. Rapinchuk***, Yale University, Department of Mathematics, 10 Hillhouse Avenue, New Haven, CT 06511. *On the conjecture of Borel and Tits for abstract homomorphisms of algebraic groups.*

The conjecture of Borel-Tits (1973) states that if G and G' are algebraic groups defined over infinite fields k and k', respectively, with G semisimple and simply connected, then given any abstract representation $\rho\colon G(k) \to G'(k')$ with Zariski-dense image, there exists a commutative finite-dimensional k'-algebra B and a ring homomorphism $f\colon k \to B$ such that ρ can essentially be written as a composition $\sigma \circ F$, where $F\colon G(k) \to G(B)$ is the homomorphism induced by f and $\sigma\colon G(B) \to G'(k')$ is a morphism of algebraic groups. We prove this conjecture in the case that G is either a universal Chevalley group of rank ≥ 2 or the group $\mathbf{SL}_{n,D}$, where D is a finite-dimensional central division algebra over a field of characteristic 0 and $n \geq 3$, and k' is an algebraically closed field of characteristic 0. In fact, we show, more generally that if R is a commutative ring and G is a universal Chevalley-Demazure group scheme of rank ≥ 2, then abstract representations over algebraically closed field of characteristic 0 of the elementary subgroup $E(R) \subset G(R)$ have the expected description. We also give applications to deformations of representations of $E(R)$. (Received August 14, 2011)

1077-20-249 **Robin M. Lassonde*** (`lassonde@umich.edu`). *Splittings of Non-Finitely Generated Groups.*

In 1998, P. Scott defined the algebraic intersection number of two splittings of a finitely generated group. I prove that this definition also works for arbitrary groups. Whereas Scott's proof relied on local finiteness of the Cayley graph, my proof utilizes Bass-Serre trees. I then modify later results by Scott-Swarup and Niblo-Sageev-Scott-Swarup on splittings of finitely generated groups over finitely generated subgroups to work without any of the finite generation assumptions. I will give motivating examples and present some of the main results. (Received August 16, 2011)

1077-20-259 **Emille Davie Lawrence*** (`edlawrence@usfca.edu`), University of San Francisco, Department of Mathematics, 2130 Fulton St., San Francisco, CA 94117-1080. *A new distinguished form for 3-braids and its applications to the σ-order on B_3.* Preliminary report.

The braid groups have been an interesting field of study in low-dimensional topology and algebra since Emil Artin introduced the notion of a braid in the 1920s. Over the years it has been discovered that the braid groups play a useful role in knot theory, robotics, theoretical physics, and a variety of other areas. In 1992 Patrick Dehornoy proved that the braid groups were left-orderable, however he used methods that were foreign to most topologists. Soon after, a 5-author paper gave a completely topological proof to braid group orderability, and furthermore, they proved that this order was equivalent to Dehornoy's. We will give a brief introduction to the σ-order on B_n. He will also show how a new distinguished form for 3-braids allows us to determine positivity in the σ-order using left handle reduction. (Received August 16, 2011)

1077-20-266 **Joseph Kirtland*** (`joe.kirtland@marist.edu`), Department of Mathematics, 3399 North Road, Poughkeepsie, NY 12601. *Finite Groups with all Subgroups not Contained in the Frattini Subgroup Permutable.*

Let G be a finite group. A subgroup H of G is a *permutable subgroup* of G if $HK = KH$ for all subgroups K of G. It will be shown that if all subgroups not contained in the Frattini subgroup are permutable in a group G, then all subgroups are permutable in G. (Received August 17, 2011)

1077-20-344 **Arturo Magidin*** (`magidin@member.ams.org`), 217 Maxim Doucet Hall, P.O. Box 41010, University of Louisiana, Lafayette, LA 70506. *The nonabelian tensor square of nilpotent product of cyclic groups.* Preliminary report.

In 2008, R. Blyth, P. Moravec, and R.F. Morse proved that if $F(n,c)$ is the relatively free nilpotent group of class c and rank n, then the nonabelian tensor square is given by

$$F(n,c) \otimes F(n,c) \cong (F(n,c+1))' \times F^{\mathrm{ab}}_{\binom{n+1}{2}},$$

where F^{ab}_k is the free abelian group of rank k. They also determined the structure of $(F(m,c))'$, thus completing the description.

The group $F(n,c)$ can be thought of as the c-nilpotent product of n copies of the infinite cyclic group. We discuss extensions of the results above to the c-nilpotent product of arbitrary cyclic groups, provided that no prime less than c divides the order of any finite factor (the "small class" case). (Received August 24, 2011)

1077-20-394 **Guillaume Duval*** (guillaume.duval@insa-rouen.fr), 1 chemin du Chateau, Les Trois Pierres, Les Trois Pierres. *Higher variationnal equations between Kolchin solvability and virtual Abelianity.*

In the current "Galois approach to the integrability of Hamiltonian systems", which was develloped by many authors among other by Ziglin, Baider-Churchill-Rod-Singer, Morales-Ramis, one use the following implication: If the original system is Liouville integrable, then all variationnal equations along a particular trajectory (the VE_p, for p>=1), are linear systems with virtually Abelian Galois groups. Up to now, most authors were working with the first variationnal equation for two reasons : first because in practice VE_1, gives in general very strong obstruction to the integrability of the original Hamiltonian system, secondly because the VE_p, for p>=2 are very big and complicated linear systems. In the present talk, we shall present some structural properties of these higher variationnal equations which allow to simplify their study. More precisely, we shall show that assuming that VE_1 is virtually Abelian, the virtual Abelianity of VE_p for p>=2, reduces to the linear dependance of some primitiv integrals of algebraic functions. This is a join work with Andrzej Maciejewski. (Received September 05, 2011)

1077-20-429 **Dessislava Hristova Kochloukova*** (desi@ime.unicamp.br), Rua Sérgio Buarque de Holanda, 651, Departamento de matemática, IMECC, Universidade de Campinas, UNICAMP, Campinas, 13083-859, Brazil, and **Robert Bieri** (roebu4@hotmail.com) and **Ross Geoghegan** (ross@math.binghamton.edu). *Sigma invariants for Thompson and generalised Thompson groups.* Preliminary report.

We study the Sigma invariants for the Thompson group F and some new results on the generalized Thompson groups of type F. The results on the Sigma invariants of the group F is a joint work with R. Bieri and R. Geoghegan, published in Groups Geom. Dyn. 4 (2010), no. 2. We will discuss the Sigma invariants in dimension 2 of the generalised Thompson groups of type F, this is a joint work with Robert Bieri (not submitted at the time of the writing of the abstract). In this case decompositions of the generalised Thompson groups as fundamental groups of graph of groups is vital for understanding the Sigma2 invariants. (Received August 31, 2011)

1077-20-446 **Grant S Lakeland*** (glakeland@math.utexas.edu), Department of Mathematics, 1 University Station C1200, Austin, TX 78712. *Dirichlet-Ford Domains and Arithmetic Reflection Groups.* Preliminary report.

One major recent result in the theory of groups of isometries of hyperbolic space is that there exist only finitely many maximal arithmetic hyperbolic reflection groups. This raises questions as to the possibility of their classification. One such question, asked by Agol, Belolipetsky, Storm and Whyte, is whether all such groups are congruence. By considering certain Ford fundamental domains, we show that this question has a negative answer, by exhibiting counterexamples. (Received September 01, 2011)

1077-20-638 **Xinyun Zhu*** (zhu_x@utpb.edu), Xinyun Zhu, Odessa, TX 79762. *Zero-divisor graphs with seven vertices.* Preliminary report.

Given a connected graph, there is a necessary condition $\star$ for G being a zero-divisor graph,that is , for any nonadjacent vertices a and b, there exists a vertex c such that $N(a) \cup N(b) \subset \overline{N(c)}$, where $N(x)$ denotes the set of all vertices which is adjacent to x and $\overline{N(x)} = N(x) \cup \{x\}$. Inspired by the work in "Johnothon A. Sauer, Semigroups and their zero-divisor graphs" regarding the classification of all the zero-divisor graphs with six vertices, we obtain a family of zero-divisor graphs with seven vertices. We also obtain a family of connected graphs with seven vertices which satisfies the necessary condition $\star$ of zero-divisor graphs, but are not the zero-divisor graphs. (Received September 09, 2011)

1077-20-685 **Gareth A. Jones*** (G.A.Jones@maths.soton.ac.uk), School of Mathematics, University of Southampton, Highfield, Southampton, SO17 1PF, England. *Abelian coverings of the platonic maps.* Preliminary report.

I shall explain how ordinary and modular representation theory of finite groups can be used to classify the regular dessins (i.e. orientably regular hypermaps) which are abelian coverings of the platonic maps. (Received September 10, 2011)

1077-20-688 **Gerald W. Schwarz*** (schwarz@brandeis.edu), Department of Mathematics MS 050, Brandeis University, PO Box 549110, Waltham, MA 02454, and **Hanspeter Kraft**, Department of Mathematics, Rheinsprung 21, 4051 Basel, Switzerland. *Reduced Null Cones.*

Let G be a complex reductive group and V a G-module. Let $\pi\colon V \to V/\!\!/G$ be the quotient morphism and set $\mathcal{N}(V) = \pi^{-1}(\pi(0))$. We consider the following question. Is the null cone $\mathcal{N}(V)$ reduced, i.e., is the ideal of $\mathcal{N}(V)$ generated by G-invariant polynomials? We have complete results when G is SL_2, SL_3 or simple of adjoint type and when G is semisimple of adjoint type and the G-module is irreducible. (Received September 10, 2011)

1077-20-704 **Eric C Rowell*** (rowell@math.tamu.edu), Math Dept., Texas A&M University, MS 3368, College Station, TX 77843, and **Cesar Galindo** and **Seung-Moon Hong**. *Localization of Braid Group Representations.*

I will discuss recent work with Galindo and Hong generalizing the notion of localization for sequences of braid group representations as introduced in previous work with Wang. The main thrust of this work is an apparent relationship between our form of localization and finiteness of the braid group images. (Received September 10, 2011)

1077-20-716 **Simon M Smith*** (simon.smith@chch.oxon.org), 230 West Willow Street, Apt 304, Syracuse, NY 13202. *Infinite primitive permutation groups whose set of subdegrees has a finite upper bound.*

A permutation group G acts *primitively* on a set Ω if it is transitive and any point stabiliser G_α is a maximal subgroup of G. In the finite case, such groups are the basic units from which all permutation groups are comprised. For $\alpha \in \Omega$ the orbits of the point stabilizer G_α are called *suborbits* of G, and the cardinality of a suborbit is a *subdegree* of G.

Most standard methods for determining the structure of finite primitive permutation groups do not translate well to infinite groups. A novel approach for examining the structure of infinite primitive permutation groups is to look at their subdegrees. In this talk I shall give a brief summary of this approach, before describing a new result classifying all infinite primitive permutation groups whose set of subdegrees has a finite upper bound. (Received September 11, 2011)

1077-20-729 **Daciberg Lima Goncalves*** (dlgoncal@ime.usp.br), Rua do Matao 1010, Sao Paulo, SP 05508-090, Brazil, and **Dessislava H. Kouchloukova**, Department of Mathematics, University of Campinas, Campinas, SP 13083-970, Brazil. *Σ theory and twisted conjugacy classes.*

Using Σ theory we show that for large classes of groups G there is a subgroup H of finite index in $Aut(G)$ such that for $\varphi \in H$ the Reidemeister number $R(\varphi)$ is infinite. In some cases we even proof that $H = Aut(G)$. These cases includes the generalized Thompson's groups $F_{n,0}$ and their finite direct products, This was the initial motivation. Some cases where we obtain H of finite index, but not necessarily equals to $Aut(G)$ are: 1) nilpotent-by-abelian of type FP_∞, 2) G of type FP_2 but without free non-abelian subgroups and with maximal metabelian quotient not polycyclic, 3) some direct products of groups, 4) the pure symmetric automorphism group. (Received September 11, 2011)

1077-20-751 **Hernando Bermudez*** (hbermud@emory.edu), 400 Dowman Drive, W401, Atlanta, GA 30322, and **Skip Garibaldi** and **Victor Larsen**. *A Unified Solution to Some Linear Preserver Problems.*

We obtain a general theorem that allows the determination of the group of linear transformations on a vector space V that preserve a polynomial function p on V for several interesting pairs (V, p). The proof is based on methods from the theory of semisimple linear algebraic groups, in particular a theorem of Demazure on the automorphism group of some projective varieties. Along the way we make evident the connection between the transformations that preserve the polynomial and those that preserve a set of "minimal" elements of V, a connection that had previously been observed for numerous special cases. (Received September 12, 2011)

1077-20-774 **Daniel K. Nakano*** (nakano@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30602. *Cohomology for Finite Groups of Lie Type.*

In this talk I will present new techniques (inspired by work of Bendel-Nakano-Pillen) for computing cohomology for the finite Chevalley group $G(\mathbb{F}_q)$ directly in terms of cohomology for the ambient algebraic group G and its associated Frobenius kernels. These techniques will be used to compute the first and second cohomology group when M is a simple $G(\mathbb{F}_q)$-module. A salient feature of our results is that we require no twisting of the coefficient module by the Frobenius morphism, which enables us to make calculations for relatively small values of p and q.

Our calculations extend the seminal cohomological calculations of Cline-Parshall-Scott (1975), Jones (1975), Bell (1978), and Kleshchev (1994). This research was conducted by the University of Georgia VIGRE Algebra Group during the academic years 2009-10 and 2010-11. (Received September 12, 2011)

1077-20-834 **Mark Brittenham** and **Susan Hermiller***, Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130. *Stackable groups.* Preliminary report.

Stackability is a combinatorial condition on the Cayley graph of a finitely generated group which implies solvability of the word problem. More specifically, this property provides an inductive algorithm which, upon input of a word that represents the identity of the group, outputs a van Kampen diagram for that word over a canonical presentation. The stackable property provides a uniform model of finite complete rewriting systems for groups and of almost convexity for groups, and the class of stackable groups also includes Thompson's group F. We'll also discuss how the inductive nature of the van Kampen diagram procedure can be applied to computing filling functions for stackable groups. (Received September 13, 2011)

1077-20-856 **John C. Meakin*** (jmeakin@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Subgroups of semigroups freely generated by idempotent matrices.* Preliminary report.

We discuss recent progress on the problem of determining the structure of the maximal subgroups of the free idempotent generated semigroup on the biordered set of idempotents of a ring. The structure of these groups is not yet known, even if the ring is the ring of $n \times n$ matrices over a division ring. (Received September 13, 2011)

1077-20-902 **Stephen Majewicz*** (smajewicz@kbcc.cuny.edu), Mathematics Dept., Kingsborough Community College, 2001 Oriental Blvd., Brooklyn, NY 11235. *Quantum Algorithms for Fixed Points and Invariant Subgroups.*

In this talk, I will discuss how to use Grover's quantum search algorithm to solve problems concerning fixed points and invariant subgroups of automorphisms. This is joint work with Marianna Bonanome. (Received September 14, 2011)

1077-20-919 **James B Wilson*** (jwilson@math.colostate.edu), Department of Mathematics, Colorado State University, 101 Weber Building, Fort Collins, CO 80523. *Automorphisms and isomorphism of finite p-groups.* Preliminary report.

The study of isomorphisms of finite groups has two largely unrelated thrusts: one to determine structural properties that demonstrate when groups are non-isomorphic, and the other to produce efficient tools to prove when groups are isomorphic. Both problems appear most difficult for nilpotent groups of class 2. We introduce conclusive isomorphism invariants and polynomial-time isomorphism tests for a super-exponentially sized family of isomorphism types of p-groups of class 2. These results depend in part on independent work with P. Brooksbank, M. Lewis, and L. Ronyai. (Received September 14, 2011)

1077-20-934 **Daniel Groves**, **Jason Fox Manning*** (j399m@buffalo.edu) and **Henry Wilton**. *Recognizing 3-manifold groups.*

I'll talk about the problem of recognizing whether a group presentation is the presentation of a closed aspherical 3-manifold group. (Received September 14, 2011)

1077-20-966 **Maria D. Vega*** (vega@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803, and **Daniel S. Sage** (sage@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Twisted Frobenius–Schur Indicators for Hopf Algebras.*

The classical Frobenius–Schur indicators for finite groups are character sums defined for any representation and any integer $m \geq 2$. In the familiar case $m = 2$, the Frobenius–Schur indicator partitions the irreducible representations over the complex numbers into real, complex, and quaternionic representations. In recent years, several generalizations of these invariants have been introduced. Bump and Ginzburg, building on earlier work of Mackey, have defined versions of these indicators which are twisted by an automorphism of the group. In another direction, Linchenko and Montgomery have defined Frobenius–Schur indicators for semisimple Hopf algebras. We have constructed twisted Frobenius–Schur indicators for semisimple Hopf algebras; these include all of the above indicators as special cases and have similar properties. This is joint work with Daniel Sage. (Received September 15, 2011)

1077-20-995 **Keith M Jones*** (keith.jones@trincoll.edu), 291 Grandview Terrace, Hartford, CT 06114. Σ^1 *for Semi-Direct Products Acting on Locally Finite Trees.*

For an isometric action ρ by a finitely generated group G on a proper CAT(0) space M, the invariant $\Sigma^1(\rho) \subseteq \partial M$, introduced in 2003 by Bieri and Geoghegan, provides a notion of "connectivity at infinity" for G.

I will discuss how the natural and well-known connection between Bass-Serre theory and covering space theory provides a framework for the calculation of $\Sigma^1(\rho)$ in the case that ρ is a cocompact action by a semidirect product $G = B \rtimes_\varphi A$ (A a finitely generated group) on a locally finite tree Bass-Serre tree T for A. This leads to a technical theorem providing conditions for the inclusion in, or exclusion from, $\Sigma^1(\rho)$ for a point of ∂M.

This leads to some nice easily stated consequences, particularly when A is a free group and T is its Cayley graph. In this case, points of ∂M are represented by words over the set of generators and their inverses, and we can prove, for example: $\Sigma^1(\rho)$ *contains any endpoint represented by an infinite word containing infinitely many mutually distinct subwords lying in* $\ker \varphi$. (Received September 15, 2011)

1077-20-1054 **Lynnelle L Ye*** (lynnelle@stanford.edu), 531 Lasuen Mall, P.O. Box 16820, Stanford, CA 94309. *Bounds and Asymptotics for Various Properties of Numerical Semigroups.*

A numerical semigroup S is a subset of the nonnegative integers $\mathbb{N}_0$ which contains 0, is closed under addition, and has finite complement in $\mathbb{N}_0$. We call the cardinality of $\mathbb{N}_0 \setminus S$ the genus of S, or $g(S)$, and we call the largest element of $\mathbb{N}_0 \setminus S$ the Frobenius number of S, or $F(S)$. Let $N(g)$ be the number of numerical semigroups with genus g and $C(F)$ be the number of numerical semigroups with Frobenius number F. It is known that as g increases, $N(g)$ eventually grows at a rate of φ^g. Asymptotics for $C(F)$ have not previously been computed. Here we show that as F increases, $C(F)$ grows at a rate of $\sqrt{2}^F$. We also find asymptotics for the proportion of maximal embedding dimension numerical semigroups and the typical number of effective generators of a numerical semigroup as g increases. Finally, we compute a recurrence for $N(g)$ which shows that $N(g) - N(g-1) \leq N(g+1)$ for all g, not just for g large. (Received September 15, 2011)

1077-20-1079 **Adolfo Ballester-Bolinches** (Adolfo.Ballester@uv.es), Dr. Moliner, 50, 46100 Burjassot, València, Spain, and **Ramon Esteban-Romero*** (resteban@mat.upv.es), Camí de Vera, s/n, edifici 1G, 46022 València, València, Spain. *Algorithms in* GAP *for permutability and Sylow permutability in finite groups.* Preliminary report.

The study of the classes of finite groups in which all subnormal subgroups are normal, permutable, or Sylow-permutable has been a fruitful topic in the theory of groups during the last years, with many papers and characterizations available. In this talk we present some algorithms for the recognition of groups belonging to these classes. They have been implemented in a package for the computer algebra system GAP. (Received September 16, 2011)

1077-20-1108 **Carol Jacoby** (cjacoby@jacobyconsulting.com), Jacoby Consulting, Long Beach, CA, **Katrin Leistner** (katrin.leistner@uni-duisburg-essen.de), Department of Mathematics, University of Duisburg-Essen, D 45117 Essen, Germany, **Peter Loth*** (lothp@sacredheart.edu), Department of Mathematics, Sacred Heart University, Fairfield, CT 06825, and **Lutz Struengmann** (lutz.struengmann@uni-duisburg-essen.de), Department of Mathematics, University of Duisburg-Essen, D 45117 Essen, Germany. *Abelian groups with partial decomposition bases.* Preliminary report.

We study the class of abelian groups with partial decomposition bases in $L^{\delta}_{\infty\omega}$ where δ is an ordinal. This class contains the class of Warfield groups which are abelian groups G with a decomposition basis X such that $G/\langle X\rangle$ is simply presented. In this paper, we give a classification theorem in $L^{\delta}_{\infty\omega}$ in terms of numerical invariants derived from the classical Ulm and Warfield invariants. (Received September 16, 2011)

1077-20-1122 **Lucas Sabalka*** (sabalka@math.binghamton.edu) and **Dmytro Savchuk** (dsavchuk@math.binghamton.edu). *On restricting free factors in relatively free groups.*

Let G be a free, free nilpotent, or free metabelian group, and let $A = \{a_1, ..., a_n\}$ be a basis for G. We will show that if S is a subset of a basis for G which may be expressed without the element a_n then, with small restrictions on the size of S, the set S is a subset of a basis for the relatively free group on $A - \{a_n\}$. (Received September 16, 2011)

1077-20-1137 **Stavros Argyrios Papadakis** and **Bart Van Steirteghem*** (bartvs@mec.cuny.edu), Department of Mathematics, Medgar Evers College (CUNY), 1650 Bedford Ave, Brooklyn, NY 11225. *The invariant Hilbert scheme of a spherical module.* Preliminary report.

Let G be a complex connected reductive linear algebraic group and let V be a finite-dimensional G-module. The invariant Hilbert scheme $\mathrm{Hilb}^G_h(V)$, introduced by V. Alexeev and M. Brion, parametrizes the G-stable ideals

I of the polynomial ring $\mathbb{C}[V]$ for which the G-module $\mathbb{C}[V]/I$ has prescribed multiplicities given by a function $h : \mathrm{Irr}(G) \to \mathbb{Z}_{\geq 0}$.

Suppose W is a *spherical* G-module (i.e. $\mathbb{C}[W]$ is a multiplicity-free G-module) and denote $h_W : \mathrm{Irr}(G) \to \{0, 1\}$ its *invariant Hilbert function*, so that $\mathbb{C}[W] \cong \oplus_{M \in \mathrm{Irr}(G)} M^{h_W(M)}$ as a G-module. Let $T \subset G$ be a maximal torus and let $U \subset G$ be a maximal unipotent subgroup normalized by T. There is a (unique) finite-dimensional G-module V such that $\mathbb{C}[W]^U \cong \mathbb{C}[V^U]$ as T-modules. We will discuss our work on the invariant Hilbert scheme $\mathrm{Hilb}^G_{h_W}(V)$, which provides information on the equivariant degenerations of W. (Received September 16, 2011)

1077-20-1173 **Ross Geoghegan*** (ross@math.binghamton.edu). *$\mathbb{Z}G$-modules over $CAT(0)$ spaces. Preliminary report.*

Let G be a group acting by isometries on a proper $CAT(0)$ space M and let A be a finitely generated $\mathbb{Z}G$-module. I will describe a theory of horospherical limit points of A in the boundary of M which Robert Bieri and I have been developing. In this talk I'll indicate: (1) how the resulting geometry throws light on when A is finitely generated over $\mathbb{Z}K$ where K is an appropriate subgroup of G; and (2) how the whole theory extends to the non-positively curved world some of the ingredients of "tropical geometry", specifically the so-called Gröbner fan. (Received September 17, 2011)

1077-20-1180 **Alexander I. Suciu*** (a.suciu@neu.edu), Department of Mathematics, Northeastern University, Boston, MA 02115. *Geometric and homological finiteness in free abelian covers.*

I will describe some of the inter-connections between the Bieri–Neumann–Strebel–Renz invariants, the Dwyer–Fried invariants, and the cohomology support loci of a space X, or its fundamental group G. Under suitable hypotheses, the geometric and homological finiteness properties of regular, free abelian covers of X can be expressed in terms of the resonance varieties, extracted from the cohomology ring of X. In general, though, translated components in the characteristic varieties affect the answer. Time permitting, I will illustrate the theory in the setting of toric complexes and right-angled Artin groups, as well as in the setting of smooth, complex projective and quasi-projective varieties. (Received September 17, 2011)

1077-20-1209 **Sang-hyun Kim*** (shkim@kaist.edu), Department of Mathematical Sciences, KAIST, South Korea, and **Thomas Koberda** (koberda@math.harvard.edu), Department of Mathematics, Harvard University. *Embeddability between Right-Angled Artin Groups.*

Using mapping class groups, we study the question of which right-angled Artin groups (RAAGs) embed into a given RAAG. In particular, we have a graph theoretical characterization in the case when the given RAAG is two-dimensional. (Received September 18, 2011)

1077-20-1272 **Jason Behrstock*** (jason.behrstock@lehman.cuny.edu) and **Cornelia Drutu**. *Divergence, thick groups, and morse geodesics.*

In a metric space the divergence of a pair of rays is a way to measure how quickly they separate from each other. Understanding what divergence rates are possible in the presence of non-positive curvature was raised as a question by Gromov and then refined by Gersten. We will describe a construction of groups with several interesting properties, including shedding light on the above question. (Received September 18, 2011)

1077-20-1297 **Anthony E Clement*** (aclement@brooklyn.cuny.edu), Department of Mathematics, Brooklyn College, 2900 Bedford Avenue, Brooklyn, NY 11210. *Some Observations Involving the Baumslag groups $G(m, n)$.*

In his 1969 paper, "A non-cyclic one-relator group all of whose finite quotients are cyclic", G. Baumslag showed that every finite quotient of $G = \langle a, b \,|\, a = [a, a^b] \rangle$ rewritten as $G(1, 2) = \langle a, b \,|\, b^{-1}a^{-1}bab^{-1}ab = a^2 \rangle$ is cyclic and as a result presented then yet another example of a one-relator group which is not residually finite. In this talk, I will describe the structure and present some properties of the Baumslag groups $G(m, n) = \langle a, b \,|\, b^{-1}a^{-1}ba^m b^{-1}ab = a^n \rangle$. (Received September 19, 2011)

1077-20-1323 **Thomas Koberda*** (koberda@math.harvard.edu), Department of Mathematics, 1 Oxford St., Cambridge, MA 02138. *Mapping class groups and covers of surfaces.*

If ψ is an infinite order mapping class of a surface Σ, it is possible that ψ acts trivially on the homology group $H_1(\Sigma, \mathbb{Z})$. I will discuss various methods for analyzing the action of ψ on the homology groups of certain finite covers of Σ, and I will show that often times one can find a finite cover Σ' of Σ such that ψ acts with infinite order on $H_1(\Sigma', \mathbb{Z})$. (Received September 19, 2011)

1077-20-1339 **Moshe Kamensky*** (kamensky.1@nd.edu). *Tannakian formalism over fields with operators.* Preliminary report.

I will discuss linear groups definable in fields with generalised operators, using the formalism for such fields introduced by Moosa and Scanlon. This formalism includes the cases differential and difference fields.

The goal is produce a description of the category of representations of such a group, analogous to the classical one provided by tensor categories. (Received September 19, 2011)

1077-20-1395 **Robert H Gilman*** (rgilman@stevens.edu), Stevens Institute of Technology, Department of Mathematical Sciences, Hoboken, NJ 07030. *Generic properties of finitely presented groups.* Preliminary report.

Over the last several years there has been increasing interest in generic properties of finitely presented groups. For example it has been shown that a random finitely presented group is word hyperbolic, that the isomorphism problem is solvable for most pairs of one-relator group presentations, and that random van Kampen diagrams for a fixed finite presentation have logarithmic depth. We will review developments in this area and mention some recent results. (Received September 19, 2011)

1077-20-1462 **Markus Lohrey** and **Benjamin Steinberg*** (bsteinberg@ccny.cuny.edu), New York, NY. *The submonoid membership problem for groups.*

We discuss the membership problem for finitely generated submonoids of groups. Both decidability and undecidability results will be considered. We focus on right-angled Artin groups and free metabelian groups. We also consider the membership problem for rational subsets of groups (subsets recognized by finite automata). The two problems are shown to be equivalent for groups with two or more ends. (Received September 19, 2011)

1077-20-1473 **Andrey Minchenko***, Department of Mathematics, Middlesex College, London, Ontario N6A 5B7, Canada, and **Alexey Ovchinnikov**. *Representations of reductive differential algebraic groups.*

With any reductive linear differential algebraic group G, one can associate (in a natural way) a reductive linear algebraic group H. We will discuss the relation between linear representations of G and H. In particular, if G=SL(2), we will give an efficient description of finite-dimensional extensions of irreducible representations of G by embedding into the module of differential polynomials in two variables. (Received September 19, 2011)

1077-20-1481 **László Babai*** (lbabai@gmail.com), **Robert Beals** and **Ákos Seress**. *Polynomial-time Theory of Matrix Groups.*

Given a list T of $n \times n$ matrices over a finite field, how difficult is it to determine the order of the group G generated by T and to decide membership in G? We describe the first definitive theoretical result in this decades-old quest, started by Babai and Szemerédi in 1984. Hard number theoretic problems such as factoring and discrete log stand in the way of polynomial-time solutions even in the 1×1 case. The recent result says that in a well-defined sense, these are in fact the only obstacles, at least in odd characteristic.

The framework of the algorithms is given by the now popular filtration $G \geq \mathrm{Pker}(G) \geq \mathrm{Rad}(G) \geq \{1\}$ introduced by Babai and Beals in 1997. The algorithms build on major recent progress by C. W. Parker and R. A. Wilson on the statistical analysis of Bray's algorithm for the centralizer of an involution in odd characteristic, and a related paper by Holmes et al. Other ingredients from recent progress in statistical group theory include the recognition of finite simple groups by sampling their element orders (Babai - Kantor - Pálfy - Seress) and an estimate of the frequency of r'-elements in finite simple groups (Babai - Pálfy - Saxl). (Received September 19, 2011)

1077-20-1493 **Miodrag Cristian Iovanov*** (iovanov@usc.edu), **Geoffrey Mason** (gem@ucsc.edu) and **Susan Montgomery** (smontgom@math.usc.edu). *Frobenius Schur indicators of Symmetric Tensor Categories and Doubles of Groups.* Preliminary report.

The Frobenius-Shur indicators of a group are classical invariants associated to a group. They were generalized to semisimple Hopf algebras by Montgomery and Linchenko, and then to tensor categories by Mason, Ng, Schauenburg. These indicators proved to be very useful and powerful invariants for such categories. For example, the generalized FS indicators can distinguish between nonequivalent tensor categories which have the same fusion rules (character ring). In general, these invariants are algebraic integers. For groups, they are known to be integers. Also, it was noted that in many situations such as some Drinfeld doubles of Hopf algebras they are also integers, which lead to conjecturing that they might be integers in general for any fusion symmetric tensor category. We address this question here; we give some general results and focus on the Drinfeld doubles of groups. We find equivalent conditions for all indicators of representations of D(G) to be integers, and we prove that there are large classes of groups - which include CA groups and primitive p-groups - for which this is true.

On the other hand, we use our characterizations and computer algebra to find many interesting counterexamples to this conjecture. Joint work with G.Mason, S. Montgomery, with some ideas of S-H.Ng. (Received September 20, 2011)

1077-20-1597 **Chuck Hague*** (hague@math.udel.edu). *Algebraic Frobenius splitting of bundles on flag varieties.* Preliminary report.

The program of algebraic Frobenius splitting was begun by Kumar and Littelmann to prove Frobenius splitting results on various varieties associated to linear algebraic groups (flag varieties, Schubert varieties, etc) by using purely representation-theoretic and algebraic techniques. In this talk we consider further applications of algebraic Frobenius splitting. (Received September 20, 2011)

1077-20-1605 **Aliza A. Steurer*** (asteurer@dom.edu), Dominican University, Department of Mathematics, 7900 W. Division, River Forest, IL 60305. *Using the p-Group Generation Algorithm to Generate Extensions of D_4 by $C_2 \times C_2 \times C_{2^{n-5}}$.* Preliminary report.

Let D_4 denote the dihedral group of order 8, let C_m denote the cyclic group of order m, and assume $n \geq 8$. In a recent class field theory paper, Michael Bush investigated groups that are part of an interesting family of extensions of D_4 by $C_2 \times C_2 \times C_{2^{n-5}}$. We proved that for each fixed n, there are 8 inequivalent extensions of D_4 by $C_2 \times C_2 \times C_{2^{n-5}}$ that are non-isomorphic as groups. We achieved this in two main parts. First, we used group cohomology to prove there are 8 such inequivalent extensions. Second, we used the p-group generation algorithm to find presentations for 8 non-isomorphic groups that are extensions of D_4 by $C_2 \times C_2 \times C_{2^{n-5}}$. These must be the 8 extensions of interest. In this talk, we will outline our proof. (Received September 20, 2011)

1077-20-1613 **Michael J. J. Barry*** (mbarry@allegheny.edu), Department of Mathematics, Allegheny College, 520 N. Main Street, Meadville, PA 16335. *On Conditions Relating to Nonsolvability.*

Recent work of Kaplan and Levy refining a nonsolvability criterion proved by Thompson in his N-Groups paper prompts questions on whether certain conditions on groups are equivalent to nonsolvability. (Received September 20, 2011)

1077-20-1666 **Nic Koban*** (nicholas.koban@maine.edu), 228 Main Street, Farmington, ME 04938, and **Peter Wong**. *The Ω-invariant of a semi-direct product of groups.* Preliminary report.

Suppose $G \cong H \rtimes K$ where H and K are finitely generated groups. We will describe the Ω^1 invariant of G in terms of $\Omega^1(H)$, $\Omega^1(K)$, and the action of K on H. This invariant Ω^1 is analogous to the Bieri-Neumann-Strebel invariant Σ^1 which replaces the notion of half-spaces in the definition of Σ^1 with the notion of truncated cones. (Received September 20, 2011)

1077-20-1682 **Will Dison** and **Tim Riley*** (tim.riley@math.cornell.edu). *Extreme compression and efficient computation, with application to the word problem.* Preliminary report.

I will discuss efficient calculation with highly compressed expressions for large integers and applications to finding efficient solutions to the word problem in some "hydra" examples of groups with huge Dehn function. (Received September 20, 2011)

1077-20-1684 **Noel Brady**, **Will Dison** and **Tim Riley*** (tim.riley@math.cornell.edu). *Hyperbolic hydra.*

I will describe examples of hyperbolic groups with finite-rank free subgroups of huge (Ackermannian) distortion. (Received September 20, 2011)

1077-20-1783 **Michael R Bush*** (mbush@smith.edu), Dept. of Mathematics and Statistics, Smith College, Northampton, MA 01063. *Schur σ-groups of small prime power order.*

Schur σ-groups are a class of pro-p groups first defined by Koch and Venkov in 1975. They arise naturally in algebraic number theory as the Galois groups of maximal unramified p-extensions of imaginary quadratic fields. In this talk, I'll describe work in progress to classify finite p-groups of this type using tools from computational group theory. If time permits, I'll also give a brief overview of some joint work with Nigel Boston and Farshid Hajir in which we give a heuristic for how often one expects a particular finite p-group of this type to arise as a Galois group. (Received September 20, 2011)

1077-20-1826 **David Ben McReynolds***, 150 N. University, Mathematical Science Building, West Lafayette, IN 47907. *How do you build examples?*

I will give a casual talk that addresses broadly the problem of building interesting examples of group and manifolds. (Received September 21, 2011)

1077-20-1838 **John Meier***, Department of Mathematics, Lafayette College, Easton, PA 18042. *The BNS-invariant of pure braid groups.* Preliminary report.

The first Σ-invariant of the full braid groups is rather uninteresting. The full braid group B_n contains a central element that generates the abelianization, $\mathbb{Z}$. However, as Ralph Strebel pointed out to us, the situation for the pure braid groups is more complicated. In this talk I will describe the progress made to date on computing $\Sigma^1(PB_n)$.

This is joint work with Nicholas Koban and Jon McCammond. (Received September 21, 2011)

1077-20-1887 **Dmytro M Savchuk*** (dsavchuk@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, Binghamton, NY 13902. *Schreier graphs and Schreier dynamical system of the action of Thompson's group F on the Cantor set.*

We construct Schreier graphs of the actions of Thompson's group F on the orbits of all points of the Cantor set with respect to the standard generating set x_0, x_1, classify them up to isomorphism, and study the corresponding Schreier dynamical system. Schreier dynamical systems were studied in the context of ergodic theory by Zimmer, Vershik and Grigorchuk. Sometimes it is possible to show that given an action of a group on a set, the Schreier dynamical system constructed from just one orbit, can recover the original action of the group on the whole set. We show that this is exactly the case for the action of F on the Cantor set. Finally, we show that all constructed Schreier graphs are amenable. (Received September 21, 2011)

1077-20-1907 **Dirk Schuetz*** (dirk.schuetz@durham.ac.uk), Department of Mathematical Sciences, Durham University, Science Laboratories, South Rd, Durham, DH1 3lE, England. *Novikov homology of right-angled Artin groups.*

We calculate the Novikov homology of right-angled Artin groups and related HNN extensions. This is used to construct groups with symmetric homological Sigma invariants (with respect to the antipodal map) whose homotopical Sigma invariants are not symmetric. (Received September 22, 2011)

1077-20-2014 **Oded Yacobi*** (oyacobi@math.toronto.edu), Department of Mathematics, University of Toronto, Bahen Centre, Toronto, Ontario M5S 2E4, Canada. *Polynomial functors and categorifications.*

The category P of strict polynomial functors was used by Frieldander and Suslin to study the finite generation of affine group schemes, and since their work it has been applied widely in algebraic topology. In this talk we describe actions of affine special linear Lie algebras and the Heisenberg algebra on P categorifying the Fock space representation, and relate these to Schur-Weyl duality. (Received September 21, 2011)

1077-20-2020 **Ashley R. Taylor*** (ataylor15@uco.edu), 11550 N. May, Apt 302, Oklahoma City, OK 73120, and **Devin C Smith** (conner512@hotmail.com), 11550 N. May, Apt 302, Oklahoma City, OK 73120. *Pondering and Posing Problems and Proofs Pertaining to Perfect Order Subset Groups.* Preliminary report.

A finite group is said to have perfect order subsets if the number of elements of any given order divides the order of the group. A group with perfect order subsets is often referred to as a POS group. We examine and prove new results related to POS groups. We also mention some open problems. (Received September 21, 2011)

1077-20-2054 **Trey Brock*** (trey.brock@gmail.com), W.C. Morris 222, University of Central Missouri, Warrensburg, MO 64093, and **Nicholas R Baeth**. *Monoids Defined by Second Order Recurrence Relations.* Preliminary report.

Born out of the study of non-unique factorization in integral domains, the study of factorization properties in commutative monoids has generated much interest over the past few decades. In this talk we investigate certain properties of monoids defined by linear equations in three variables whose coefficients are consecutive terms of a sequence defined by a second order recursive relation. In particular, we classify all irreducible elements of these monoids and give a measure — by way of computing certain invariants — of how they are from having unique factorization. (Received September 21, 2011)

1077-20-2154 **Jenya Kirshtein*** (ykirshte@du.edu), ykirshte@du.edu. *Recent results on Cayley-Dickson loops.*

The Cayley-Dickson loop Q_n is the multiplicative closure of basic elements of the algebra constructed by n applications of the Cayley-Dickson doubling process (the first few examples of such algebras are real numbers, complex numbers, quaternions, octonions, sedenions). A study of basic elements provides information about the underlying algebra, and is of interest, for example, in Lie theory and quantum physics. We discuss the structure of the automorphism groups, multiplication groups, and inner mapping groups of the Cayley-Dickson loops. (Received September 22, 2011)

1077-20-2180 **Nicole Lemire***, Department of Mathematics, University of Western Ontario, London, Ontario N6A 5B7, Canada. *Equivariant Birational Properties of Algebraic Tori.* Preliminary report.

We examine the equivariant birational linearisation problem for algebraic tori equipped with a finite group action. We also study bounds on *degree of linearisability*, a measure of the obstruction for such an algebraic torus to be linearisable. We connect these problems to earlier work with Vladimir Popov and Zinovy Reichstein on the classification of the simple algebraic groups which are Cayley and on determining bounds on the Cayley degree of an algebraic group, a measure of the obstruction for an algebraic group to be Cayley. (Received September 21, 2011)

1077-20-2261 **Yuri Bazlov***, Yuri.Bazlov@manchester.ac.uk, and **Arkady Berenstein**. *Noncommutative reflections.*

Groups generated by reflections are ubiquitous in mathematics and play a major role in modern representation theory. We introduce their noncommutative-geometric generalization via the notion of a reflection of a noncommutative space (graded associative algebra) A. If S is a set of reflections of A, then S-twisted derivations of A, S, and A may generate an algebra with triangular decomposition, which serves as a noncommutative analogue of a nil Hecke algebra.

More specifically, if A is an n-dimensional quantum plane, we show that A can be obtained as a Drinfeld twist of ordinary polynomial algebra and that the triangular decomposition property holds. This explains recent constructions due to the authors and independently due to Kirkman, Kuzmanovich and Zhang. Back in the classical, "commutative", setting, the results still apply and yield nil Hecke algebras for arbitrary complex reflection groups. (Received September 21, 2011)

1077-20-2320 **Kim Ruane*** (kim.ruane@tufts.edu), Department of Mathematics - Tufts University, 503 Boston Avenue, Medford, MA 02155. *Groups acting on CAT(0) spaces and their Boundaries.* Preliminary report.

I will discuss some work in progress about the topology of CAT(0) boundaries. (Received September 22, 2011)

1077-20-2323 **Nic Koban** and **Peter Wong*** (pwong@bates.edu), Department of Mathematics, Bates College, Lewiston, ME 04240. Ω^n *invariants and twisted conjugacy classes.*

A group G is said to have property R_∞ if for every automorphism $\varphi \in \mathrm{Aut}(G)$, there are an infinite number of φ-twisted conjugacy classes. The interest in R_∞ originates from topological fixed point theory. We show that if the Ω^n invariant of G is finite and nonempty then it consists of one or two points. In the case of a singleton, G has property R_∞. If Ω^n consists of two points, then there is an index 2 subgroup Γ in $\mathrm{Aut}(G)$ such that there are an infinite number of φ-twisted conjugacy classes for every $\varphi \in \Gamma$. (Received September 22, 2011)

1077-20-2439 **Parimala Raman*** (parimala@mathcs.emory.edu), Department of Mathematics and Computer Scienc, Emory University, 400 Dowman Drive Suite 401, Atlanta, GA 30322, and **Eva Bayer-Fluckiger** (eva.bayer@epfl.ch), Ecole Polytechnique Federale de Lasanne, EPFL/FSB/MATHGEOM/CSAG, 1015 Lausanne, Switzerland. *G-Galois algebras and a Hasse principle.*

We explain a local to global principle for the existence of a self-dual normal basis for G-Galois algebras over a number field. A general induction-restriction theorem leads to such a local-global principle under certain constraint on G which is satisfied if the normaliser of a 2-Sylow subgroup S controls the fusion of S in G. (jointly with Eva Bayer-Fluckiger). (Received September 22, 2011)

1077-20-2491 **Wade Mattox*** (wmattox@vt.edu), 1305 University City Blvd, Apt. # 6, Blacksburg, VA 24060. *Relating the structure of a group to the module-theoretic properties of the group von Neumann algebra over the complex group ring.*

The topic of interest is relating the structure of a group to the structure of certain modules over the complex group ring. In particular, the modules $L^p(G)$ and the group von Neumann algebra $N(G)$ are of interest. Flatness and a notion of "dimension-flatness" are the main module-theoretic properties that have been looked at. For example, If $N(G)$ is flat over $\mathbb{C}G$, what can that tell us about the structure of the group? What if $N(G)$ is dimension-flat? There are conjectures relating these hypotheses to the number of ends of a group and to the amenability of a group, respectively. Partial results and motivating examples built off the work of Peter Linnell, Wolfgang Lück and others have been found. (Received September 22, 2011)

1077-20-2573 **Margaret H Dean**, **Stephen Majewicz** and **Marcos Zyman*** (mzyman@bmcc.cuny.edu), BMCC, CUNY Mathematics Department, 199 Chambers St., New York, NY 10007. *Towers of IA-automorphisms.* Preliminary report.

For any group G, let $IA(G)$ be the subgroup of $Aut(G)$ consisting of those automorphisms that induce the identity on G/G', where G is the commutator subgroup of G. Let $G_1 = IA(G)$ and $G_i = IA(G_{i-1})$ for $i > 1$. Since $Inn(G_i) \leq G_{i+1}$, a homomorphism from G_i to G_{i+1} is obtained by mapping each element G_i to the inner automorphism it gives rise to. This induces a sequence of groups and homomorphisms called the *IA-tower* of G. The IA-tower terminates if there is an m for which G_m has trivial center and such that $Inn(G_m) = IA(G_m)$. The least such m is the *height* of the tower. In this talk, I will discuss some preliminary results regarding the height of the IA-towers of certain nilpotent and center-by-metabelian groups. (Received September 22, 2011)

1077-20-2585 **Thomas Langley*** (langley@rose-hulman.edu). *The probability that two elements commute in groups with small centers.* Preliminary report.

The probability that two elements of a non-Abelian finite group commute is at most 5/8, and this bound is realized when the center of the group is one fourth of the group. We investigate the values of this probability when the center of the group is small. We also examine related probabilities for two generalizations of commutativity in this setting, in particular the probability that a product of n group elements is equal to its reverse, or to a cyclic rearrangement of itself. (Received September 22, 2011)

1077-20-2767 **Zoran Sunic*** (sunic@math.tamu.edu). *Twin Towers of Hanoi: diameters of coupled graphs.* Preliminary report.

We use a group theoretic model of the Hanoi Towers Problem to solve a twin version of the problem. In the twin version, two sets of pegs and disks are considered simultaneously and two instances of the classical problem are being solved simultaneously, by using the same sequence of moves in both sets. We provide estimates on the length of optimal solutions to all Twin Towers of Hanoi Problems (for all initial and final configurations). The group behind the solution is a group of rooted tree automorphisms and the twin version of the problem corresponds to the action on pairs of vertices. (Received September 22, 2011)

1077-20-2773 **Susan Hermiller** and **Zoran Sunic*** (sunic@math.tamu.edu). *Sigma invariants of some self-similar groups.*

We provide calculations of Sigma invariants of some self-similar groups, including some iterated monodromy groups of post-critically finite rational maps on the Riemannn sphere. (Received September 22, 2011)

1077-20-2820 **Adam Anthony Allan*** (aallan@slu.edu), 245 Union Boulevard, Apt. 505, St. Louis, MO 63108. *Symmetry of Endomorphism Algebras - preliminary report.* Preliminary report.

Motivated by recent problems regarding the symmetry of Hecke algebras, we investigate the symmetry of the endomorphism algebra $E_P(M)$ for P a p-group and M a kP-module with k a field of characteristic p. We provide a complete analysis for cyclic p-groups and the dihedral 2-groups. We also extend this analysis for more general endomorphism algebras $E_A(M)$ where A is a Nakayama algebra or a block with cyclic defect group. The methods developed in this paper should be applicable more generally. (Received September 22, 2011)

1077-20-2938 **Alimjon K Eshmatov*** (alimjon@math.arizona.edu), 617 Santa Rita Ave, tucson, AZ 85721. *On subgroups of the Dixmier group and Calogero-Moser spaces.* Preliminary report.

We describe the structure of the automorphism groups of algebras Morita equivalent to the first Weyl algebra $A_1(k)$. In particular, we give a geometric presentation for these groups in terms of amalgamated products, using the Bass-Serre theory of groups acting on graphs. A key role in our approach is played by a transitive action of the automorphism group of the free algebra $k < x, y >$ on the Calogero-Moser varieties $\mathcal{C}_n$ defined in which is a variation of Hilbert scheme of point on the plane. In the end, we propose a natural extension of the Dixmier Conjecture for $A_1(k)$ to the class of Morita equivalent algebras. (Received September 23, 2011)

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1077-22-32 **William M. McGovern*** (mcgovern@math.washington.edu), Department of Mathematics, Box 354350, University of Washington, Seattle, WA 98195. *Rational smoothness of K-orbits in the flag variety for GL(2n).*

At the Annual Meeting last January I sketched characterizations of the K-orbits with rationally smooth closure in a flag variety G/B, where G is a complex semisimple Lie group of classical type, B is a Borel subgroup, and K is a symmetric subgroup. I could not treat the case G = GL(n), K = O(n), at that time. Here I give two criteria in this case if n is even, one a necessary one in terms of pattern avoidance and the other a necessary and sufficient one in terms of the degree of the bottom vertex in the Bruhat graph. (Received June 15, 2011)

1077-22-86 **Paul Frank Baum*** (baum@math.psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802. *Geometric Structure in the Representation Theory of Reductive p-adic Groups.*

Let G be a reductive p-adic group. Examples are GL(n, F) SL(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 (or admissible) dual of G is the set of equivalence classes of smooth irreducible representations of G. The representations are on vector spaces over the complex numbers. The smooth dual has one point for each distinct smooth irreducible representation of G. Within 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 (ABP) 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. Recent results by a number of mathematicians (e.g. V. Heiermann, M. Solleveld) provide positive evidence for ABP. (Received July 24, 2011)

1077-22-87 **David A. Vogan*** (dav@math.mit.edu). *Kazhdan-Lusztig polynomials for disconnected groups.* Preliminary report.

Suppose G is a complex connected reductive algebraic group with Cartan and Borel subgroups $H \subset B$. Let δ be an automorphism of G of finite order preserving a pinning. Suppose θ is an involutive automorphism of G commuting with δ, with fixed point group K. Write $\widetilde{G}$ for the semidirect product of G with the (finite cyclic) group of automorphisms generated by δ, and $\widetilde{K}$ for the subgroup generated by K and δ.

Write X for the complete flag variety of G. The classical Kazhdan-Lusztig polynomials describe dimensions of stalks of K-equivariant perverse sheaves on X. We consider a generalization of Kazhdan-Lusztig polynomials that compute traces of δ on stalks $\widetilde{K}$-equivariant sheaves on X. When K is replaced by B, these polynomials were introduced by Lusztig in 1983. His ideas apply to the present setting as well.

These polynomials (or rather their values at 1) play a role in the algorithm of Adams, van Leeuwen, Trapa, Yee, and the author for calculating signatures of invariant Hermitian forms, and so identifying unitary representations. (Received July 24, 2011)

1077-22-135 **Luis Alberto Lomelí*** (lomeli@math.purdue.edu). *On representations and L-functions for the classical groups in positive characteristic.* Preliminary report.

We study representations of the linear algebraic groups $G_l = \mathrm{SO}_{2l+1}$, SP_{2l}, SO_{2l}, and U_n in positive characteristic. In particular, admissible generic representations of maximal Levi subgroups $M \simeq \mathrm{GL}_m \times G_n$ of G_l, $l = m+n$, and generic constituents of their induced representations. We define L-functions and related local factors over a non-archimedean local field by means of the uniqueness property of Whittaker models à la Langlands-Shahidi. For a globally generic cuspidal automorphic representation of M there is a connection to Langlands' theory of Eisenstein series that allows us to establish a global functional equation. (Received July 29, 2011)

1077-22-186 **Eric Sommers*** (esommers@math.umass.edu), Dept of Mathematics and Statistics, LGRT, UMass, Amherst, MA 01003. *The singularities of slices in the nilpotent cone.* Preliminary report.

We report on the classification of singularities of slices between adjacent orbits in nilpotent cones, a story begun by Slodowy between the regular and subregular nilpotent orbits and solved completely by Kraft and Procesi in the classical groups. Of particular interest are slices associated to special pieces and between adjacent special orbits. This is joint work with Fu, Juteau and Levy. (Received August 09, 2011)

1077-22-331 **Joseph A. Wolf*** (jawolf@math.berkeley.edu). *Range of the Double Fibration Transform (joint work with Michael Eastwood).*

Consider a complex flag manifold $Z = G/Q$ and an orbit $D = G_0(z)$ of a real form of G. The *double fibration transform* $P : H^s(D;E) \to H^0(M_D;E')$ carries cohomology of a negative vector bundle $E \to D$ to sections of a specific other vector bundle $E' \to M_D$ on the cycle space of D. When $E \to D$ is "sufficiently" negative the action of G_0 on $H^s(D;E)$ carries over to an action on the image of P. I'll describe specific situations in which "sufficiently negative" and the image of P are explicit in terms of the inducing parameters of $E \to D$ and a system of PDE associated to the transform. (Received August 22, 2011)

1077-22-466 **Victor Guillemin*** (vwg@math.mit.edu), Department of Mathematics, MIT, Cambridge, MA 02139. *Characters of group representations and semi-classical analysis.* Preliminary report.

We will show how the character formulas of Weyl, Kirillov et.al. for representations of compact Lie groups have connections with an ostensibly unrelated topic: semi-classical analysis. (Received September 02, 2011)

1077-22-568 **Xuhua Liu*** (xzl0002@auburn.edu), Department of Mathematics and Statistics, 221 Parker Hall, Auburn University, Auburn, AL 36849, and **Tin-Yau Tam**. *Gradient Flows for the Minimum Distance to the Sum of Adjoint Orbits.*

Let G be a connected semisimple Lie group and $\mathfrak{g}$ its Lie algebra. Let $\mathfrak{g} = \mathfrak{k} \oplus \mathfrak{p}$ be the Cartan decomposition corresponding to a Cartan involution θ of $\mathfrak{g}$. The Killing form B induces a positive definite symmetric bilinear form B_θ on $\mathfrak{g}$ defined by $B_\theta(X,Y) = -B(X,\theta Y)$. Given $A_0, A_1, \ldots, A_N \in \mathfrak{g}$, we consider the optimization problem

$$\min_{k_i \in K} \left\| \sum_{i=1}^{N} \mathrm{Ad}\,(k_i) A_i - A_0 \right\|,$$

where the norm $\|\cdot\|$ is induced by B_θ and K is the analytical subgroup of G with Lie algebra $\mathfrak{k}$. We obtain the gradient flow of a corresponding smooth function on the manifold $K \times \cdots \times K$. Our results give unified extensions of several results of Li, Poon, and Schulte-Herbrüggen. They are also true for reductive Lie groups. (Received September 07, 2011)

1077-22-653 **Paul Frank Baum*** (baum@math.psu.edu). *Extended Quotients and Kazhdan-Lusztig Parameters.*

Let $\mathcal{G}$ be a reductive p-adic group. Examples are $GL(n,F), SL(n,F)$ where n can be any positive integer and F can be any finite extension of the p-adic numbers $\mathbb{Q}_p$. G denotes the Langlands dual group. G is an algebraic group over the complex numbers $\mathbb{C}$. The smooth dual of $\mathcal{G}$ is the set of (equivalence classes of) smooth irreducible representations of $\mathcal{G}$. The smooth dual of $\mathcal{G}$ is the disjoint union of subsets known as the Bernstein components. The ABP (Aubert-Baum-Plymen) conjecture states that each Bernstein component is a complex affine algebraic variety and identifies these varieties as certain extended quotients. If $\mathcal{G}$ has connected center Kazhdan-Lusztig parametrize the Bernstein component consisting of those irreducible smooth representations of $\mathcal{G}$ having a non-zero vector fixed by the Iwahori subgroup. According to ABP these Kazhdan-Lusztig parameters should have the structure of the relevant extended quotient. Is this true? This talk will explain why this is true. Most of the work of the proof is with the Langlands dual group G.
The above is joint work with Anne-Marie Aubert and Roger Plymen. (Received September 09, 2011)

1077-22-692 **Amber Russell*** (arussell@math.lsu.edu). *Graham's Variety and Perverse Sheaves on the Nilpotent Cone.*

In recent work, Graham has constructed a variety with a map to the nilpotent cone that is similar to the Springer resolution. However, Graham's map differs from the Springer resolution in that it is not in general an isomorphism over the principal orbit, but rather the universal covering map. This map gives rise to a certain semisimple perverse sheaf on the nilpotent cone. In this talk, we discuss the problem of describing the summands of this perverse sheaf. For type A, a key tool is a description of the affine paving of Springer fibers given by Tymoczko that lends itself nicely to understanding the fibers of Graham's map. (Received September 10, 2011)

1077-22-830 **Monica Nevins*** (mnevins@uottawa.ca). *Restriction to a maximal compact subgroup in the p-adic case.* Preliminary report.

Restricting unitary representations of a Lie group to its maximal compact subgroup led to the theory minimal K-types and thus a powerful classification tool. For p-adic groups, the question of restricting representations to a maximal compact subgroup is complicated by a number of factors, including: that the maximal compact subgroup is not itself a p-adic group; that there are many conjugacy classes of maximal compact subgroups; and that the representation theory of these groups is not known. We describe our recent results for low rank cases, as well as progress towards a more general theory. (Received September 13, 2011)

1077-22-840 **Mary Clair Thompson*** (mct0006@auburn.edu), 1355 Commerce Dr #408, Auburn, AL 36830, and **T.Y. Tam**. *Convergence of Aluthge Iteration in Semisimple Lie Groups.* Preliminary report.

A recent result of Antezana et al. asserts that the iterated Aluthge sequence converges in the context of matrix groups. We extend the result to the convergence of the sequence in noncompact semisimple Lie groups. We also study the convergence of sequences closely related to the iterated Aluthge sequence. (Received September 13, 2011)

1077-22-874 **Adam Koranyi*** (adam.koranyi@lehman.cuny.edu). *Twisted Poisson integrals on bounded symmetric domains.*

What we call a twisted Poisson kernel on the unit disc or on a bounded symmetric domain is a product of powers of the ordinary Poisson kernel and of the Szego kernel. The corresponding Poisson integrals are eigenfunctions of certain modified Laplace operators. They have recently been studied, for the classical domains, by K. Okamoto and his collaborators. Group theoretically they can be interpreted as Poisson transforms from line bundles on the Shilov boundary to line bundles on the domain. New results include a classification-free extension of those of Okamoto et al. to all symmetric domains and the formulation of Hua-type differential equations in the tube type case. (Received September 13, 2011)

1077-22-1044 **Dan M Barbasch*** (dmb14@cornell.edu) and **Peter A Trapa**. *Unipotent representations for Sp(p,q) and O*(n).* Preliminary report.

In this work, joint with P. Trapa, we establish the unitarity of the unipotent representations in the sense of Arthur or Adams-Barbasch-Vogan for the real forms Sp(p,q) and O*(n). Unipotent representations are conjectured to be the building blocks of the unitary fual of a reductive real group. The techniques rely heavily on properties of the associated cycle or asymptotic support of an admissible module. (Received September 15, 2011)

1077-22-1220 **Jose A Franco*** (jose_franco@baylor.edu), One Bear Place #97328, Waco, TX 76798. *Global SL(2,R) representations of the Schrodinger equation with time-dependent potentials.* Preliminary report.

We study the representation theory of the solution space of the one-dimensional Schrodinger equation with time-dependent potentials that posses sl(2,R)-symmetry. We give explicit local intertwining maps to multiplier representations and show that the study of the solution space for potentials of the form $V(t,x) = g_2(t)x^2 + g_1(t)x + g_0(t)$ reduces to the study of the potential free case. We also show that the study of the time-dependent potentials of the form $V(t,x) = cx^{(-2)} + g_2(t)x^2 + g_0(t)$ reduces to the study of the potential $V(t,x) = cx^{(-2)}$. Therefore, we study the representation theory associated to solutions of the Schrodinger equation with this potential. The subspace of solutions for which the action globalizes is constructed via nonstandard induction outside the semisimple category. (Received September 18, 2011)

1077-22-1342 **Aloysius G Helminck*** (loek@ncsu.edu), Department of Mathematics, Campus Box 8205, NC State University, Raleigh, NC 27695. *Generalized Cartan subspaces.* Preliminary report.

Let G be a connected reductive algebraic group defined over a field k of characteristic not 2, σ an involution of G defined over k, H a k-open subgroup of the fixed point group of σ and G_k (resp. H_k) the set of k-rational points of G (resp. H). The variety G_k/H_k is a generalization of a real reductive symmetric spaces to arbitrary fields and is called a symmetric k-variety. For real and p-adic symmetric k-varieties the space $L^2(G_k/H_k)$ of square integrable functions decomposes into several series, one for each H_k-conjugacy class of Cartan subspaces of G_k/H_k. In this talk we will discuss some recent results about the H_k-conjugacy classes of Cartan subspaces. (Received September 19, 2011)

1077-22-1380 **Dan Ciubotaru*** (ciubo@math.utah.edu) and **Syu Kato**. *Formal degrees of discrete series for classical affine Hecke algebras and p-adic groups.*

The stability of L-packets of discrete series for p-adic groups implies that the formal degrees of the discrete series in the same L-packet have to be proportional. In the category of representations with unipotent cuspidal support in the sense of Lusztig, this problem can be translated to one for affine Hecke algebras with unequal parameters. Following Reeder, Opdam, and Solleveld, the formal degree of a discrete series for affine Hecke algebras are known up to a rational constant (depending on the discrete series). Reeder conjectured a precise form for this constant, and verified the conjecture for the Hecke algebras arising for split exceptional groups.

In joint work with Syu Kato, we compute the missing constants for the affine Hecke algebras of classical types with unequal parameters. The method of calculation is a consequence of a new algorithm for the W-structure of tempered modules for these Hecke algebras, based on Kato's exotic geometry. (Received September 19, 2011)

1077-22-1388 **Bent Orsted*** (orsted@imf.au.dk). *Segal-Bargmann transforms: Old and new.* Preliminary report.

The classical Segal-Bargmann transform is an important integral operator giving the equivalence between two models of the metaplectic representation. It has been extended to many equally interesting situations, involving Hilbert spaces of holomorphic functions and harmonic analysis on Lie groups. We shall mention some new analogues in connection with Euclidian Jordan algebras and minimal unitary representations, where we find an integral transform between two models of the representations; in particular, there is a natural extension of the theory of spherical harmonics to this setting. Here we report on joint work with J. Hilgert, T. Kobayashi, and J. Moellers. (Received September 19, 2011)

1077-22-1415 **Benjamin Trahan*** (trahan@math.utah.edu), trahan@math.utah.edu. *Lefschetz Functors for the Metaplectic Group.*

In a recent paper, Ciubotaru and Trapa defined a family of exact functors carrying spherical Harish-Chandra modules for real classical linear algebraic groups to representations of a certain algebra called the graded affine Hecke algebra. Representations of this algebra can then be translated, thanks to results of Lusztig, Barbasch, and Moy, into representations of a p-adic group of the same type as the original real group. The result, in effect, is a Lefschetz functor for real classical linear algebraic groups; it also embeds the spherical unitary dual for the real group into the spherical unitary dual for the p-adic group. This talk describes the first extension to a non-linear example, an analagous functor for genuine representations of the real and p-adic metaplectic groups. (Received September 22, 2011)

1077-22-1515 **Erik P. van den Ban*** (E.P.vandenBan@uu.nl), Department of Mathematics, Utrecht University, PO Box 80 010, 3518 TA Utrecht, Netherlands. *Cusp forms for semisimple symmetric spaces.* Preliminary report.

We report on joint work with Job Kuit and (partly) Henrik Schlichtkrull.

In Harish-Chandra's work on harmonic analysis for a general real semisimple Lie group G, the notion of cusp form plays a fundamental role. The space $\mathcal{C}_{\text{cusp}}(G)$ of cusp forms is a subspace of the Schwartz space $\mathcal{C}(G)$, characterized by vanishing of suitable integral transforms. A famous result of Harish-Chandra asserts that $\mathcal{C}_{\text{cusp}}(G)$ equals the discrete part $\mathcal{C}_d(G)$ of $\mathcal{C}(G)$.

In the past decades, the theory of harmonic analysis on a general semisimple symmetric space G/H has been developed to a large extent, resulting in a Plancherel theorem. However, a suitable notion of cusp form has not yet been developed. A few years ago, M. Flensted-Jensen proposed such a notion, which would generalize the notion for the group. In the present talk we will show that with a small adaptation, this idea works for spaces of split rank 1. The resulting space $\mathcal{C}_{\text{cusp}}(G/H)$ is contained in $\mathcal{C}_{\text{d}}(G/H)$ but need not be equal to the latter. (Received September 20, 2011)

1077-22-1572 **Annegret Paul*** (annegret.paul@wmich.edu). *Unitary Representations of Double Covers of Linear Groups.* Preliminary report.

We report on some recent progress on the unitary genuine representations of double covers of certain linear real Lie groups. (Received September 20, 2011)

1077-22-1590 **Francois Rouviere*** (frou@unice.fr). *Mean value theorems on symmetric spaces.*

Revisiting some mean value theorems by F. John, resp. S. Helgason, I will discuss their extension to symmetric spaces, resp. their restatement in a more detailed form, with emphasis on their relation to the infinitesimal structure of the symmetric space. (Received September 20, 2011)

1077-22-1600 **Kumar Balasubramanian*** (kumar@math.ou.edu), Department of Mathematics, 601 Elm Ave, PHSC 423, Norman, OK 73019. *Self-dual representations with vectors fixed under an Iwahori subgroup.* Preliminary report.

An irreducible smooth self-dual representation of a reductive p-adic group preserves either a non-zero symmetric or a non-zero alternating form on the underlying space and accordingly is said to have sign plus one or minus one. There is strong evidence that this sign is always one in the case of representations with non-trivial Iwahori fixed vectors. We will discuss some of this evidence. (Received September 20, 2011)

1077-22-1640 **Leticia I Barchini*** (leticia@math.okstate.edu), 403 Mathematical Sciences, OSU, Stillwater, OK 74078. *On the associated cycle of $(\mathfrak{g}, K)$-modules for $\mathfrak{g}_{\mathbb{R}} = \mathfrak{sp}(p, q)$ or $\mathfrak{so}^*(2n)$.*

The most important invariant of an irreducible admissible representation M of a semisimple Lie group G_R is its global character, Θ. Via the exponential map, Θ lifts to an invariant eigendistribution θ on a neighborhood of the origin in $\mathfrak{g}_{\mathbb{R}}$. Barbasch-Vogan showed that θ admits an assymptotic expansion and the Fourier transform of the leading term is a linear combination of invariant Liouville measures on nilpotent G_R-orbits. The assymptotic cycle of M is a linear combination of these orbits with multiplicities, m_i. Schmid and Vilonen proved that a geometric counterpart of the assymptotic cycle is the associated cycle of the Harish-Chandra module M. The geometry of the invariant comes from associating to M a $(\mathcal{D}, K)$-module. The leading term of the characteristic cycle of the $(\mathcal{D}, K)$-module is closely related to the associated cycle of M. The talk will focus on the study of associated cycle for a class of irreducible modules when $\mathfrak{g}_{\mathbb{R}} = \mathfrak{sp}(p, q)$ or $\mathfrak{so}^*(2n)$. We will discuss aspects of the computation of multiplicity polynomials as well as information on annihilators encoded in the leading term of the characteristic cycles. (Received September 20, 2011)

1077-22-1738 **Ivan Mirkovic***, Dept of Math, Umass, Amherst, MA 01003. *Representation Theory of semisimple Lie algebras in positive characteristic.* Preliminary report.

Methods developed with Bezrukavnikov and Rumynin. (Received September 20, 2011)

1077-22-1916 **Annegret Paul**, **Siddhartha Sahi** and **Wai Ling Yee***, wlyee@uwindsor.ca. *Generalized Harish-Chandra Modules for Mixed Subgroups.*

Two major tools in representation theory are:

1) restricting representations to compact subgroups since the representation theory of compact groups is well understood (this leads to the category of Harish-Chandra modules) and

2) exploiting joint eigenspaces of a Cartan (weight theory, which leads to Category $\mathcal{O}$).

Motivated by combining the theory of compact groups with highest weight theory, we define mixed subgroups. The category of $(\mathfrak{g}, M)$ modules, where M is a mixed subgroup, generalizes both Category $\mathcal{O}$ and the category of Harish-Chandra modules: they can be recovered by choosing M appropriately.

We classify the irreducibles in $C(\mathfrak{g}, M)$. We relate $K\backslash G/B$, $M\backslash G/B$, and discuss the Bruhat order. Finally, we show certain equivalence classes of mixed subgroup orbits on the flag variety to be in bijection with mixed subgroup orbits on flag varieties for smaller generalized Harish-Chandra pairs: this permits a generalization of the common technique of using root subsystems to simplify Kazhdan-Lusztig-Vogan polynomial computations.

This is joint work with Annegret Paul and Siddhartha Sahi. (Received September 21, 2011)

1077-22-1929 **Henrik Schlichtkrull*** (schlicht@math.ku.dk). *Counting lattice points on homogeneous spaces.*

We consider a homogeneous space Z=G/H of a real reductive Lie group G with a closed connected subgroup H. The investigation concerns the decay at infinity of smooth functions on Z, and the results are used to determine the asymptotic density of lattice points on Z (representing joint work with B. Krotz and E. Sayag). (Received September 21, 2011)

1077-22-1974 **Vitaly Bergelson**, **Neil Hindman** and **Kendall Williams*** (kendall.williams@usma.edu). *Elements of Tensor Products of Ultrafilters on $\mathbb{N}$.* Preliminary report.

Let $a_1, a_2, \ldots, a_m \in \mathbb{Z}$, $a_m > 0$, and $\langle x_n \rangle_{n=1}^{\infty}$ in $\mathbb{N}$. A Milliken-Taylor system, $MT(\langle a_i \rangle_{i=1}^{m}, \langle x_n \rangle_{n=1}^{\infty})$, is $\{\sum_{i=1}^{m} a_i \sum_{t \in F_i} x_t : F_1, F_2, \ldots, F_m$ are increasing finite nonempty subsets of $\mathbb{N}\}$. Given $\langle x_n \rangle_{n=1}^{\infty}$ in $\mathbb{N}$ and $A \subseteq \mathbb{N}$, there is a sum subsystem $\langle y_n \rangle_{n=1}^{\infty}$ of $\langle x_n \rangle_{n=1}^{\infty}$ such that the finite sums of $\langle x_n \rangle_{n=1}^{\infty}$ are contained in A if and only if there is an idempotent p in the Stone-Čech Compactification of $\mathbb{N}$ such that $A \in p$ and for each $m \in \mathbb{N}$, the finite sums of $\langle x_n \rangle_{n=1}^{\infty}$ are in p. A similar result holds where the finite sums are replaced by the Milliken-Taylor system and A is an element of a sum of ultrafilters. Further generalizations of this result hold wherein the Milliken-Taylor system is replaced by a more general analogous set and A is an element of an arbitrary polynomial evaluated on ultrafilters or it is an element of a tensor product of ultrafilters. (Received September 21, 2011)

1077-22-2027 **Daniel Juteau**, **Carl Mautner*** (cmautner@math.harvard.edu) and **Geordie Williamson**. *Parity Sheaves and Tilting Modules.*

The geometric Satake theorem, as proved by Mirkovic-Vilonen, states that the category of rational representations of a reductive group G over a field k is equivalent to a category of perverse sheaves on the affine Grassmannian for the Langlands dual group. We prove that under mild restrictions on the characteristic of k, the tilting modules for G correspond to perverse sheaves characterized by a simple geometric property - a parity vanishing condition on stalks and costalks. (Received September 21, 2011)

1077-22-2107 **S. A. Salamanca-riba***, ssalaman@nmsu.edu, and **A. Pantano** and **A. Paul**. *On the classification of some unitary representations.*

We will discuss some parametrizations of unitary representations for certain double covers of real Lie groups (Received September 21, 2011)

1077-22-2432 **Hideko Sekiguchi***, Graduate School of Mathematical Sciences, The University of Tokyo, 3-8-1 Komaba, Meguro, Tokyo 153-8914, Japan. *Penrose transforms between symmetric spaces.* Preliminary report.

We determine the image of the Penrose transform, from the Dolbeault cohomology group on the indefinite Grassmann manifold consisting of maximal positive k-planes to the space of holomorphic functions over the bounded symmetric domain. Furthermore, we generalize twistor transforms, and prove that there is a duality between Dolbeault cohomology groups on two indefinite Grassmann manifolds, namely, that of positive k-planes and that of negative k-planes. (Received September 22, 2011)

1077-22-2459 **Robert J. Stanton*** (stanton@math.ohio-state.edu), 231 W. 18th Ave., Columbus, OH 43210-1174, and **Marcus J. Slupinski**. *Special geometries arising from some special symmetric spaces.* Preliminary report.

Berger showed that an irreducible Riemannian manifold is either a symmetric space or the holonomy group acts transitively on the unit sphere in the tangent space. For irreducible Riemannian symmetric spaces, Helgason did a detailed investigation of the harmonic analysis of the tangent space. We consider irreducible manifolds with affine connection of special symplectic type and the holonomy action on the tangent space. We prove the existence of special pseudo-Kähler metrics generalizing a result of Hitchin. The main new tool is detailed information about the secant variety to the minimal orbit in the tangent space. (Received September 22, 2011)

1077-22-2489 **Keith Ouellette*** (keith.r.ouellette@gmail.com). *On the Fourier inversion formula for SL_3.* Preliminary report.

In 2006, we presented a new way to obtain the Fourier inversion formula for wave packets on the full modular group. We will illustrate the ideas behind this method in the setting of SL_3 for wave packets built from cuspidal maximal parabolic Eisenstein series and use the Fourier inversion formula to compute the Plancherel measure. (Received September 22, 2011)

1077-22-2884 **Stephen DeBacker***, Department of Mathematics, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109-1043, and **Loren Spice**, Texas Christian University, 2840 W. Bowie St, Fort Worth, TX 76109. *Unexpected twists in positive depth L-packets.* Preliminary report.

The conjectural Local Langlands Correspondence (LLC) states that the set of irreducible smooth discrete series representations of a p-adic group may be partitioned into finite sets, called L-packets, such that many wonderful properties hold. One of the expected properties states that an appropriate combination of characters of the representations in an L-packet will be stable – that is, as a function on the set of strongly regular semisimple rational elements, the combination should assume the same value at any two elements that are conjugate over the algebraic closure. We have found that, in a very natural setting, the “obvious” L-packet does not have this property. To overcome this difficulty, a certain twist must be added to the mix. (Received September 22, 2011)

26 ► Real functions

1077-26-359 **George A Anastassiou*** (ganastss@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152. *Fractional Inequalities Revisited.* Preliminary report.

In this work we use primarily the Caputo fractional derivative, as the most important in applications, and we present first fractional differentiation inequalities of Opial type where we involve the so called balanced fractional derivatives. We continue with right and mixed fractional differentiation Ostrowski inequalities in the univariate and multivariate cases. Then we present right and left, as well as mixed, Landau fractional diferentiation inequalities in the univariate and multivariate cases. The inequalities are given for various norms. (Received August 25, 2011)

1077-26-649 **Javad Namazi*** (namazi@fdu.edu), Madison, NJ 07940. *A Pointwise Convergence and Bessel Capacity.*

Let $1 < p < \infty$, and k and m be positive integers such that $0 \leq (k-2m)p \leq n$. Let Ω be an open set in R^n. It is shown that there exists a sequence of positive constants c_j such that for every f in the Sobolev space $W^{k,p}(\Omega)$,

$$\lim_{r\to 0} \frac{1}{r^{2m}|B(x,r)|}\int_{B(x,r)}[f(y) - \sum_{j=0}^{m-1} c_j r^{2j}\Delta^j f(x)]dy = c_m \Delta^m f(x)$$

for all $x \in \Omega$ except on set of zero Bessel capacity. (Received September 09, 2011)

1077-26-957 **Udita Nalin Katugampola*** (uditanalin@yahoo.com), Department of Mathematical Sciences, Delaware State University, Dover, DE 19901. *Generalized Fractional Integrals, Derivatives and their Mellin's transforms.*

In this paper we present generalizations to two existing fractional integrals and derivatives, which generalize the Riemann-Liouville and Hadamard fractional operators into a single form. Conditions are given for such fractional operators to be bounded in an extended Lebesgue-measurable space. The existence and uniqueness results for single term generalized fractional Differential Equations (FDE) have also been established. We also obtain Mellin transforms of such generalized fractional operators which play an important role in solving fractional differential equations. We further investigate the hidden structure behind the generalized δ_k^n operators, which shows some connection to the Stirling numbers of the second kind and Lah numbers. (Received September 14, 2011)

1077-26-2606 **Yang Wang*** (gt_undergrad@yahoo.com), 5228 Madison Ave., Apt-A05, Okemos, MI 48864. *Lipschitz Equivalence of Cantor Sets.*

Two sets E, F are said to be Lipschitz equivalent if there is a map $f : E \longrightarrow F$ such that both f and f^{-1} are Lipschitz. In this talk we consider the Lipschitz equivalence of two Cantor sets. We present necessary and sufficient conditions for their equivalence. In particular, we show that the algebraic properties of the contraction ratios for the Cantors sets play significant role here. (Received September 22, 2011)

1077-26-2795 **Michael J. Evans** and **Manuel J. Sanders III***, mjsander@uscb.edu. *Some Subclasses of the Real-Valued Honorary Baire Two Functions on* $\mathbb{R}^n$. Preliminary report.

Certain subclasses of the class of Baire one real-valued functions have very nice properties, especially concerning their points of continuity and their preservation of connectedness for many connected sets. A Gibson [weakly Gibson] function $f : \mathbb{R}^n \to \mathbb{R}$ is defined by the requirement that $f(\overline{U}) \subseteq \overline{f(U)}$ for every open [open connected] set U in $\mathbb{R}^n$. It is known that Baire one, Gibson functions are continuous, and that Baire one, weakly Gibson functions have Darboux-like properties in the sense that if $U \subseteq \mathbb{R}^n$ is an open connected set and $U \subseteq S \subseteq \overline{U}$, then $f(S)$ is an interval. A summary of the study of the situation where the Baire one condition is replaced by honorary Baire two will be discussed. Distinctly different results are found. (Received September 22, 2011)

28 ► Measure and integration

1077-28-79 **Anna Savvopoulou***, annsavvo@iusb.edu, and **karin Reinhold**. *Variation and oscillation inequalities for convolution products.*

We establish variation and oscillation inequalities for convolution products of probability measures defined on the integers. (Received July 19, 2011)

1077-28-1181 **Kate E. Ellis** (kellis1@csustan.edu), **Michel L. Lapidus** (lapidus@math.ucr.edu), **Michael C. Mackenzie** (michael.mackenzie@uconn.edu) and **John A. Rock*** (jarock@csupomona.edu), Department of Mathematics and Statistics, Cal Poly Pomona, 3801 W Temple Ave, Pomona, CA 91768. *Multifractal spectra of certain self-similar measures as abscissa of convergence functions.*

The construction of a self-similar measure supported in the unit interval yields a multifractal decomposition of the support when the measure is not the natural mass distribution of a self-similar set. Such a decomposition comprises a collection of disjoint sets whose Hausdorff dimensions form a continuum known as a multifractal spectrum. In this talk, a technique that follows along the lines of a classic result of A. S. Besicovitch and S. J. Taylor (stated in modern terminology due to M. L. Lapidus) will be shown to recover the multifractal spectrum of a certain type of self-similar measure as the concave envelope of the abscissa of convergence function associated with the corresponding family of partition zeta functions. These and related results are established in the paper Partition zeta functions, multifractal spectra, and tapestries of complex dimensions by K. E. Ellis, M. L. Lapidus,

M. C. Mackenzie, and J. A. Rock. This paper will appear in the Mandelbrot Memorial Volume to be published by World Scientific. (Received September 17, 2011)

1077-28-1531 **Robert S. Strichartz***, Math Dept, Malott Hall, Cornell Univ, Ithaca, NY 14853.
Constructing invariant Laplacians on Julia sets. Preliminary report.

I will discuss joint work with REU students Taryn Flock, Stella Dong, Tarik Aougab, Calum Spicer and Emad Totari over the past several years on the general topic of constructing Laplacians on Julia sets satisfying an invariance condition with respect to the polynomial or rational function that defines the Julia set. The Julia set may be parametrized by the exterior ray angles, and this gives it the structure of the quotient of a circle with points identified. We attempt to transport the measure and energy from the circle to the Julia set. For the measure this is trivial, but for the energy it invloves renormalization, and the renormalization factor is determined by solving a nonlinear eigenvalue problem. By some miracle we don't understand, in all the examples we studied the nonlinear problem may be reduced to a linear problem. We prove many interesting properties of the eigenfunctions of the Laplacian, and we develop numerical methods to approximate graphs of them. (Received September 20, 2011)

1077-28-2420 **Nishu Lal*** (nishul@math.ucr.edu), Department of Mathematics, University of California, Riverside, Riverside, CA 92521, and **Michel Lapidus** (lapidus@math.ucr.edu), Department of Mathematics, University of California, Riverside, Riverside, CA 92521.
Factorization of the spectral zeta function of differential operators on fractals.

We investigate the factorization formula of the spectral zeta function of Laplacian-like operators on self-similar sets, in particular, those operators for which the decimation method is well established. We will consider the Sturm−Liouville operator on the half real line and C. Sabot's work connecting the spectrum of this operator with the iteration of a rational map of several complex variables. The Sturm-Liouville operator on $[0, \infty)$ is viewed as a limit of the sequence of operators $\frac{d}{dm_{<n>}} \frac{d}{dx}$ with Dirichlet boundary condition on $I_{<n>} = [0, \alpha^{-n}]$ which are the infinitesimal generators of the Dirichlet form $(a_{<n>}, m_{<n>})$. We obtain a factorization of the spectral zeta function expressed in terms of the zeta function associated with the dynamics of the corresponding renormalization map induced by the decimation method, viewed as a rational function on the complex projective plane $\mathbb{P}^2(\mathbb{C})$. Furthermore, we conclude by showing that a similar factorization formula exists for other fractals, including the infinite Sierpinski gasket. Joint work with M. Lapidus. (Received September 22, 2011)

30 ► Functions of a complex variable

1077-30-58 **Tamas Forgacs*** (tforgacs@csufresno.edu). *Multiplier sequences for simple sets of polynomials.* Preliminary report.

Let $Q = \{q_k(x)\}_{k=0}^{\infty}$ be a simple set of polynomials. We call a sequence of real numbers $\{\gamma_k\}_{k=0}^{\infty}$ a Q-multiplier sequence, if $\sum a_k \gamma_k q_k(x)$ has only real zeros whenever $\sum a_k q_k(x)$ has only real zeros. While multiplier sequences for the standard and Hermite bases have been completely characterized by Pólya-Schur (1914) and Piotrowski (2007) respectively, very little is known about multiplier sequences for other special, and more general bases. In this talk we exhibit that every multiplier sequence for a simple *orthogonal* set of polynomials must be a Hermite multiplier sequence, and describe how multiplier sequences for simple sets of polynomials relate to known sets of multiplier sequences. (Received July 13, 2011)

1077-30-147 **R M Ali*** (rosihan@cs.usm.my), School of Mathematical Sciences, Universiti Sains Malaysia, 11800 Penang, Malaysia, and **Y Abu-Muhanna**. *Bohr's phenomenon for analytic functions into the exterior of a compact convex body.*

A Bohr's inequality for the class of analytic functions mapping the unit disk into the exterior of a compact convex body is established. In this general case, the radius obtained is $|z| < 3 - 2\sqrt{2}$. When the compact convex body is the closed unit disk, a sharp radius of 1/3 is obtained. (Received August 02, 2011)

1077-30-276 **See Keong Lee*** (sklee@cs.usm.my), School of Mathematical Sciences, Universiti Sains Malaysia, 11800 Minden, Penang, Malaysia. *Coefficient Estimates for Bi-univalent Ma-Minda Starlike and Convex Functions.*

In this paper, we investigate estimates for the initial coefficients of normalized analytic functions f defined on the open unit disk $\mathbb{D}$ with f and its inverse $g = f^{-1}$ satisfying the condition that $zf'(z)/f(z)$ and $zg'(z)/g(z)$ are both subordinate to certain starlike univalent function $\varphi(z)$ whose range $\varphi(\mathbb{D})$ is symmetric with respect to the real axis. Certain other related functions are also considered and connection to the previously known results are also indicated. (Received August 18, 2011)

1077-30-328 **Brent J Carswell** and **Rachel J Weir*** (rweir@allegheny.edu), Department of Mathematics, Allegheny College, Meadville, PA 16335. *Weighted reproducing kernels and the Bergman space.*

Using weighted reproducing kernels, we describe the orthocomplement of gM in M when M is a singly generated shift invariant subspace of the Bergman space and g is a finite Blaschke product vanishing at the origin. We also discuss the case when g is an infinite Blaschke product, and we present an approximation result for weighted kernels corresponding to Blaschke products. The proofs all involve a formula relating reproducing kernels corresponding to two different measures, where one measure is a weighted version of the other. (Received August 22, 2011)

1077-30-1015 **John Wermer*** (wermer@math.brown.edu), 128 Irving Ave, Providence, RI 02906. *Polynomial Hulls of Certain Compact Manifolds.*

Let X be a compact set in C^n and let $X^\wedge$ denote the polynomial hull of X. Rossi's Local Maximum Principle suggests that $X^\wedge \backslash X$ is either empty or has analytic structure. In full generality, this is false. Question: Let X be a smooth compact orientable k-manifold in C^n. When does $X^\wedge \backslash X$ possess analytic structure? For $k = 1$ (smooth curves) it is known that, when X is not equal to $X^\wedge m$, the answer is "always". A classical result by A. Browder from 1961 gives that, for $k = n$, the cohomology group $H^k(X^\wedge, C) = 0$, and so $X^\wedge$ is not X. For $k = 2$, we discuss some consequences of Browder's result. For general x, we give a necessary condition on x in order that $X^\wedge \backslash X$ has analytic structure for. Finally, we point out contributions to this problem, in terms of the existence of certain (1,1) currents, due to Duval and Sibony, in the 1990's. (Received September 15, 2011)

1077-30-1066 **Brian J. Cole** (Brian_Cole@brown.edu), Department of Mathematics, Brown University, Providence, Rhode Island 02912, U.S.A.. *A non-semialgebraic interpolation body* Preliminary report.

Let A be a uniform algebra on a set X, and fix distinct points $\zeta_1, \ldots, \zeta_n$ in X. The associated *interpolation body* is the set

$$\mathcal{E} = \{ (z_1, \ldots, z_n) \in \mathbf{C}^n \,\big|\, \forall \epsilon > 0 \; \exists f \in A, \; \|f\| < 1 + \epsilon, \; f(\zeta_i) = z_i, \; i = 1, \ldots, n \}.$$

Note that $\mathcal{E}$ is a compact, convex subset of $\mathbf{C}^n$. As a special case, consider $X = \Omega$, a complex manifold, and $A = H^\infty(\Omega)$. Pick's theorem describes $\mathcal{E}$ in terms of algebraic inequalities when Ω is the unit disk in $\mathbf{C}$, and hence $\mathcal{E}$ is a semialgebraic set in this case. More generally, it is known that $\mathcal{E}$ is semialgebraic when Ω is the unit bi-disk in $\mathbf{C}^2$ or a finite Riemann surface. In the negative direction, we prove the following

Theorem. *There exists an interpolation body $\mathcal{E}$ for a uniform algebra so that $\mathcal{E}$ is not semialgebraic.* (Received September 15, 2011)

1077-30-1564 **G Wang*** (gwang@math.fsu.edu) and **Craig Nolder**. *Fourier multipliers and Dirac operators.*

We use Fourier multipliers of the Dirac operator and Cauchy transformation to obtain composition theorems and integral representations. In particular we calculate the multiplier of the Π-operator. This operator is the hypercomplex version of the beurling Ahlfors transform in the plane. The hypercomplex Beurling Ahlfors transform is a direct generalization of the Beurling Ahlfors transform and reduces to this operator in the plane. We give an integral representation for iterations of the hypercomplex Beurling Ahlfors transform and we present here a bound for the L^p norm. Such L^p bounds are essential for applications of the Beurling Ahlfors transform in the plane. The upper bound presented here is $m(p^\star - 1)$ where m is the dimension of the Euclidean space on which the function is defined, $1 < p < \infty$ and $p^\star = max(p, \frac{p}{p-1})$. We use recent estimates on second order Riesz transforms to obtain this result. Using the Fourier multiplier of the Π operator we express this operator as a hypercomplex linear combination of second order Riesz transforms. (Received September 20, 2011)

1077-30-1942 **J. Marshall Ash*** (mash@math.depaul.edu), DePaul University, Mathematics Department, Chicago, IL 60614. *An analytic function without radial boundary values.*

It is a fairly well known, but not immediately accessible, fact that there exists a function analytic on $D = \{z \in \mathbb{C} : |z| < 1\}$ that has a radial limit at no point of the boundary $\{z \in \mathbb{C} : |z| = 1\}$. The function $f(z) = \sum_{n=0}^{\infty} z^{n!}$ can easily be shown to be be an example of such a function. The very short proof of this is buried in the paper of J. M. Ash and M. T. Karaev, "On the boundary behavior of special classes of C-functions and analytic functions," which will appear in the International Mathematical Forum. Since I think this is a useful fact, I will sketch the proof that the analytic on D function $f(z)$ is radially divergent on the entire boundary of D. (Received September 21, 2011)

1077-30-2312 **Kourosh Tavakoli***, ktavakoli@gc.cuny.edu. *Limit Behavior of Iterated Holomorphic Function Systems.*

In this talk, I will consider all the iterated holomorphic function systems from a domain to one of its subdomain. I will show that under certain condition every point on the boundary of the subdomain is the accumulation point of some iterated holomorphic function system. (Received September 22, 2011)

1077-30-2698 **Tamas Forgacs** (tforgacs@csufresno.edu) and **Andrzej Piotrowski*** (apiotrowski@uas.alaska.edu). *Polynomial Coefficients of Differential Operators which are Diagonal with respect to the Hermite Basis.* Preliminary report.

Let $\{\gamma_k\}$ be a sequence of real numbers and let $\{H_k(x)\}$ denote the set of Hermite polynomials. Define a linear operator $T : \mathbb{R}[x] \to \mathbb{R}[x]$ by declaring $T[H_k(x)] = \gamma_k H_k(x)$ for all k. This linear operator can be represented in the form $T = \sum_{k=0}^{\infty} T_k(x)D^k$, where D denotes differentiation with respect to x. We seek to determine an explicit form of the polynomial coefficients $T_k(x)$ in the differential operator representation. (Received September 22, 2011)

1077-30-2718 **Arthur A. Danielyan*** (adaniely@usf.edu), Department of Mathematics and Statistics, 4202 East Fowler Ave, PHY 114, Tampa, FL 33620-5700. *On a polynomial approximation problem.*

Let F be an arbitrary closed subset on the unit circle T and let f be a continuous complex valued function on F. We consider the problem of uniform approximation of f on F by polynomials P_n (of variable z) which are uniformly bounded on T. In a particular case when F is a closed arc of T, this problem was solved by L. Zalcman in 1982. In this talk we give the solution of the problem in the general case. As an application of the main result we also present a new proof for the classical interpolation theorem due to W. Rudin and L. Carleson. (Received September 22, 2011)

1077-30-2765 **Stacey Muir*** (muirs2@scranton.edu), University of Scranton, Mathematics Department, Scranton, PA 18510. *Convolutions of Complex-Valued Harmonic Mappings.* Preliminary report.

We will discuss the mapping properties of the convolution of complex-valued harmonic mappings defined on the open unit disk $\mathbb{D} \subset \mathbb{C}$. Unlike in the analytic case, it is known that the convolution of two harmonic mappings with a convex image does not necessarily result in a mapping with a convex image. We will present some conditions that assure local univalence of a harmonic convolution and provide a number of examples where the convolution has a convex image. (Received September 22, 2011)

31 ► *Potential theory*

1077-31-1921 **Martin Gutting***, University of Kaiserslautern, Department of Mathematics, P. O. Box 3049, D-67653 Kaiserslautern, Germany. *Fast Multipole Accelerated Solution of the Oblique Boundary Value Problem.*

The oblique boundary value problem of potential theory plays an important role in physical geodesy, in particular in modeling the gravitational field. Thereby, the boundary is the known surface of the Earth itself and the measurements can be considered as discrete scattered directional derivatives of the potential on the surface or on parts of that surface. The Runge-Walsh approximation allows the construction of the solution in terms of harmonic splines. These localizing trial functions lead to a system of linear equations whose solution provides directly the - possibly local - solution of the boundary value problem. To obtain a fast matrix-vector multiplication fast multipole methods are developed for the occurring kernels. In combination with a domain decomposition method that helps to precondition the system of linear equations an iterative solver can determine quickly the desired approximation. (Received September 21, 2011)

1077-31-2160 **Lucio M-G Prado*** (lprado@bmcc.cuny.edu), Department of Mathematics, BMCC, The City of New York, 199 Chambers Street, New York, NY 10007. *Existence of p-Flows in $\mathbb{Z}^n$ and T_d.*

The aim of this talk is to present concepts and techniques from p-potential theory on Riemannian manifolds adapted to *finite* and *infinite graphs*. The principal tool will be p-capacity that it will be computed for $\mathbb{Z}^n$ and show that it is related the Riemann Zeta function. In this way, the lattices $\mathbb{Z}^n$ will be classified as p-hyperbolic graphs under determined condition in terms of n and p. By combining p-capacity with Kevin-Nevanlinna-Royden criterion for graphs, adapted from continuous settings, the existence of nontrivial p-flows in the lattices $\mathbb{Z}^n$ will be shown. Finally, if time permits, similar results for homogenous trees T_d will be discussed. (Received September 21, 2011)

1077-31-2427 **Elena Kotevska*** (elena.kotevska@tfb.uklo.edu.mk). *Real Earth Based Geopotential Determination.* Preliminary report.

For computational reasons, the spline interpolation of the Earth's gravitational potential is usually done in a spherical framework. However, the increasing observational accuracy require adequate mathematical methods and observing of the geophysically more relevant surfaces. In this work, we propose a spline method with respect to the real Earth surface. The spline formulation reflects the specific geometry of a given regular surface . This is due to the representation of the reproducing kernel as a Newton integral over the inner space of a regular surface. Moreover, the approximating potential functions have the same domain of harmonicity as the actual Earth's gravitational potential. This is a step forward in comparison to the spherical harmonic spline formulation involving functions harmonic down to the Runge sphere. It turns out that in the case of the spherical Earth, the representation of this kernel can be considered a kind of generalization to spherically oriented kernels. Keywords: , regular surface, reproducing kernel, harmonic function. (Received September 22, 2011)

32 ► *Several complex variables and analytic spaces*

1077-32-415 **Alexander J. Izzo*** (aizzo@math.bgsu.edu). *Function algebras invariant under group actions.* Preliminary report.

Motivated by his work on a conjecture of William Arveson in operator theory, Ronald Douglas raised the following question, where S denotes the unit sphere in complex n-space. If A is a function algebra on S that contains the ball algebra $A(S)$ and whose maximal ideal space is S, and if A is invariant under the action of the n-torus on S, does it follow that $A = C(S)$? When $n = 1$, Wermer's maximality theorem gives immediately that the answer is yes. Surprisingly, in higher dimensions the answer depends on the dimension. We will discuss the solution to Douglas' question and present related results of a more general nature concerning function algebras that are invariant under group actions. (Received August 30, 2011)

1077-32-439 **Robert A Bridges*** (bridges@purdue.edu). *Schroeder's Equation in Several Variables.*

If $\phi : \mathbb{D} \to \mathbb{D}$ is analytic fixing 0, Schroeder's equation asks one to find an analytic f and $c \in \mathbb{C}$ satisfying

$$f \circ \phi = cf.$$

In 1884 Koenigs showed that there is such an f, which is bijective near 0, if and only if $c = \phi'(0) \neq 0$. If C_ϕ is the composition operator sending g, a function defined on $\mathbb{D}$, to $g \circ \phi$, Koenig's solution gives an eigenvector & value of C_ϕ. Additionally, it is a first step in understanding intertwining maps and models of iteration which have been a fruitful approach for composition operators.

The overall goal is to find such a model for iteration with domain $\mathbb{B}^n$.

In 2003 Cowen and MacCluer formulated a several variables Schroeder's equation. Let $\mathbb{B}^n$ be the unit ball in $\mathbb{C}^n$, and $\phi : \mathbb{B}^n \to \mathbb{B}^n$ analytic, fixing 0, $\phi'(0)$ full rank, and $|\phi(z)| < |z|, z \neq 0$. Does there exist an analytic $F : \mathbb{B}^n \to \mathbb{C}^n$ so that

$$F \circ \phi = \phi'(0)F?$$

This talk will give necessary and sufficient conditions for a solution. (Received September 01, 2011)

1077-32-656 **Yunus E Zeytuncu*** (zeytuncu@math.tamu.edu), Texas A&M University Milner Hall, Mailstop 3368, College Station, TX 77843. *Regularity of Weighted Bergman Projections.*

Let $\mathbb{D}$ be the unit disc in $\mathbb{C}^1$ and λ be a radially symmetric nonvanishing continuous function on $\mathbb{D}$. The weighted Bergman space $A^2(\mathbb{D}, \lambda)$ is the space of holomorphic functions that are square integrable with respect to the weight $\lambda(z)dA(z)$ and the weighted Bergman projection $\mathbf{B}_\lambda$ is the orthogonal projection operator from $L^2(\mathbb{D}, \lambda)$ onto $A^2(\mathbb{D}, \lambda)$. In this talk, we discuss the relation between regularity (L^p and Sobolev) of the weighted Bergman projection $\mathbf{B}_\lambda$ and analytic properties of the weight function λ on $\mathbb{D}$. We present examples where regularity of $\mathbf{B}_\lambda$ changes significantly as λ changes. (Received September 09, 2011)

1077-32-672 **Mark Agranovsky*** (agranovs@014.net.il), Department of Mathematics, Bar-Ilan University, 52900 Ramat-Gan, Israel. *Abel-Radon transform and CR functions.*

CR functions on real manifolds in C^n are described as the kernel of the Abel-Radon transform on different varieties of complex lines (Received September 09, 2011)

1077-32-798 **Brett D. Wick*** (wick@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, 686 Cherry Street, Atlanta, GA 30332-1060. *Carleson Measures for Besov-Sobolev Spaces and Non-Homogeneous Harmonic Analysis.*

In this talk we will discuss the characterization of Carleson measures for the Besov–Sobolev space of analytic functions B_2^σ on the complex ball of $\mathbb{C}^d$. In particular, we demonstrate that for any $\sigma \geq 0$, the Carleson measures for the space are characterized by a "T1 Condition". The method of proof of these results is an extension and another application of the work originated by Nazarov, Treil and Volberg. Additionally, the method of non-homogeneous harmonic analysis of Nazarov, Treil and Volberg is extended to handle "Bergman–type" singular integral operators, which is key to the characterization of Carleson measures. (Received September 12, 2011)

1077-32-959 **David Scheinker***, dscheink@gmail.com. *Rational inner functions and the Nevanlinna-Pick problem on D^n.* Preliminary report.

Fix a rational inner function f on D with degree N. If one chooses any $N+1$ distinct points x_1,...,x_{N+1} in D, then the the Nevanlinna-Pick problem with data x_1,...,x_{N+1} and $f(x_1)$,...,$f(x_{N+1})$ has a unique solution. Furthermore, essentially every Nevanlinna-Pick problem on D with a unique solution arrises this way. In this talk, we give some examples of Nevanlinna-Pick problems on D^n with $n > 1$ demonstrating the ways in which this behavior of rational inner functions on D extends and fails to extend to D^n. (Received September 14, 2011)

1077-32-1113 **Xiaojun Huang*** (huangx@math.rutgers.edu), Department of Mathematics, Rutgers University, New Brunswick, NJ 08903, and **Shanyu Ji** and **Wanke Yin**. *Gaps for proper holomorphic maps between balls.*

We give a survey on a gap rigidity problem in Several Complex Variables for proper holomorphic maps between balls, inlcuding a joint paper with Ji and Yin (Received September 16, 2011)

1077-32-2683 **Jerry R. Muir*** (muirj2@scranton.edu), Department of Mathematics, University of Scranton, Scranton, PA 18510. *Necessary Conditions for the Existence of Higher Order Extensions of Univalent Mappings from the Disk to the Ball.* Preliminary report.

If $G : \mathbb{C}^{n-1} \to \mathbb{C}$ is a holomorphic function such that $G(0) = 0$ and $DG(0) = 0$ and f is a normalized univalent mapping of the unit disk $\mathbb{D} \subseteq \mathbb{C}$, we consider the normalized extension of f to the Euclidean unit ball $\mathbb{B} \subseteq \mathbb{C}^n$ given by $\Phi_G(f)(z) = (f(z_1) + G(\sqrt{f'(z_1)}\,\hat{z}), \sqrt{f'(z_1)}\,\hat{z})$, $z \in \mathbb{B}$, $\hat{z} = (z_2, \dots, z_n)$. While for a given f, $\Phi_G(f)$ will maintain certain geometric properties of f, such as convexity or starlikeness, if G is a polynomial of degree 2 of sufficiently small norm, these properties may be lost whenever G contains a nonzero term of higher degree. By establishing separate necessary and sufficient conditions for the extension of Loewner chains from $\mathbb{D}$ to $\mathbb{B}$ through Φ_G, we are able to completely classify those starlike and convex mappings f on $\mathbb{D}$ for which there exists a G with nonzero higher degree terms such that $\Phi_G(f)$ is a mapping of the same type on $\mathbb{B}$. (Received September 22, 2011)

33 ► Special functions

1077-33-9 **Eric Rains*** (rains@caltech.edu), Department of Mathematics, 1200 E California Blvd., 176 Sloan, MC 253-37, Pasadena, CA 91125. *Beyond q: Special functions on elliptic curves.*

An important thread in modern representation theory (and combinatorics) is that many important objects have so-called q-analogues, generalizations depending on a parameter q which reduce to more familiar objects when $q = 1$. For instance, the Schur functions (irreducible characters of the unitary group) have q, t-analogues, namely the famous Macdonald polynomials, and similarly the Koornwinder polynomials are six-parameter q-analogues of the characters of other classical groups. It turns out that many q-analogues extend further to *elliptic* analogues, in which q is replaced by a point on an elliptic curve. The Macdonald/Koornwinder polynomials are no exception; I'll describe a relatively elementary approach to those polynomials and how to modify the approach to obtain an elliptic analogue. (Received September 22, 2011)

1077-33-81 **Mohamed T Boudjelkha*** (boudjm@rpi.edu), Mathematical Sciences Department, Amos Eaton # 404, Rensselaer Polytechnic Institute, Troy, NY 12180. *On the Approximation of the Lower Generalized Incomplete Gamma Function,Arising in Heat Conduction Problems.*

In this paper we consider the Lower Generalized Incomplete Gamma Function. Properties, approximations and applications are discussed. Closed form expressions are also obtained. (Received July 20, 2011)

1077-33-684 **E. K. Narayanan** and **Angela Pasquale*** (pasquale@math.univ-metz.fr), Laboratoire de Mathematiques, Batiment A, Ile du Saulcy, Universite Paul Verlaine - Metz, 57045 Metz, France, and **Sanjoy Pusti**. *The bounded hypergeometric functions associated with root systems.*

Let G be a connected semisimple Lie group with finite center. In 1969, Helgason and Johnson determined an explicit parametrization of the set of spherical functions on G which are bounded. This result has several important consequences on the L^1 spherical harmonic analysis on G.

By restriction to a Cartan subspace, the spherical functions on G can be considered as special instances of the hypergeometric functions associated with root systems. This class of (generally multivariate) hypergeometric functions has been introduced by Heckman and Opdam in the late 1980s, with important contributions by Cherednik and by Opdam in the middle 1990s and, more recently, by Schapira in 2008. In this talk, we extend the result of Helgason and Johnson and find a parametrization of the hypergeometric functions associated with root systems which are bounded. Some applications are presented. (Received September 10, 2011)

1077-33-714 **Nobuhiro Asai*** (nasai@auecc.aichi-edu.ac.jp), 1, Hirosawa, Igaya, Kariya, Aichi, 448-8542, Japan. *MRM triples associated with Brenke type generating functions.* Preliminary report.

In this talk, we will treat the following classical problem:
"Determine all possible orthogonal polynomials generated by Brenke type generating functions,

$$\psi(t,x) := B(t)h(tx) = \sum_{n=0}^{\infty} h_n P_n(x) t^n, \tag{1}$$

where functions $h(x)$ and $B(t)$ are analytic around the origin,

$$h(x) = \sum_{n=0}^{\infty} h_n x^n, \ B(t) = \sum_{n=0}^{\infty} b_n t^n$$

with $h_n \neq 0$ for $n \geq 0$ and $h(0) = B(0) = 1$ just for normalizations". Chihara ('68 '71) classified them essentially into four classes I–IV. However, explicit expressions of $\psi(t,x)$ for each class, that is, $B(t)$ and $h(t)$, were not obtained in his papers. Moreover, the associated Jacobi-Szegö parameters for Class IV were not given although several examples were mentioned briefly by a very vague explanation. In this talk, we will report that $B(t)$ and $h(t)$ for each class can be expressed by q-hypergeometric series and the Jacobi-Szegö parameters for Class IV coincide with those of discrete q-Hermite polynomials. The present results are based on the joint work with I.Kubo (Hiroshima, Japan) and H.-H. Kuo (LSU). (Received September 19, 2011)

1077-33-969 **Hiroshi Miki*** (miki@amp.i.kyoto-u.ac.jp), Yoshida-Honmachi, Sakyo-Ku, Kyoto City, Kyoto 606 8501, Japan, and **Satoshi Tsujimoto** (tujimoto@i.kyoto-u.ac.jp), Yoshida-Honmachi, Sakyo-Ku, Kyoto City, Kyoto 606 8501, Japan. *Discrete integrable systems of skew orthogonal polynomials.*

It is well known that many integrable systems are connected to orthogonal functions. These orthogonal fucntions appear as a wave function of the Lax pair and their spectral transfomations correspond to the flow of the continuous and discrete integrable systems. From the point of view, several new integrable systems has been proposed. We focus on the skew orthogonal polynomials (SOPs) which are originally introduced in the random matrix theory in order to calculate the correlation function of the orthogonal or symplectic ensembles. One of the corresponding continuous integrable systems is already known as Pfaff lattice but the the corresponding discrete integrable system remains to be found.

In this talk, the discrete spectral transformation of SOPs is presented and its relation to the random matrix theory is also discussed. From the spectral transformation, the corresponding discrete integrable systems are derived both in $1+1$ and $2+1$ dimensional case. Especially, in $2+1$ dimensional case, such system can be extended to 2×2 matrix form. (Received September 15, 2011)

1077-33-1046 **Dmitry Korotkin** and **Vasilisa Shramchenko*** (vasilisa.shramchenko@usherbrooke.ca), 2500 boul. de l'Université, Université de Sherbrooke, Département de Mathématiques, Sherbrooke, Quebec J1K 2R1. *Higher genus Weierstrass sigma-function.*

We propose a new way to generalise the Weierstrass sigma-function to higher genus Riemann surfaces. Our definition of the odd higher genus sigma-function is based on a generalization of the classical representation of the elliptic sigma-function via Jacobi theta-function. The odd higher genus sigma-function is associated with an odd spin line bundle on a given Riemann surface. We also define an even sigma-function corresponding to an arbitrary even spin structure on the surface. The proposed generalization of the sigma-function differs essentially from the existing ones; our way of generalization applies to any Riemann surface and naturally continues the approach of Felix Klein who generalized the sigma-function to the class of hyperelliptic curves. (Received September 15, 2011)

1077-33-1306 **Hiroshi Kawakami**, **Akane Nakamura** and **Hidetaka Sakai***, 3-8-1, Komaba, Meguro-ku, Tokyo, 153-8914, Japan. *Degeneration scheme of 4-dimensional Painlevé type equations.*

There are four types of 4-dimensional Painlevé type equations which are obtained from deformation of Fuchsian equations. Namely, these are the Garnier system with 2 variables, a Fuji-Suzuki system, a Sasano system, and a matrix sixth Painlevé system.

We obtained a degeneration scheme which appear from the confluent of these associated Fuchsian equations. We only consider unramified case. The number of 4-dimensional Painlevé type equations obtained from the degeneration scheme is 22, including 9 nonlinear partial differential equations.

Although isomonodromic deformation theory were fully developed after Jimbo-Miwa-Ueno's result (1980), we used classification of linear equations with spectral types and it permitted us this detailed study. All of the systems are expressed in the form of Hamiltonian system, and especially it is simply written by using the Hamiltonians of the classical Painlevé systems. (Received September 19, 2011)

1077-33-1428 **Emma Previato*** (ep@bu.edu), Department of Mathematics and Statistics, Boston University, Boston, MA 02215-2411. *Sigma function and random matrices.*

A link between random-matrix theory and isomonodromy deformations was found in the 1970s; then isomonodromy was related to hierarchies of integrable PDEs: there is no systematic way of transforming one type of problems into the other. The theme of this talk is that of deriving both types of equations from the study of special functions, with the goal of creating a dictionary.

Sato's tau function was written (A. Nakayashiki), in the algebro-geometric case, in terms of the (Kleinian) sigma function, generalized by V.M. Buchstaber, V.Z. Enolskii and D. Leykin. Moving the curve in moduli, sigma obeys a Gauss-Manin connection. Sato's tau function was used to produce solutions to isomonodromy problems: apparently, not yet the function sigma. This issue has potential applications to mirror symmetry (Yu.I. Manin).

Firstly, we give a heat equation for sigma (work with J.C. Eilbeck, J. Gibbons and Y. Ônishi). Then we give a link between integrable PDEs and ODEs with the Painlevé property (work with G.N. Benes). Lastly, we suggest a different interpretation of the appearance of the sigma function in the dispersionless hierarchies in terms of isomonodromy; we propose generalizations of Painlevé VI in this setting (work with V.Z. Enolskii and F. Nijhoff). (Received September 19, 2011)

1077-33-1721 **Bonita V. Saunders*** (bonita.saunders@nist.gov), National Institute of Standards &Technology, 100 Bureau Drive, Stop 8910, Gaithersburg, MD 20899. *Constructing Interactive 3D Visualizations for the NIST Digital Library of Mathematical Functions.*

In May 2010 the National Institute of Standards and Technology (NIST) launched the NIST Digital Library of Mathematical Functions (DLMF). The DLMF and its associated hardcopy version, NIST Handbook of Mathematical Functions, replace the well-known 1964 NBS Handbook of Mathematical Functions edited by Abramowitz and Stegun. More than 200 of the over 600 figures in the DLMF are interactive 3D visualizations of complex functions. We discuss the challenges of designing and rendering the visualizations using techniques from mesh generation, computer graphics, and approximation theory to capture key function features such as zeros, poles, branch cuts and other singularities. (Received September 20, 2011)

1077-33-2768 **Michael Anthony Maroun*** (mmaro001@ucr.edu), 1005 Via Zapata APT 302, Riverside, CA 92507. *Number Theoretic Solutions to a Certain Nonlinear Cauchy Problem with Optimized Constraints.*

I consider the dynamics of a one dimensional flow on the interval [0, 1] of the real line. The flow is constrained by a conservation principle and obeys a nonlinear Burgers' type PDE. There arises a functional equation for the solution and the analytic solutions of this functional equation have connections to number theoretic special functions. (Received September 23, 2011)

34 ► Ordinary differential equations

1077-34-54 **Mouffak Benchohra** (benchohra@yahoo.com), Laboratoire de Mathematiques, Universite de Sidi Bel-Abbes, BP 89, 22000, Sidi Bel-Abbes, Algeria, **Naima Hamidi** (hamidi.naima@yahoo.fr), Laboratoire de Mathematiques, Universite de Sidi Bel-Abbes, BP 89, 22000, Sidi Bel-Abbes, Algeria, and **Johnny Henderson*** (Johnny_Henderson@baylor.edu), Department of Mathematics, Baylor University, Waco, TX 76798-7328. *Existence of solutions for fractional differential equations with anti-periodic boundary conditions.*

We are concerned with the existence of a class of Caputo fractional differential equations with anti-periodic boundary conditions. We give two results: the first is based on Banach's fixed point theorem and the second is based on Schauder's fixed point theorem. (Received July 11, 2011)

1077-34-160 **Zhivko S. Athanassov*** (zhivko@math.bas.bg), G. Bonchev Str. 8, 1113 Sofia, Bulgaria. *Topological Aspects of Stability of Trajectories.* Preliminary report.

This talk is about the concept of stability of trajectories with respect to a given set. Conditions are examined under which a trajectory returns infinitely often in an arbitrarily restricted neighborhood of each of its points (Poisson stability). Sufficient conditions are imposed which allow the development of results concerning sets of points of a given perfect set whose trajectories under continuous motions are Poisson stable. The previous work of Poincare', Denjoy and Trjitzinsky on the Poisson stability were on the case of discrete motions. Furthermore, the concept of quasi-nonwandering points is introduced in conection with the notions of wandering and nonwandering points and their topological properties, and results on sets of such points are presented. (Received August 03, 2011)

1077-34-239 **John R. Graef*** (john-graef@utc.edu), Department of Mathematics, University of Tennessee at Chattanooga, Chattanooga, TN 37403, and **Lingju Kong** (lingju-kong@utc.edu), Department of Mathematics, University of Tennessee at Chattanooga, Chattanooga, TN 37403. *Positive solutions for a class of higher order boundary value problems with fractional q-derivatives.*

In this paper, we study the boundary value problem with fractional q-derivatives

$$-(D_q^\nu u)(t) = f(t,u),\ t \in (0,1),$$

$$(D_q^i u)(0) = 0,\ i = 0,\dots,n-2, \quad (D_q u)(1) = \sum_{j=1}^m a_j (D_q u)(t_j) + \lambda,$$

where $q \in (0,1)$, $m \geq 1$ and $n \geq 3$ are integers, $n-1 < \nu \leq n$, $\lambda \geq 0$ is a parameter, $f : [0,1] \times \mathbb{R} \to [0,\infty)$ is continuous, $a_i \geq 0$ and $t_i \in (0,1)$ for $i = 1,\dots,m$,and D_q^ν is the q-derivative of Riemann-Liouville type of order ν. The uniqueness, existence, and nonexistence of positive solutions are investigated in terms of different ranges of λ. (Received August 16, 2011)

1077-34-295 **Eric José Avila*** (avila@uady.mx), 97204 Merida, Mexico. *Stability and bifurcations in an epidemic model with nonlinear incidence rate and varying immunity period.* Preliminary report.

In this paper a SIR model with distributed delay and nonlinear incidence rate is considered, in order to model the dynamics of infectious diseases with varying immunity period. We will present results about stability and bifurcation analysis. Numerical simulations to support our analytical findings are carried out. (Received August 18, 2011)

1077-34-541 **Ruyong Feng*** (ryfeng@amss.ac.cn), No.55 Zhongguancun East Road, Beijing, 100190, Peoples Rep of China. *Computing the Galois Group of Linear Difference-Differential Equations.*

In this talk, we shall show that the Galois group of linear difference-differential equations can be generated by those of the suitable linear differential equations and linear difference equations. These linear differential equations and difference equations can be obtained from the original equations. (Received September 07, 2011)

1077-34-578 **J Diego Ramirez*** (jdr3542@louisiana.edu), P.O. Box 43671, Lafayette, LA 70504, and **Aghalaya S Vatsala**. *Fractional Differential Equations with Periodic Boundary Conditions. Generalized Monotone Method and Conditions for Uniqueness.*

Recently we developed Generalized Monotone Iterative Technique for Periodic Boundary Value Problems with Caputo Fractional Derivative of order q, $0 < q < 1$. Our approach simplifies the computations because it uses Initial Value Problem instead of Linear Periodic Boundary Problem, and we obtained coupled minimal and maximal solutions. In this work we show some conditions that are necessary for the solution to be unique. (Received September 07, 2011)

1077-34-603 **Maria C.A. Leite*** (Maria.Leite@utoledo.edu), **Xiamgming Xiao** and **Meijun Zhu**.
Climate-driven dynamics of seasonal influenza in the tropical regions. Preliminary report.

The seasonal dynamics of influenza in the tropical and subtropical regions are not well documented and less defined (Viboud et al., 2006). We introduce a novel approach to analyze seasonal dynamics and inter-annual fluctuation of influenza transmission in Hong-Kong during 1990 - 2009. I will discuss mathematical epidemiological models, which incorporate three ecology-based response functions of influenza virus and human to air temperature and specific humidity. Also, I will discuss our numerical simulation results obtained when the mathematical models are driven by monthly air temperature and specific humidity data from the NCEP Re-Analysis data set. Interestingly, our model reproduce the reported double peaks of influenza A cases in Hong-Kong: one winter peak and one summer peak. (Received September 08, 2011)

1077-34-681 **Toka Diagana*** (tdiagana@howard.edu), Department of Mathematics, Howard University, 2441 6th Street NW, Washington, DC 20059. *Existence Results for Some Higher-Order Nonautonomous Differential Equations in Hilbert Space.* Preliminary report.

In this talk we discuss the existence of Stepanov-like $C^{(n)}$-pseudo almost automorphic solutions to some nonautonomous higher-order differential equations on a complex Hilbert space. To illustrate our abstract results, we study the existence of Stepanov-like $C^{(n)}$-pseudo almost automorphic solutions to a plate-like equation. (Received September 09, 2011)

1077-34-727 **Camilo Sanabria*** (camilo.sanabria@bcc.cuny.edu), Department of Mathematics and Computer Sc., CUNY Bronx Community College, 2155 University Ave. CPH 121, Bronx, NY 10453. *Reductive connections and Ruled surfaces.*

We consider a meromorphic connection with reductive Galois group over a compact Riemann Surface. In this setting, we take the projective bundle defined by the symmetric algebra of rational first integrals. Using a result of E. Compoint and of M. Singer we prove that this projective space bundle is a ruled surface that characterizes the class of projectively equivalent connections up to rational pullback. (Received September 11, 2011)

1077-34-783 **Chunqing Lu*** (clu@siue.edu), Southern Illinois University Edwardsville, Edwardsville, IL 62026. *Bifurcation of Solutions to a Second Order Nonlinear Singular Differential Equation from Boundary Layer Theory.*

A second order nonlinear differential equation

$$y'' + F(x, y) = 0$$

where $F(t, y) = \frac{h(t)}{f(y)}$ and $f(0) = h(0) = 0$ is considered in this paper. We assume that $h(t)$ and $f(y)$ are continuous and increasing functions and that $M_1|x| \leq |h(x)| \leq M_2|x|$ and $P_1|y| \leq |f(y)| \leq P_2|y|$ for some positive constants M_1, M_2, P_1, and P_2. The following boundary conditions are imposed to the equation

$$y'(\xi) = C, y(1) = 0,$$

where $\xi < 1$ and C are two constants.

The above boundary value problem arises from boundary layer theory. For example, the classical Blasius equation

$$f'''(\eta) + f(\eta)f''(\eta) = 0$$

in the case that $f''(\eta) > 0$ for all η can be transformed into the second order nonlinear equation

$$y'' + \frac{x}{y} = 0$$

using Crocco transformation, $f'(\eta) = x, y = f''(\eta)$. This paper proves the following theorems.

1. If $\xi \geq 0$, then there exists at most one solution to the boundary value problem.
2. If $\xi < 0$, then there exist some $C < 0$ such that the boundary value problem admits at least two solutions.

(Received September 12, 2011)

1077-34-831 **Ainhoa Aparicio-Monforte**, **Elie Compoint** and **Jacques-Arthur Weil*** (jacques-arthur.weil@unilim.fr), XLIM, CNRS and Université de Limoges, France. *Constructive approaches to Kovacic's reduced forms of linear differential systems.*

Consider a linear differential system $[A]$: $Y' = AY$ with coefficients in a differential field k. Let $Lie(G)$ denote the Lie algebra of the differential Galois group G of $[A]$. Kovacic and Kolchin showed that, via a gauge transformation, one can transform $[A]$ to an equivalent system $[B]$: $Z' = BZ$ with the property that $B \in Lie(G)(\overline{k})$. A system with this property is said to be in reduced form. When a system is in reduced form, one can read immediately the properties of the Lie algebra $Lie(G)$. In this talk, I will discuss recent constructive approaches to this result. For example, when G is reductive and unimodular, the system $[A]$ is in reduced form if and only if all of its invariants (rational solutions of appropriate symmetric powers) have constant coefficients (instead of rational functions). I will also focus on reducible systems, such as those appearing as variational equations in Hamiltonian mechanics, to show how one can design reduction algorithms in this case and progress towards methods to compute the Lie algebra $Lie(G)$ directly. (Received September 13, 2011)

1077-34-1038 **Aghalaya S Vatsala*** (Vatsala@Louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504-1010, and **Donna Stutson**. *Generalized Monotone Method and Gauss Seidel Method for Caputo and Riemann Liouville Fractional Differential Systems.* Preliminary report.

Generalized monotone method is a useful technique to compute solutions of nonlinear differential equations when the forcing function is the sum of an increasing and decreasing functions. In addition, this method has the special advantage for Caputo or Riemann Liouville fractional differential equations since we do not need to compute Mittag-Leffler function in each iterates. In this work we show that the generalized monotone method can be used in conjunction with Gauss-Seidel technique. This will accelerate the convergence process. (Received September 15, 2011)

1077-34-1092 **Gangaram S. Ladde*** (gladde@usf.edu), Department of Mathematics and Statistics, 4202 East Fowler Avenue, PHY 114, Tampa, FL 33620-5700. *Energy/Lyapunov Function Method for Solving Stochastic Differential Equations.*

Developing a very general conceptual algorithm for finding solution process of first order nonlinear stochastic differential equations, several types of differential equations are solved in explicit/implicit form. The scope of this approach is exhibited by presenting several special classes of stochastic differential equations in a systematic way. Moreover, the approach initiates a research area, "Methods of Solving Differential Equations". This opens a door for young researchers, in particular, serious undergraduate students and interdisciplinary researchers with minimal mathematical background to undertake the research work in mathematical sciences. (Received September 16, 2011)

1077-34-1096 **Chan-Gyun Kim*** (cgkim75@gmail.com), Department of Mathematics, College of William and Mary, Williamsburg, VA 23185. *Three solutions theorem for p-Laplacian boundary value problems.*

The three solutions theorem is established for p-Laplacian boundary value problems in the presence of two pairs of lower and upper solutions, which are well ordered by the relationship between the lower and upper solutions and degree theory. In addition, an application for the three solutions theorem is given. (Received September 16, 2011)

1077-34-1132 **Zachary Denton*** (zhdenton@gmail.com), Mathematics Department, University of Louisiana at Lafayette, P.O. Box 41010, Lafayette, LA 70504, and **Aghalaya Vatsala**. *Generalized Quasilinearization Method for Nonlinear Riemann-Liouville Fractional Differential Equations.* Preliminary report.

Existence and comparison results of the linear and nonlinear Riemann-Liouville fractional differential equations and systems of order q, $0 < q < 1$, are recalled, modified, and developed where necessary. Generalized quasilinearization method is developed for nonlinear fractional differential equations of order q where the nonlinear function $f(t, x)$ can be split into two functions, one convex and one concave. Quadratic convergence to the unique solution is proved via weighted sequences. (Received September 16, 2011)

1077-34-1156 **Diego Torrejon*** (dito_656@hotmail.com), 7214 Highland St., Springfield, VA 22150. *An Analytical Approach to Solving Green Oxidation Processes.*

Oxidation, a process in which oxygen is added to break pollutants or organic wastes, is important in many industries. However, this process often uses chemicals that can result in the production of hazardous substances, so it is imperative to be able to control the process to make it environmentally safe.

In this talk, we study the problem of suicidal inactivation of enzymes and man-made oxidation catalysts. Based on experimental data obtained from our colleagues at Carnegie Mellon University, we formulate a system of differential equations that models chemical reactions and analyze its numerical and analytical properties. The main goal is to be able to estimate the rates of the reactions based on limited experimental observations. The nonlinear 3-dimensional ODE system under investigation does not allow for an exact solution. However, noticing its similarity with Michaelis-Menten system, we have been able to develop quasi-state approximation of the model that together with perturbation techniques has allowed us to derive a highly accurate approximate solution. Analytical results developed using this approach, generalized upon previously known relations between the rate constants, allow for a much deeper understanding and control of the oxidation processes. (Received September 17, 2011)

1077-34-1224 **Tingting Fang*** (tfang@math.fsu.edu), Department of Mathematics, Florida State University, Tallahassee, FL 32306, and **Mark van Hoeij**. *Solve Linear Differential Equations in terms of Hypergeometric Functions.*

The goal in this talk is to solve second order linear differential equations in terms of hypergeometric ${}_2F_1$ functions. We use 2-descent to reduce the equation to another differential equation with fewer singularities. Next, we treat equations with 4 true singularities (plus any number of removable singularities) by constructing tables of Belyi or near Belyi maps. (Received September 18, 2011)

1077-34-1249 **Jianjun Paul Tian*** (jtian@wm.edu), 121 Jones Hall, Williamsburg, VA 23187, and **Yang Kuang** and **Hanchun Yang**. *Intracellular Viral Life-cycle Induced Rich Dynamics in Tumor Virotherapy.* Preliminary report.

The intracellular viral life-cycle is an important process in tumor virotherapy. Most mathematical models for tumor virotherapy do not incorporate the intracellular viral life-cycle. In this article, a model for tumor virotherapy with the intracellular viral life-cycle is presented and studied. The period of the intracellular viral life-cycle is modeled as a delay parameter. The model is a nonlinear system of delay differential equations. It displays interesting and rich dynamic behaviors. There exists two sets of stability switches as the period of the intracellular viral life-cycle increases. One is around the infection free equilibrium solution, and the other is the positive equilibrium solution. This intracellular viral life-cycle may explain the oscillation phenomena observed in many studies. An important clinic implication is that the period of the intracellular viral life-cycle should also be modified when a type of a virus is modified for virotherapy, so that the period of the intracellular viral life-cycle is in a suitable range which can break away the stability of the interior equilibrium solution. (Received September 18, 2011)

1077-34-1251 **Jianjun Paul Tian*** (jtian@wm.edu), 121 Jones Hall, Williamsburg, VA 23187. *Mathematical Model for Two Germline Stem Cells Competing for Niche Occupancy.* Preliminary report.

In the Drosophila germline stem cell ovary niche, two stem cells compete with each other for niche occupancy to maintain stem cell quality by ensuring that differentiated stem cells are rapidly pushed out the niche and replenished by normal ones. To gain a deep understanding of this biological phenomenon, we have derived a mathematical model for explaining the physical interactions between two stem cells. The model is a system of two nonlinear first order and one second order differential equations coupled with E-cadherins expression levels. The model can explain the dynamics of the competition process of two germline stem cells and may help reveal missing information obtained from experimental results. The model predicts several qualitative features in the competition process, which may help design rational experiments for a better understanding of the stem cell competition process.

This is a joint work with Zhigang Jin and Ting Xie in Stowers Institute for Medical Research. (Received September 18, 2011)

1077-34-1262 **Robert J. Buckingham*** (buckinrt@uc.edu), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221, and **Peter D. Miller**. *Asymptotics of rational Painleve II solutions.*

The nonhomogenous Painleve II equation has exactly one rational solution for specific values of the nonhomogenous term α. Clarkson and Mansfield observed that the zeros (or poles) of these rational solutions appear to have a highly regular triangular structure. We prove that, in the large-α limit, the scaled zeros (or poles) fill out a certain curvilinear triangular region in the complex plane. We also discuss progress on computing the leading-order asymptotic behavior of the rational solutions inside, outside, and at the edge of this root region. (Received September 22, 2011)

1077-34-1278 **Hongying Shu*** (hongyingshu2010@gmail.com), Department of Mathematics and Statistics, University of New Brunswick., Fredericton, NB E3B 5A3, Canada, and **Lin Wang** (lwang2@unb.ca), Department of Mathematics and Statistics, University of New Brunswick., Fredericton, NB E3B 5A3, Canada. *Role of $CD4^+$ T-cell proliferation in HIV infection under antiretroviral therapy.* Preliminary report.

For HIV patients, lifelong therapy is generally required to control their viral replication and it is very difficult to effectively eradicate HIV infection from the host. In this paper, using a mathematical model, we show that the stimulation of $CD4^+$ T cells to proliferate in the presence of HIV is one possible factor causing such a difficulty. This is based on the fact that if the proliferation rate is non-negligible, then the model exhibits a backward bifurcation and hysteresis. Fitting to clinic data shows that the $CD4^+$ T-cell proliferation does play an important role for HIV infection under antiretroviral therapy. The model and analysis are then extended to incorporate a bilinear term to account for the loss of free infectious virions during attacking the target cells. Our analysis suggests that, to effectively control HIV infection, antiretroviral therapies should aim at increasing the effectiveness of reverse transcriptase inhibitors and protease inhibitors, discouraging the stimulation of $CD4^+$ T cells, and increasing the loss rate of virus particles when they infect the healthy $CD4^+$ T cells. (Received September 18, 2011)

1077-34-1293 **Kathryn Lois Ashley*** (klashle@clemson.edu), **Jerome Goddard II** (jgoddard@aum.edu) and **Victoria Sincavage** (vsincav@g.clemson.edu). *Ecological Systems, Nonlinear Boundary Conditions, and Σ-Shaped Bifurcation Curves.* Preliminary report.

We examine a one dimensional reaction diffusion model with a weak Allee growth rate that appears in population dynamics. Noteworthy, we combine grazing along with a certain nonlinear boundary condition that models negative density dependent dispersal on the boundary and analyze the effects on the steady states. In particular, we examine the bifurcation curves of positive solutions as the grazing parameter is variegated. Our results are acquired through the adaptation of a Quadrature method and Mathematica computations. Specifically, we computationally ascertain the existence of Σ-shaped bifurcation curves with at least twelve positive steady states for a certain range of the grazing parameter. (Received September 18, 2011)

1077-34-1794 **Namjip Koo*** (njkoo@cnu.ac.kr), Department of Mathematics, Chungnam National University, Daejeon, 305-764, South Korea, and **Sung Kyu Choi**, Department of Mathematics, Chungnam National University, Daejeon, 305-764, South Korea. *Stability of solutions for fractional differential equations.*

In this talk we recall some definitions and basic theorems on the fractional calculus. Then we present some results on the boundedness and Mittag-Leffler stability of solutions of the fractional differential equations using Lyapunov-type functions and fractional comparison principle. (Received September 21, 2011)

1077-34-1857 **Douglas R. Anderson**, **Richard I. Avery**, **Johnny Henderson** and **Xueyan Liu*** (Xueyan_Liu@baylor.edu), Department of Mathematics, Baylor University, One Bear Place #97328, Waco, TX 76798-7328. *Existence of Positive Solutions of a Second Order Right Focal Boundary Value Problem.*

A new fixed point theorem utilizing operators and functionals is applied to the existence of at least one possitive solution of a second order right focal boundary value problem. The sets in the fixed point theorem are defined using operators which leads to functional type boundaries of positive solutions of the boundary value problem over some parts of the domain. (Received September 21, 2011)

1077-34-1873 **Lingju Kong*** (Lingju-Kong@utc.edu), Department of Mathematics, University of Tennessee at Chattanooga, Chattanooga, TN 37403. *Existence of multiple solutions for a class of fractional boundary value problems.*

By using variational methods, we obtain criteria for the existence of multiple solutions of the fractional boundary problem of the form

$$\begin{cases} \frac{d}{dt}\left(\frac{1}{2}\,{}_0D_t^{-\beta}(u'(t)) + \frac{1}{2}\,{}_tD_T^{-\beta}(u'(t))\right) + \lambda f(t,u(t)) = 0 \quad \text{a.e. on } [0,T], \\ u(0) = u(T) = 0, \end{cases}$$

where $T > 0$, $\lambda > 0$ is a parameter, $0 \leq \beta < 1$, ${}_0D_t^{-\beta}$ and ${}_tD_T^{-\beta}$ are, respectively, the left and right Riemann-Liouville fractional integrals of order β, $f : [0,T] \times \mathbb{R} \to \mathbb{R}$ is a continuous function. This problem has its motivation from the fractional advection-dispersion equation and has been recently studied in a nice paper by Jiao and Zhou [Comput. Math. Appl. **62** (2011), 1181–1199]. We notice that when $\beta = 0$, the above problem has the following form

$$\begin{cases} u''(t) + \lambda f(t,u(t)) = 0 \quad \text{a.e. on } [0,T], \\ u(0) = u(T) = 0, \end{cases}$$

which has been extensively studied in the literature. Our results are new even for this special case. (Received September 22, 2011)

1077-34-1940 **Zachary J. Abernathy*** (abernathyz@winthrop.edu) and **Jesus Rodriguez**. *On the Solvability of Nonlinear Sturm-Liouville Problems.*

In this talk, we establish sufficient conditions for the existence of solutions to the nonlinear differential equation

$$(p(t)x'(t))' + q(t)x(t) + \psi(x(t)) = G(x(t))$$

subject to general non-local boundary conditions of the form

$$\begin{cases} \alpha x(0) + \beta x'(0) + \eta_1(x) = \phi_1(x) \\ \\ \gamma x(1) + \delta x'(1) + \eta_2(x) = \phi_2(x). \end{cases}$$

The results obtained in this talk depend in a crucial way on the relationship between the eigenvalues of a linear Sturm-Liouville problem and the rate of growth of nonlinearities present in both the differential equation and the boundary conditions. (Received September 21, 2011)

1077-34-2150 **Avner Friedman** and **Abdul-Aziz Yakubu*** (ayakubu@howard.edu), 2441 6th Street NW, Washington, DC 20059. *Fatal Disease and Demographic Allee Effect: Population Persistence and Extinction.*

In this talk, we will prove that the presence of an Allee effect in host demographics matters even at large population densities. That is, we will show that a small perturbation to the disease-free equilibrium can eventually lead to host population extinction. We will focus on the following question. If a healthy stable host population at the disease-free equilibrium is subject to the Allee effect, can a small number of infected individuals with a fatal disease cause the host population to go extinct? To answer this question, we will use an SI epidemic model to obtain model parameters that lead to host population persistence and model parameters that lead to host extinction. (Received September 21, 2011)

1077-34-2227 **Bo Yang*** (byang@kennesaw.edu), 1000 Chastain Road, #1601, Kennesaw, GA 30144. *Upper and lower estimates for positive solutions of the higher order Lidstone boundary value problem.*

We consider the higher order Lidstone boundary value problem. New upper and lower estimates for positive solutions of the problem are obtained. A discussion of the sharpness of the estimates is included. (Received September 21, 2011)

1077-34-2231 **Faina Berezovskaya*** (fberezovskaya@howard.edu), 6 Str., ASB-B, Mathematics Department, Howard, Washington, DC 20059. *On the asymptotic behavior of the solutions to the replicator equation.*

Considering dynamics of selection systems (Lotka-Voltera 'type) and the corresponding replicator equations we apply Newton polygon method for finding the asymptotic behavior of the solutions. We show that under conditions of non-degeneracy trajectories of the systems have power asymptotes which are defined with the help of edges and vertexes of Newton polygon. Results are complete when interaction matrix has rank 1 or 2 and can be extended for higher rank by methods of Power Geometry. Examples of selection systems are discussed. (Received September 21, 2011)

1077-34-2322 **Ovidiu Costin*** (costin@math.ohio-state.edu), 100 Math Tower, 231 West 18th Avenue, Columbus, OH 43210, **Rodica D Costin** (rcostin@math.ohio-state.edu), 100 Math Tower, 231 West 18th Avenue, Columbus, OH 43210, **Min Huang**, 5734 S. University Avenue, Chicago, IL 60637, and **Wilhelm Schlag**, 5734 S. University Avenue, Chicago, IL 60637. *Constructive methods for the global analysis of solutions of differential equations.*

I will discuss rigorous connection methods for analyzing global properties of solutions of differential equations. As an application, I will look at the gap property of the $L_\pm$ operators arising in the radial asymptotic stability analysis of the ground state soliton for the cubic nonlinear Schrödinger or Klein-Gordon equations in three dimensions. I will also mention applications to integrable models.

Work in collaboration with R. D. Costin (OSU), M. Huang and W. Schlag (U. Chicago) (Received September 22, 2011)

1077-34-2754 **Jean-Jacques Kengwoung-Keumo*** (jjkengwk@nmsu.edu), 749 E. University Ave. Apt. 3, Las Cruces, NM 88001. *Competition between two phytoplankton species under predation and allelopathic effects.*

We consider a model describing competition between two phytoplankton species for a growth-limiting resource in a chemostat. We allow for the possibility that one of these species is toxin-producing, and so has an allelopathic effect on the other, and that both species serve as prey for an herbivorous zooplankton species. Conditions for the coexistence of all species (as the allelopathic and other parameters are varied) are investigated both analytically and numerically. (Received September 22, 2011)

35 ► Partial differential equations

1077-35-2 **W. Schlag*** (schlag@math.uchicago.edu), Department of Mathematics, 5734 South University Avenue, Chicago, IL 60637. *Recent developments in nonlinear dispersive evolution equations: from concentration-compactness to invariant manifolds.*

The field of nonlinear dispersive evolutions equations has undergone rapid changes in recent years. The equations in question are Hamiltonian and encompass a wide class ranging from nonlinear Klein-Gordon, wave, and Schroedinger equations on the one hand, to more geometric equations such as wave maps and other so-called 'field equations' of physics on the other hand. These equations have traditionally been studied from the point of view of the fundamental well-posedness problem locally in time which often requires large amounts of analytical machinery. The question of global-in-time properties of the evolution is the subject of much ongoing research in nonlinear evolution equations. Within the past five to six years, several open problems have been settled in the field by introducing new ideas such as concentration-compactness for evolution equations, and the use of invariant manifolds from hyperbolic dynamics. We shall give an overview over some of these developments. The author's work is joint with Kenji Nakanishi from Kyoto University, Japan, and Joachim Krieger from EPFL, Switzerland. (Received September 18, 2011)

1077-35-41 **Mihaela Manole*** (michaela2050@yahoo.com), 1701 CR 262, Nacogdoches, TX 75965, and **Radu Precup**. *The Nonlinear Schrödinger Equation via Fixed Point Principles.*

Starting with the existence and uniqueness result for the non-homogenous Schrödinger equation with the source term in $H^{-1}(\Omega)$, we present existence results for the nonlinear perturbated Schrödinger equation via Banach, Schauder and Leray-Schauder principles.
(Received June 30, 2011)

1077-35-55 **Bonni J Kealy*** (bkealy@math.wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113, and **David J Wollkind**. *A Nonlinear Stability Analysis of Vegetative Turing Pattern Formation for an Interaction-Diffusion Plant-Surface Water Model System in an Arid Flat Environment.*

The development of spontaneous stationary vegetative patterns in an arid flat environment is investigated by means of a weakly nonlinear diffusive instability analysis applied to the appropriate model system for this phenomenon. In particular, that process can be modeled by a partial differential interaction-diffusion equation system for the plant biomass density and the surface water content defined on an unbounded flat spatial domain. The main results of this analysis can be represented by closed-form plots in the rate of precipitation versus the specific rate of plant density loss parameter space. From these plots, regions corresponding to bare ground and vegetative patterns consisting of parallel stripes, labyrinth-like mazes, hexagonal arrays of gaps, irregular mosaics, and homogeneous distributions of vegetation, respectively, may be identified in this parameter space. Then those theoretical predictions are compared with both relevant observational evidence involving tiger and pearled bush patterns and existing numerical simulations of similar model systems as well as placed in the context of the results from some recent nonlinear vegetative pattern formation studies. (Received July 12, 2011)

1077-35-64 **M Burak Erdoğan** and **William R Green*** (wrgreen2@eiu.edu), 600 Lincoln Ave., Charleston, IL 61920. *Dispersive estimates for Schrödinger operators in dimension two with obstructions at zero energy.*

Consider the Schrödinger operator $H = -\Delta + V$ on $\mathbb{R}^2$ and $P_{ac}(H)$ the projection onto the absolutely continuous spectrum of H. We prove $L^1(\mathbb{R}^2) \to L^\infty(\mathbb{R}^2)$ estimates for the evolution $e^{itH}P_{ac}(H)$ when there are obstructions, resonances and/or an eigenvalue of H at zero energy. In particular, we show that the existence of a mild resonance of H at zero energy does not destroy the t^{-1} decay rate. We also show that the existence of a more singular resonance or eigenvalue at zero energy destroys the decay rate, but does lead to a bounded evolution. (Received July 15, 2011)

1077-35-74 **Sharad Deep Silwal*** (sharad@math.ksu.edu), **Diego Maldonado** (dmaldona@math.ksu.edu) and **Sapto Indratno** (saptotea@yahoo.com). *The critical density property and Harnack's inequality in spaces of homogeneous type.* Preliminary report.

In their pioneering work in the context of non-divergence form PDEs in 1981, Krylov and Safonov introduced a new probabilistic approach to Harnack's inequality. The so-called critical density property was the central idea in their technique. We describe a new axiomatic approach to Harnack's inequality in spaces of homogeneous type based on the critical density property and the doubling property as a weight. Our approach avoids the use of BMO and covering lemmas and sheds some new light onto the role of the critical density property. This is joint work with Diego Maldonado and Sapto Indratno. (Received September 20, 2011)

1077-35-106 **Sukjung Hwang*** (shwang@iastate.edu), 421 Carver Hall, Ames, IA 50010, and **Gary Lieberman** (lieb@iastate.edu), 422 Carver Hall, Ames, IA 50010. *Hölder continuity of a bounded weak solution of generalized parabolic $p-$Laplacian type equations.* Preliminary report.

Originally DiBenedetto and Chen-DiBenedetto gave proofs of Hölder continuity of a bounded weak solution of nonlinear parabolic $p-$Laplacian equations by separating degenerate ($p > 2$) and singular ($1 < p < 2$) cases because of different natures. Here we generalize structure conditions of $p-$Lapalcian equation to deliver a uniform proof for the Hölder continuity of a bounded weak solution of both degenerate and singular cases by adopting Lieberman's work on nonlinear elliptic $p-$Laplacian equations considering in the setting of Orlicz spaces. Using two kinds of energy estimates, the local energy and logarithmic energy integrals, we capture behaviors of degenerate and singular equations without separation. Also using geometric characters, our proof does not rely on any of alternatives which is based on the size of solutions. (Received July 27, 2011)

1077-35-141 **Michael Sever*** (sever@math.huji.ac.il), Department of Mathematics, The Hebrew University, Givat Ram, Jerusalem, Israel. *Nonrelativistic Euler-Maxwell systems.*

Construction of nonrelativistic Euler-Maxwell sysyems, candidates for MHD models, is reconsidered using previous results on characterization of Galilean symmetric approximations of Maxwell's equations. In the context of a single fluid, the results are limited and disappointing. The Lundquist system, including the seemingly heroic expression for the electric field, all but necessarily results from the assumptions of Galilean symmetry and nonnegligible magnetic force on the fluid. However, the construction reveals an unexpected restriction on the applicability of the Lundquist model. At the expense of increased complexity, the difficulty is removed by consideration of a plasma model, including two fluids with charge per unit mass of opposite sign. (Received August 01, 2011)

1077-35-170 **Indranil SenGupta*** (isengupta@utep.edu), Department of Mathematical Sciences, 500 W. University Ave., (Bell Hall), University of Texas- El Paso, El Paso, TX 79968. *Existence of solutions for financial models with transaction costs and stochastic volatility.*

The option pricing problem when the asset is driven by a stochastic volatility process and in the presence of transaction costs leads to solving a nonlinear partial differential equation. The nonlinear term in the PDE reflects the presence of transaction costs. When using a stochastic volatility model the market is incomplete and the option price is not unique. However, under a particular market completion assumption we derive the nonlinear PDE whose solution may be used to find the price of options. Under suitable conditions, we prove the existence of strong solutions of the problem. (Received August 06, 2011)

1077-35-171 **Indranil SenGupta*** (isengupta@utep.edu), Department of Mathematical Sciences, 500 W. University Ave., (Bell Hall), University of Texas- El Paso, El Paso, TX 79968, and **Maria C. Mariani** (mcmariani@utep.edu). *Financial models used in biology.*

Nonlinear analysis is a very useful tool for modern mathematical finance. We propose a model for some problem in biology. Under appropriate assumptions we use the techniques used in financial mathematics to solve that biological model. The technique depends on the use of nonlinear theory of partial differential equations. We show some applications of this problem. (Received August 06, 2011)

1077-35-183 **Pablo U Suarez*** (psuarez@desu.edu), Department of Mathematical Sciences, Delaware State University, 1200 N. DuPont Highway, Dover, DE 19901. *Exponential Operator Splitting for the generalized Kawahara equation.*

In this paper we present a split scheme to handle the generalized Kawahara equation. The Kawahara equation is a fifth order non-linear partial differential equation. This equation occurs in the theory of magneto-acoustic waves in plasmas and also in shallow water waves with surface tension. In this work we present an easy and fast algorithm to handle the fifth order derivative and the non-linearity. The method is based on Strang's splitting scheme and uses the fast Fourier transform for handling high order derivatives. Our method is both fast and accurate. To test our results we present three test cases and compare them against analytical solutions. We also calculate numerically the conserved quantities of linear momentum and energy and compare them with known analytical results. (Received August 16, 2011)

1077-35-204 **Helge Kristian Jenssen** (jenssen@math.psu.edu) and **Irina A Kogan*** (iakogan@ncsu.edu). *Conservation laws with prescribed eigencurves.*

We consider systems of hyperbolic conservation laws for n unknown functions in one space and one time variable. There is a local frame on $\mathbb{R}^n$, called eigenframe, associated with each system (consisting of the eigenvectors of the Jacobian matrix of the flux). The integral curves of such frame, called eigencurves, contain rarefaction curves and play an important role in solving the Cauchy problems for such systems.

In this talk, we explore the properties of a conservative system that are determined by the frame alone. Given a local frame on $\mathbb{R}^n$, what degree of freedom do we have, if we want to construct a system of conservation laws with this eigenframe? To what extent does a frame determine the number of companion conservation laws (entropies) associated with a system? A broader goal of this project is to obtain geometric classification of hyperbolic conservation laws that would lead to a better understanding of the properties of their solutions. (Received August 11, 2011)

1077-35-220 **Sarah Jane Hamilton*** (hamilton@math.colostate.edu), hamilton@math.colostate.edu. *Implementation of a Direct D-bar Reconstruction Algorithm for Recovering a Complex Admittivity Distribution from Electrical Impedance Tomography Data.* Preliminary report.

Electrical Impedance Tomography is a fairly new, portable, relatively inexpensive, real-time imaging system that requires no ionizing radiation. Electrodes are placed at the surface of a body and low frequency and amplitude current is applied on the electrodes. The currents penetrate the body to varying depths before returning to the electrodes where the voltage value on each electrode is measured. By applying a basis of current patterns one can obtain enough information to create a picture of the complex admittivity distribution (conductivity along with permittivity) inside the domain. Recovery of this interior complex admittivity distribution from boundary measurements is a severely ill-posed inverse problem and has been the source of much research over the last 30 years. In this poster, a direct D-bar reconstruction algorithm for once differentiable admittivities is presented. Reconstructions from both simulated (Finite Element Method) and experimental data are included. (Received September 09, 2011)

1077-35-228 **John Lowengrub**, **Edriss S. Titi** and **Kun Zhao*** (kzhao@mbi.osu.edu). *Global dynamics of a diffuse interface model for solid tumor growth.*

In this talk I will report recent progress on the rigorous analysis of a diffuse interface model which arises in modeling of spinodal decomposition in binary fluid in a Hele-Shaw cell, tumor growth and cell sorting, and two phase flows in porous media. We consider the system of partial differential equations in bounded domains in 2D or 3D. The system is supplemented by initial data and no-flux boundary conditions. The first part of the results is contributed to the existence, uniqueness and regularity of solutions to the initial-boundary value problem. First, it is shown that, for large data, strong solutions are globally (locally resp.) well-posed in 2D (3D resp.). Second, it is shown that strong solutions indeed possess the same regularity as regular solutions. Moreover, it is shown that solutions enjoy the Gevrey regularity within their life-spans. In the second part, the long-time asymptotics of the solutions is studied. It is shown that, in 2D and 3D, strong solutions converge to constant equilibria exponentially as time goes to infinity provided that the initial perturbations are small. On the other hand, for large initial perturbations, it is shown that the constant states are still global attractors of the model under mild conditions on the volume of domain. (Received August 15, 2011)

1077-35-244 **Bonni J Kealy*** (bkealy@math.wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113, and **David J Wollkind** (dwollkind@wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113. *Vegetative Pattern Formation Model Systems: Comparison of Turing Diffusive and Differential Flow Instabilities.*

A particular interaction-diffusion plant-surface water model system for the development of spontaneous stationary vegetative patterns in an arid flat environment is investigated by means of a weakly nonlinear diffusive instability analysis. The main results of this analysis can be represented by closed-form plots in the rate of precipitation versus the specific rate of plant loss parameter space. From these plots, regions corresponding to bare ground and vegetative patterns consisting of tiger bush, labyrinth-like mazes, pearled bush, irregular mosaics, and homogeneous distributions of vegetation may be identified in this parameter space. Then those Turing diffusive instability predictions are compared with both relevant observational evidence and existing numerical simulations involving differential flow migrating stripe instabilities for the associated interaction-dispersion-advection plant-surface water model system. (Received August 30, 2011)

1077-35-277 **Dmitry Pelinovsky*** (dmpeli@math.mcmaster.ca). *Broad Band Solitons in a Periodic and Nonlinear Maxwell System.*

We consider the nonlinear Maxwell equations with the small linear periodic refractive index. We show that the system of infinitely many coupled-mode equations for the Fourier amplitudes of counter-propagating waves cannot be truncated if no linear constant-coefficient dispersion is present. The new system of infinitely many coupled mode equations is analyzed for the existence of gap soliton solutions. We reduce it to an infinite system of coupled nonlinear Schrödinger equations, for which we show the existence of coupled solitons by both Rayleigh-Ritz methods and numerical solution of the differential equations. Lifting the approximations of the coupled NLS solutions back to the coupled mode equations, we show that the broad band solitons are robust in the time-dependent computations. This is a joint work with Gideon Simpson (University of Toronto) and Michael Weinstein (Columbia University). (Received August 18, 2011)

1077-35-279 **Dmitry Pelinovsky*** (dmpeli@math.mcmaster.ca). *Enstrophy growth in the viscous Burgers equation.*

We study bounds on the enstrophy growth for solutions of the viscous Burgers equation on the unit circle. Using the variational formulation of Lu Lu and Doering, we prove rigorously that the maximizer of the enstrophy's rate of change is sharp in the limit of large enstrophy up to a numerical constant but does not saturate the Poincaré inequality for mean-zero 1-periodic functions. Using the dynamical system methods, we give an asymptotic representation of the maximizer in the limit of large enstrophy as a viscous shock on the background of a linear rarefractive wave. Using this asymptotic construction, we prove that the enstrophy achieve a larger growth when the initial data to the viscous Burgers equation saturates the Poincaré inequality up to a numerical constant. We construct an exact solution of the Burgers equation that describes a formation of a nearly stationary shock on the background of a linear rarefractive wave. We prove that the maximum enstrophy achieved in the time evolution is scaled as $E^{3/2}$, where E is the large initial enstrophy, whereas the time needed for reaching the maximal enstrophy is scaled as $E^{-1/2}$. We also give similar scaling rates for the Burgers equation on an infinite line subject to the nonzero boundary conditions. (Received August 18, 2011)

1077-35-287 **Vitor Leite Nunes*** (vitor@vt.edu), Interdisciplinary Center for Applied Mathemat, Virginia Polytechnic Institute & State Univer, Wright House (0531),West Campus Drive, blacksburg, VA 24060. *Frechet Sensitivity Analysis for the Convection-Diffusion Equation.*

In this work, we consider Fréchet derivatives of solutions to the convection-diffusion equation with respect to parameters and demonstrate their applicability in parameter estimation. This includes showing that the Fréchet derivative operator is Hilbert-Schmidt and the implications for uncertainty quantification. In addition to numerical results, we introduce a finite dimensional representation of the operator, and discuss sufficient conditions for the convergence of finite dimensional singular values to their infinite dimensional counterparts. (Received August 18, 2011)

1077-35-296 **Dehua Wang*** (dwang@math.pitt.edu). *Transonic flow in gas dynamics.*

The mixed type problem of transonic flows past an obstacle will be considered. Recent results on the construction of global solutions will be presented. A connection with the isometric embedding problem in geometry will also be discussed. (Received August 18, 2011)

1077-35-305 **Eunkyung Ko*** (ek94@msstate.edu), 319 N.Jackson st. 1A, Starkville, MS 39759. *Analysis of classes of elliptic equations with nonlinear boundary conditions arising in combustion theory.*

We study positive solutions to classes of semilinear elliptic equations with nonlinear boundary conditions arising in combustion theory. We discuss existence, multiplicity and uniqueness results when a parameter in our model varies. We prove existence and multiplicity results by the method of sub-super solutions, and uniqueness results by establishing apriori estimates. (Received August 19, 2011)

1077-35-307 **Eunkyung Ko*** (ek94@msstate.edu), 319 N.Jackson st. 1A, Starkville, MS 39759.
Uniqueness and multiplicity results for classes of infinite positone problems.

We study positive solutions to the singular boundary value problem

$$-\Delta u = \lambda \frac{f(u)}{u^\beta} \qquad \text{in } \Omega,$$
$$u = 0 \text{ on } \partial\Omega,$$

where λ is a positive parameter, $\beta \in (0,1)$ and Ω is a bounded domain in $\mathbb{R}^N, N \geq 1$. Here $f \in C([0,\infty),(0,\infty))$ is nondecreasing and satisfies $\lim_{u\to\infty} \frac{f(u)}{u^{\beta+1}} = 0$. We discuss the existence of multiple positive solutions for a certain range of λ and a uniqueness result for $\lambda \gg 1$. A simple model that will satisfy our hypotheses is $f(u) = e^{\frac{\alpha u}{\alpha+u}}$ for $\alpha \gg 1$. We extend our multiplicity result to classes of systems, including $p-$Laplacian systems, when the nonlinearities satisfy certain combined sublinear conditions at infinity. We also extend our results to the case when Ω is an exterior domain.
(Received August 19, 2011)

1077-35-321 **Jon Jacobsen*** (jacobsen@math.hmc.edu), **Yu Jin**, **Mark Lewis** and **Hannah McKenzie**. *R_0 analysis of a spatiotemporal model for a stream population.* Preliminary report.

We consider a framework for studying population persistence in spatiotemporal models based on an infinite dimensional analogue of the basic reproductive number R_0 used in structured population models. We consider applications in the context of population persistence in streams. (Received August 21, 2011)

1077-35-327 **Qi Ye*** (qye3@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616, **Gregory Fasshauer** (fasshauer@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616, and **Igor Cialenco** (fasshauer@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616. *Approximation of Stochastic Partial Differential Equations by a Kernel-based Collocation Method.*

In this paper we present the theoretical framework needed to justify the use of a kernel-based collocation method (meshfree approximation method) to estimate the solution of high-dimensional stochastic partial differential equations. Using an implicit time stepping scheme, we transform stochastic parabolic equations into stochastic elliptic equations. Our main attention is concentrated on the numerical solution of the elliptic equations at each time step. The estimator of the solution of the elliptic equations is given as a linear combination of reproducing kernels derived from the differential and boundary operators of the PDE centered at collocation points to be chosen by the user. The random expansion coefficients are computed by solving a random system of linear equations. Numerical experiments demonstrate the feasibility of the method. (Received August 22, 2011)

1077-35-337 **Jeremy L Marzuola*** (marzuola@math.unc.edu). *Solitons on manifolds.*

We will discuss the results of several joint ongoing projects (with subsets of collaborators Pierre Albin, Hans Christianson, Colin Guillarmou, Jason Metcalfe, Laurent Thomann and Michael Taylor), which explore the existence, stability and dynamics of nonlinear bound states and quasimodes on manifolds of both positive and negative curvature with various symmetry properties. (Received August 23, 2011)

1077-35-420 **Jerome Goddard II*** (jgoddard@aum.edu), Department of Mathematics, P.O. Box 244023, Montgomery, AL 36124, and **E. Lee** and **R. Shivaji**. *Population models with diffusion, strong Allee effect, and nonlinear boundary conditions.*

We discuss the steady state solutions of a diffusive population model with strong Allee effect, namely,

$$\begin{aligned} -\Delta u &= a(x)u + b(x)u^2 - m(x)u^3 - ch(x); \quad \Omega \\ \alpha(u)\frac{\partial u}{\partial \eta} &+ [1-\alpha(u)]\,u = 0; \quad \partial\Omega \end{aligned}$$

where Ω is a subset of $\mathbb{R}^n$ with $n \geq 1$, $a(x), b(x)$, and $m(x)$ are Holder continuous functions such that $b(x), m(x)$ are strictly positive on the closure of Ω with $a(x) < 0$ for some x in Ω, $c \geq 0$, $\alpha(u) : \mathbb{R} \longrightarrow [0,1]$ is a non-decreasing smooth function, and $\frac{\partial u}{\partial \eta}$ is the outward normal derivative. Our study is focused on a population that satisfies a certain nonlinear boundary condition and on its persistence when constant yield harvesting is introduced. We establish our existence results by the method of sub-super solutions. (Received August 30, 2011)

1077-35-463 **Laihan Luo*** (lluo@nyit.edu), 1855 Broadway, New York, NY 10023. *Well Known Equations and Not Well Known Behavior of Solutions.* Preliminary report.

The main subject of the proposal is to study the long time behavior of solutions of initial-value problems for some well known partial differential equations. The Heat equation, the generalized Burgers equations, The generalized

Korteweg-de Vries-Burgers (GKdV-B) equation, the generalized regularized long wave-Burgers (GRLW-B) equation, and the generalized Benjamin-Ono-Burgers equation are the examples of the partial differential equations. (Received September 02, 2011)

1077-35-465 **Majid Bani-Yaghoub*** (mbani@math.tamu.edu), Department of Mathematics, Mailstop 3368, College Station, TX 77843. *Dynamics of single species influenced by age-dependent dispersal and maturation time delay.* Preliminary report.

Considering the traveling wave solutions of an age-structured single species model, it is shown that the propagation patterns of the single species are greatly dependent on mature and immature dispersal rates. A traveling wavefront remains qualitatively the same when the dispersal rates are slightly perturbed. However, depending on the slope of birth function at the positive equilibrium, a monotonic traveling wave may become oscillatory under large perturbations. Employing this result, it is determined whether the densities of new colonies reach to the equilibrium monotonically or through long-term oscillations. Moreover, under certain conditions, the interplay between the maturation time delay and the density dependent birth function results in periodic forms of survival or extinction-survival of single species. (Received September 02, 2011)

1077-35-489 **Michael E. Taylor*** (met@math.unc.edu), Mathematics Department, University of North Carolina, Chapel Hill, NC 27599. *Gibbs phenomena and Pinsky phenomena for solutions to nonlinear Schrodinger equations.*

We discuss solutions to nonlinear Schrodinger equations on Euclidean space, given piecewise smooth initial data with jumps. We describe results on the nature of the convergence as t tends to zero. Results include analogues of the Gibbs phenomenon over the locus where the jumps occur, and also special effects related to the Pinsky phenomenon (arising in multidimensional Fourier inversion), which relate to focusing effects. (Received September 04, 2011)

1077-35-502 **Florin Catrina*** (catrinaf@stjohns.edu), St. John's Hall, 8000 Utopia Pkwy, Queens, NY 11439. *On Radial Solutions of certain Nonlinear Elliptic PDE's.*

In this talk we present an identity satisfied by solutions of nonlinear Sturm-Liouville equations, and applications to proving non-existence of radial solutions for semi-linear elliptic partial differential equations in spherically symmetric domains. This work helps explain in part the role played by critical exponents in nonlinear elliptic PDE's. (Received September 05, 2011)

1077-35-504 **Magaji Y Adamu*** (magajiadamu78@yahoo.com), Mathematical Science Programme, ATBU Bauchi, Nigeria, Bauchi, Nigeria, and **Dauda G Yakubu** and **Enoch Suleiman**, , Nigeria. *Hirota Bilinear Equations and their Connection with Linear Superposition Principle.* Preliminary report.

The existence of N-soliton solutions often implies integrability of the considered differential equations and interactions between solitons are elastic and nonlinear, but unfortunately, the linear superposition principle does not hold for soliton equations. But since bilinear equations are the nearest neighbours to linear equations, they are therefore expected to some other ways similar to the linear equations. As a result a linear superposition principle of exponential travelling waves of Hirota bilinear equations is going to be considered and analyzed, with the aim to construct some subclass of N-soliton solutions formed by linear combinations of exponential travelling waves. Examples are going to be considered for the Sawada-Kotera and a (2+1)-dimensional equations. (Received September 13, 2011)

1077-35-506 **Pierre M Germain***, pgermain@cims.nyu.edu. *Global existence for water wave equations.*

I will present results giving global existence and scattering for two fundamental water wave models (gravity and capillary waves) if the data are small. The proofs rely on the method of space-time resonances, which I will illustrate. I will also discuss the resonant structure of more general models. This is joint work with N. Masmoudi and J. Shatah. (Received September 06, 2011)

1077-35-510 **Cong Phuc Nguyen** (pcnguyen@math.lsu.edu), Department of Mathematics, Louisiana State University, 303 Lockett Hall, Baton Rouge, LA 70803, and **Tuoc Van Phan*** (phan@math.utk.edu), Department of Mathematics, University of Tennessee, 277 Ayres Hall, 1403 Circle Drive, Knoxville, TN 37996. *Stationary Navier-Stokes equations with singular external forces.*

We introduce new functional spaces which include some Morrey spaces. We then show that for a sufficiently small given external force in these spaces, there exists unique solution of Navier-Stokes equations (in $\mathbb{R}^n, n \geq 3$). The stability of these stationary solutions are also established. Our results extend the results of H. Kozono and

M. Yamazaki (1995) where the existence and stability of stationary solutions of Navier-Stokes equations were obtained in Morrey spaces.

This is a joint work with Nguyen Cong Phuc. (Received September 06, 2011)

1077-35-515 **Dumitru Motreanu*** (motreanu@univ-perp.fr), Department of Mathematics, University of Perpignan, 66860 Perpignan, France. *Nonlinear parametric Neumann problems with bifurcation and control properties.*

For a nonlinear Neumann problem driven by the p-Laplacian and depending on a positive real parameter, it is shown the existence of a value of the parameter such that for smaller numbers the corresponding problem has at least two positive solutions, whereas for bigger ones the corresponding problem has no positive solution. The reaction term in the equation has a (p-1)-superlinear growth near +-infinity and (p-1)-sublinear growth near 0, so our result covers combined effects of concave and convex nonlinearities. An evolutionary version of this bifurcation property is given in terms of certain nonlinear control systems. (Received September 06, 2011)

1077-35-526 **Jiecheng Chen**, **Dashan Fan** and **Lijing Sun*** (sun2@uwm.edu), Department of Mathematical Science, Milwaukee, WI 53201. *Unimodular Fourier Multipliers On Modulation Spaces.* Preliminary report.

Recently, it has been shown that the unimodular Fourier multipliers $e^{it|\Delta|^{\frac{\alpha}{2}}}$ are bounded on all modulation spaces. In this paper, using the almost orthogonality of projections and some techniques on oscillating integrals, we obtain asymptotic estimates for the unimodular Fourier multipliers $e^{it|\Delta|^{\frac{\alpha}{2}}}$ on the modulation spaces. As applications, we give the grow-up rates of the solutions for the Cauchy problems for the free Schrödinger equation, the wave equation and the Airy equation with the initial data in a modulation space. We also obtain a quantitative form about the the solution to the Cauchy problem of the nonlinear dispersive equations. (Received September 06, 2011)

1077-35-532 **Guillaume Bal*** (gb2030@columbia.edu), 500 W 120th St, New York, NY 10023. *Hybrid inverse problems and internal functionals.*

Recent Coupled-physics imaging modalities combine the high contrast of one modality with the high resolution of another modality. The solution to such problems involves analyzing hybrid inverse problems with internal functionals. This talk will review recent results obtained in this area. (Received September 06, 2011)

1077-35-534 **Guillaume Bal*** (gb2030@columbia.edu), 500 W 120th St, New York, NY 10023. *Random fluctuations of solutions to partial differential equations.*

The theory of homogenization is well understood for many elliptic partial differential equations. The theory of the random fluctuations (random corrector) of the heterogeneous solution is much less understood. This talk will review recent results obtained in this area and present some applications for such theoretical results. (Received September 06, 2011)

1077-35-538 **Xinfu Chen**, Department of Mathematics, University of Pittsburgh, Pittsburgh, PA 15260, **Cody Pond**, Department of Mathematics, Tulane University, New Orleans, LA 70118, and **Xuefeng Wang*** (xdw@tulane.edu), Department of Mathematics, Tulane University, New Orleans, LA 70118. *Effective Boundary Conditions Resulting from Anisotropic and Optimally Aligned Coatings: the Two Dimensional Case.*

Of concern is a thermally conducting body insulated by a thin anisotropically conducting coating. The coating is "optimally aligned" in the sense that the normal vector inside the coating is always an eigenvector of the thermal tensor. We study the effects of the coating by investigating the limiting behavior of solutions u of the heat equation with either Dirichlet or Neumann boundary condition imposed on the outer boundary of the coating, as the thickness of the coating shrinks to zero. In the two-dimensional case, we find the complete list of "effective boundary conditions" satisfied by the limit of u on the boundary of the uncoated body. This list contains not only the usual Dirichlet, Neumann and Robin boundary conditions, but also some new and even nonlocal ones involving the Dirichlet-to-Neumann mapping, the Hilbert transformation and the Laplace-Beltrami operator. We also prove that u converges to its limit in various norms that include the L^2, the Sobolev and the Hölder ones. During the course of this study, we establish a Schauder theory for the regularity of weak solutions of general second order parabolic equations near an interface where the "transmission condition" is satisfied. (Received September 06, 2011)

1077-35-579 **Robert P Gilbert*** (gilbert@math.udel.edu), 317 Ewing Hall, University of Delaware, Newark, DE 19716, **Alexander Panchenko** (panchenko@math.wsu.edu), Pullman, WA 99164, and **Ana Vasilic** (vasilic021@gmail.com), Abu Dhabi. *Acoustic Propagation in a Random Saturated Medium: The Biphasic Case.*

Osteoporosis is characterized by a decrease in strength of the bone matrix. Since the loss of bone density and the destruction of the bone microstructure is most evident in osteoporosis cancellous bone, it is natural to consider developing accurate ultrasound models for the isonification of cancellous bone. We develop 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 a stationary random, scale-separated microstructure. The ratio ε of the macroscopic length scale and a typical size of the microstructural inhomogeneity is a small parameter of the problem. We employ stochastic two-scale convergence in the mean to pass to the limit $\varepsilon \to 0$ in the governing equations. The effective model is a biphasic phase viscoelastic material with long time history dependence. (Received September 07, 2011)

1077-35-582 **Tao Luo*** (tl48@Georgetown.edu). *On the transonic shocks of Euler-Poisson equations.*

In this talk, I will present some results on the existence of unique and multiple transonic shock solutions and their stability for a system of Euler-Poisson equations. This is a joint work with Rauch, Xie and Xin. (Received September 07, 2011)

1077-35-586 **Jingsong He** and **Junyi Tu*** (junyi@mail.usf.edu), Tampa, FL 33613, and **Xiaodong Li** and **Lihong Wang**. *Explicit Flow Equations and Recursion Operator of the ncKP hierarchy.*

The explicit expression of the flow equations of the noncommutative Kadomtsev-Petviashvili(ncKP) hierarchy is derived. Compared with the flow equations of the KP hierarchy, our result shows that the additional terms in the flow equations of the ncKP hierarchy indeed consist of commutators of dynamical coordinates $\{u_i\}$. The recursion operator for the flow equations under n-reduction is presented. Further, under 2-reduction, we calculate a nonlocal recursion operator $\Phi(2)$ of the noncommutative Korteweg-de Vries(ncKdV) hierarchy, which generates a hierarchy of local, higher-order flows. Thus we solve the open problem proposed by P.J. Olver and V.V. Sokolov(Commun.Math.Phys. 193 (1998), 245-268). (Received September 07, 2011)

1077-35-604 **Wen-Xiu Ma*** (mawx@cas.usf.edu), Department of Mathematics and Statistics, 4202 E Fowler Avenue, University of South Florida, Tampa, FL 33620. *Nonlinear multi-integrable couplings with Hamiltonian structures.*

Multi-integrable couplings of soliton equations are presented through introducing non-semisimple matrix Lie algebras. The corresponding variational identity yields Hamiltonian structures of the resulting multi-integrable couplings. The key point is the existence of non-degenerate, symmetric and ad-invariant bilinear forms on the adopted Lie algebras. Illustrative examples will be given to shed light on the computational paradigm. (Received September 08, 2011)

1077-35-605 **Peter J. Olver*** (olver@math.umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *Dispersive Quantization — the Talbot Effect.*

The evolution, through linear dispersion, of piecewise constant periodic initial data leads to surprising quantized structures at rational times, and fractal, non-differentiable profiles at irrational times. Similar phenomena have been observed in optics and quantum mechanics, where it is known as the Talbot effect after an optical experiment by one of the founders of photography, and lead to intriguing connections with exponential sums arising in number theory. Ramifications of these observations for numerics and nonlinear dispersion will be discussed. (Received September 08, 2011)

1077-35-613 **Allan Greenleaf*** (allan@math.rochester.edu), 918 Hylan Building, University of Rochester, Rochester, NY 14627, and **Yaroslav Kurylev**, **Matti Lassas**, **Ulf Leonhardt** and **Gunther Uhlmann**. *Schrödinger hats: cloaked amplifiers via transformation optics.*

The advent of transformation optics and metamaterials has made possible devices producing extreme effects on wave propagation. We will describe a class of invisible reservoirs and amplifiers for waves, which we refer to as Schrödinger hats. The unifying principle on which these are based admits such devices for any wave phenomenon modeled by either the Helmholtz or Schrödinger equation, e.g., polarized waves in electromagnetism, acoustical waves and matter waves in quantum mechanics. Schrödinger hats occupy one part of a parameter-space continuum of wave-manipulating structures which also contains standard transformation optics based cloaks, resonant cloaks and cloaked sensors. We discuss their properties and some possible implementations. (Received September 08, 2011)

1077-35-615 **Plamen Stefanov*** (stefanov@math.purdue.edu), West Lafayette, IN 47907, and **Gunther Uhlmann**. *Recovery of a source or a sound speed with one measurement and applications.*

We study the problem of recovery the source $a(t,x)F(x)$ in the wave equation in anisotropic medium with a known so that $a(0,x) \neq 0$, with a single measurement. We use Carleman estimates combined with geometric arguments and give sharp conditions for uniqueness. We also study the non-linear problem of recovery the sound speed in the equation $u_{tt} - c^2(x)\Delta u = 0$ with one measurement. We give sharp conditions for stability, as well. An application to thermoacoustic tomography will be also presented. (Received September 08, 2011)

1077-35-632 **Robin Young*** (young@math.umass.edu). *Some exact solutions to nonlinear hyperbolic PDE.*

I shall present some interesting exact solutions to hyperbolic systems. These demonstrate some of the different phenomena that can occur as a result of interactions of waves with O(1) strength. I'll present solutions of the compressible Euler equations which shed light on the vacuum as well as shock formation and cancellation, and includes a nontrivial space-periodic solution. I'll also present an example of nonuniqueness of solutions without shocks for a system which is not in conservative form. (Received September 08, 2011)

1077-35-655 **Juraj Foldes*** (juraj.foldes@vanderbilt.edu). *Asymptotic properties of perturbed parabolic equations.*

Positive solutions of nonlinear parabolic problems can have very complex behavior. However, assuming certain symmetry conditions, it is possible to prove that the solutions converge to the space of symmetric functions. We show that this property is 'stable'. More specifically if the symmetry conditions are replaced by asymptotically symmetric ones, the solutions still approach the space of symmetric functions. We discuss problems on bounded and unbounded domains and,by possibly surprising counterexamples, we show optimality of our assumptions. As an application, we formulate new results on convergence of solutions to a single equilibrium. (Received September 09, 2011)

1077-35-664 **Irena M Lasiecka*** (il2v@virginia.edu), Department of Mathematics, University of Virginia, Char;lottesville, VA 22901, and **Justin Webster** (jtw3k@virginia.edu), Department of Mathematiics, University of Virginia, Charlottesville, VA 22901. *Long time behavior of Flow-Structure interactions arising in modeling of subsonic and supersonic flows of gas.* Preliminary report.

We shall consider a model of flow-structure interaction which consists of perturbed wave equation coupled with a nonlinear plate. The interaction between two media takes place at the edge of the plate. We shall consider both subsonic and supersonic case. It is known that in the latter case the static problem looses ellipticity. Questions such as existence and uniqueness of finite energy solutions will be addressed first. The final goal is to determine geometric conditions for the configuration which would lead to asymptotic stability. This includes convergence to the equilibria (subsonic case) and existence of global attractors (supersonic case). This latter case presents a challenge of dealing with the system which does not have a gradient structure -in addition to the loss of regularity due to the boundary interaction. Both, spectral analysis, and microlocal analysis will be employed for the proof. (Received September 09, 2011)

1077-35-666 **Irena Lasiecka** (il2v@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22901, and **Yongjin Lu*** (yl7m@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22901. *"Uniform decays of energy and blow up of steady states in unstable systems arising in fluid structure interactions".*

Fluid structure interaction comprising of Navier Stokes equation coupled to a dynamic system of elasticity is considered. It will be shown that under some geometric conditions related to partial flatness of the elastic domain the energy (kinetic and potential) associated with the model tends to zero when $t \to \infty$. Since the energy does not provide full topological measure for the state, there are unstable equilibria which lead to solutions blowing up to infinity when $t \to \infty$. In order to counteract this phenomena a boundary feedback in the form of porous force acting on the interface is introduced.

In this talk we shall discuss effectiveness of this feedback in forcing uniform decays of both *the energy* and the *full state*. It will be shown, in particular, that a pure porous force applied on the interface will provide uniform decay of the energy but not of the state. Unstable equilibria (in the annihilator of the energy) still persist.

Elimination of the latter is achieved by applying an additional static boundary feedback. (Received September 09, 2011)

1077-35-697 **Jing Zhang*** (jz4f@virginia.edu), Jing Zhang, Department of Mathematics, University of Virginia, Charlottesville, VA 22904, and **Roberto Triggiani**, Roberto Triggiani, Department of Mathematics, University of Virginia, Charlottesville, VA 22904. *Linear and non-linear boundary stabilization in $L_2 \times H^{-1}$ of the system of dynamic elasticity with Dirichlet Boundary dissipation: a direct approach.* Preliminary report.

We consider the multi-dimensional system of dynamic elasticity with suitable (linear or non-linear) dissipation in the Dirichlet boundary conditions. We seek stabilization in the natural/optimal state space $L_2 \times H^{-1}$ by a "direct" approach. Under some geometrical conditions, this result can be obtained by suitable "energy-methods in differential form". To eliminate geometrical conditions, a micro-local analysis/pseudo-differential approach is needed. All this is the counterpart of known results for the wave equation (I.Lasiecka and R.Triggiani, 1986-92). It uses also suitable trace regularity results of the system of dynamic elasticity by MA Horn (1998), which extended corresponding results for second order hyperbolic equations by Lasiecka-Triggiani (1992). (Received September 10, 2011)

1077-35-710 **Steve Zelditch*** (zelditch@math.northwestern.edu), Department of Mathematics Northwestern Univer, 2033 Sheridan Road, Evanston, IL 60208-2370. *Global harmonic analysis of eigenfunctions in the real and complex domain.* Preliminary report.

I will present some new asymptotics results on the eigenfunctions of the Laplace operator of a compact Riemannian manifold (M, g) as the eigenvalue tends to infinity. When (M, g) is real analytic, eigenfunctions can be analytically continued to the complexification of M (i.e. to Grauert tubes), and there are complex analogues of the standard problems in the real domain– local Weyl laws with remainder, zeros etc. and their relations to complex geodesics. I will discuss the new phenomena in the complex domain. (Received September 11, 2011)

1077-35-712 **Ranis N Ibragimov*** (Ranis.Ibragimov@utb.edu), Brownsville, TX 78520. *Lie group analysis - a microscope of physical and engineering sciences.*

The aim of this presentation is, from the one hand, to impart to the wide audience of researchers and students with the comprehensive and easy to follow introduction to Lie's group analysis and, from the other hand, is to present several recent results in this area whose discussion discloses the advantages to be gained from the use of the group theoretic approach. The emphasis will be on an application of Lie group analysis to nonlinear Navier-Stokes equations modelling the large-scale atmospheric motion around the rotating Earth. The inquiry is motivated by dynamically significant Coriolis forces in meteorology and oceanographic applications. This project is aimed to contribute to a better observational knowledge of the spatial and temporal distribution of mixing in the atmosphere and the ocean than achieved to date. The exact solutions are obtained in terms of elementary functions and visualized. One of the impacts of the project is, from one hand, to learn more about the influences of large scale fluid flows on the environment, highlighted by fundamental issues such as global warming and long term climate change and, from the other hands, is to illustrate the advantages of mathematical modeling of e.g., oil spill associated with the Deepwater Horizon incident. (Received September 11, 2011)

1077-35-713 **Daniele Garrisi*** (garrisi@postech.ac.kr), Namgu, Hyojadong, San 31, POSTECH, Mathematical Science Building #302, Pohang, Gyeongbuk 790784, South Korea. *Standing-waves solutions to a system of non-linear Klein-Gordon equations with a sub-critical growth non-linearity.* Preliminary report.

We consider a system of non-linear Klein-Gordon equations

$$\partial_{tt}v_j - \Delta v_j + m_j^2 v_j + \partial_{v_j} F(v) = 0, \quad 1 \le j \le k.$$

We assume that $F \in C^1(\mathbb{R}^k, \mathbb{R})$ and $F(0) = 0$. Moreover,

$$|DF(u)| \le c(|u|^{p-1} + |u|^{q-1}), \quad u \in \mathbb{R}^k$$

$$F(u) + \frac{1}{2}\sum_{j=1}^{k} m_j^2 u_j^2 \ge 0$$

and $m_j > 0$ for every j. Standing-waves k-uples solutions to the NLKG

$$v_j(t,x) = e^{-i\omega_j t}u_j(x), \quad (u_j, \omega_j) \in H^1(\mathbb{R}^N, \mathbb{R}) \times \mathbb{R}$$

correspond to solutions of the elliptic systems

$$-\Delta u_j + (m_j^2 - \omega_j^2)u_j + \partial_j F(u) = 0, \quad 1 \le j \le k.$$

We show that there is a solution (u, ω) such that u_j is radially symmetric and $\omega_j \in (0, m_j)$. (Received September 11, 2011)

1077-35-733 **Georg Hetzer*** (hetzege@auburn.edu), **Tung Nguyen** and **Wenxian Shen**. *Two-Species Competition Model with Nonlocal Dispersal.*

This talk deals with coexistence and extinction for two-species Volterra-Lotka competition systems with nonlocal dispersal. Sufficient conditions in terms of diffusion, reproduction, self-limitation, and competition rates are presented for existence, uniqueness, and stability of coexistence states as well as for the extinction of one species. The focus is on environments with hostile surroundings, which corresponds to the case of Dirichlet boundary conditions for systems with random dispersal. Similar results hold for isolated and periodic environments, which correspond to Neumann and periodic boundary conditions, respectively, in case of random dispersal. Important tools are a comparison principle, sub- and super-solutions, and the principal eigenvalue theory for nonlocal dispersal operators. (Received September 11, 2011)

1077-35-734 **Georg Hetzer*** (hetzege@auburn.edu). *Energy Balance Climate Models with Bio-Feedback.*

Energy balance climate models are simple diagnostic models which describe the evolution of a long-term mean of temperature by employing the relevant balance equations for the heat fluxes involved. The mean horizontal heat flux is approxiamted by a diffusion operator, and important feedback processes appear in the net radiation flux. Based on daisy world models, I am going to describe a mathematical framework for adding a bio-feedback, which means in the context of an energy balance model, the interaction between vegetation and net radiation flux. A basic dynamic theory for the resulting reaction-diffusion problem will be presented. (Received September 11, 2011)

1077-35-736 **Jared Speck***, Department of Mathematics, Massachusetts Institute of Technology, 77 Massachusetts Ave, Room 2-163, Cambridge, MA 02139-4307. *Global Stability Results for Relativistic Fluids in Expanding Spacetimes.*

In this talk, I will discuss the future-global nonlinear behavior of relativistic fluids evolving in expanding spacetimes. I will focus on how the global behavior of the fluid is affected by both the expansion rate and the fluid equation of state. This topic is physically relevant for the following reasons: i) Experimental evidence indicates that our spacetime is expanding. However, there is a debate over the precise rate. ii) In cosmology, fluids are often used to model the "normal" matter content of our universe. This talk is further motivated by the following prior results: a) In Minkowski spacetime, D. Christodoulou showed that non-zero uniform fluid solutions are unstable. More precisely, arbitrarily small perturbations of their initial data can lead to finite-time shock formation. b) In contrast, I. Rodnianski and I showed that under some often-made assumptions on the equation of state, the non-zero uniform solutions are future-stable when the fluid is irrotational and the expansion rate is exponential; such a rate can be generated by including a positive cosmological constant in Einstein's equations. Furthermore, I recently removed the assumption of irrotationality. This talk concerns expansion rates in between 0 and exponential without the irrotationality assumption. (Received September 11, 2011)

1077-35-744 **Vincent Jugnon*** (vjugnon@math.mit.edu), **Habib Ammari**, **Hyeonbae Kang**, **Mark Asch** and **Lili Guadarrama Bustos**. *Transient wave imaging with limited-view data.*

We consider for the wave equation the inverse problem of identifying locations of point sources and dipoles from limited-view data. Using as weights particular background solutions constructed by the geometrical control method, we recover classical imaging algorithms by appropriately averaging limited-view data. We show both analytically and numerically that if one can construct accurately the geometric control, then one can perform imaging with the same resolution using limited-view as using full-view data. (Received September 12, 2011)

1077-35-769 **Gigliola Staffilani*** (gigliola@math.mit.edu). *Dispersive equations and their role beyond PDE.*

Arguably the star in the family of dispersive equations is the Schrödinger equation. Among many mathematicians and physicists it is regarded as fundamental, in particular to understand complex phenomena in quantum mechanics.

But not many people may know that this equation, when defined on tori for example, has a very reach and more abstract structure that touches several fields of mathematics, among which analytic number theory, symplectic geometry, probability and dynamical systems.

In this talk I will illustrate in the simplest possible way how all these different aspects of a unique equation have a life of their own while interacting with each other to assemble a beautiful and subtle picture. This picture is not yet completely well understood and many questions and open problems are there ready to be solved by a new generation of mathematicians. (Received September 12, 2011)

1077-35-791 **Florentina Tone*** (ftone@uwf.edu), University of West Florida, Department of Mathematics and Statistics, Pensacola, FL 32514, and **Xiaoming Wang**, Florida State University, Department of Mathematics, Tallahassee, FL 32306. *On the long-time stability of a semi-impicit Euler scheme for the 2d thermohydraulics equations.*

In this talk we will discuss the H1-stability for all positive time of a semi-implicit Euler scheme for the 2d thermohydraulics equations. More precisely, we will discretize the 2D thermohydraulics equations in time using a semi-implicit Euler scheme and with the aid of a discrete Gronwall lemma and of a discrete uniform Gronwall lemma, we will prove that the numerical scheme is unconditionally stable (uniformly in time). (Received September 12, 2011)

1077-35-826 **John V Matthews*** (Matt-Matthews@utc.edu), 615 McCallie Ave, Dept 6956, Chattanooga, TN 37403, and **Boris Belinskiy**. *A Local Approach for an Inverse Problem on a Semi-Axis.*

We use a boundary control approach to recover an unknown potential for the wave equation on a semi-axis. Both spectral and dynamical methods are considered to produce data from the forward problem, and we use local Krein and Gelfand-Levitan approaches to solve the inverse problem. Corresponding numerical algorithms were implemented to demonstrate the efficacy of our approach with numerous computational examples. (Received September 13, 2011)

1077-35-853 **Joseph L. Shomberg*** (jshomber@providence.edu) and **Sergio Frigeri** (sergio.frigeri@unipv.it). *Global Attractors for Damped Semilinear Wave Equations with a Robin–Acoustic Boundary Perturbation.* Preliminary report.

Under consideration is the damped semilinear wave equation

$$u_{tt} + u_t - \Delta u + u + f(u) = 0$$

on a bounded domain Ω in $\mathbb{R}^3$ with a perturbation parameter $\varepsilon > 0$ occurring in an acoustic boundary condition, limiting ($\varepsilon = 0$) to a Robin boundary condition. With minimal assumptions on the nonlinear term f, the existence and uniqueness of global weak solutions is shown. Also, the existence of a family of global attractors is shown to exist. After proving a general result concerning the robustness of a one-parameter family of sets, the result is applied to the family of global attractors. Because of the complicated boundary conditions for the perturbed problem, fractional powers of the Laplacian are not well defined; moreover, because of the restrictive growth assumptions on f, the family of global attractors is obtained from the asymptotic compactness method developed by J. Ball for generalized semiflows. (Received September 13, 2011)

1077-35-882 **Netra P Khanal*** (nkhanal@ut.edu), 401 W. Kennedy Blvd, Tampa, FL 33606. *Extended fifth-order KdV type equations.*

The dual-Petrov-Galerkin method is applied to some integrable and non-integrable fifth-order KdV type equations. The method is implemented to compute the solitary wave solutions of these equations and the numerical results imply that this scheme is capable of capturing the details of these solutions with modest computational costs. (Received September 13, 2011)

1077-35-912 **Guoping Zhang***, 1700 E Cold Spring Ln, Baltimore, MD 21251. *Standing wave solutions of nonlinear Schrödinger equation with saturable nonlinearity.* Preliminary report.

In this talk I will present our recent work on the existence of standing wave solutions of nonlinear Schrödinger equation with saturable nonlinearity and unbounded potential (Received September 14, 2011)

1077-35-925 **Lingyun Qiu*** (qiu@purdue.edu), **Elena Beretta** and **Maarten de Hoop**. *Lipschitz stability of an inverse problem for a Schrödinger type equation.*

Consider the inverse problem of determining the potential q from the Neumann-to-Dirichlet map Λ_q of a Schrödinger type equation

$$\begin{cases} -(\Delta + q)u = & 0, \quad \text{in } \Omega \\ u = & g, \quad \text{on } \partial\Omega. \end{cases}$$

A relevant question, specially in applications, is the stability of the inversion. In this work, a Lipschitz type stability is established assuming a priori that q is piecewise constant with a bounded know number of unknown values. (Received September 15, 2011)

1077-35-926 **Suzanne Lenhart*** (lenhart@math.utk.edu), U of Tennessee, Math Dept., Knoxville, TN 37996. *Optimal control of PDE population models involving resources.*

We study optimal control of an elliptic partial differential equation modeling a population. The goal is to maximize the net benefit in the conservation of a singles species with a fixed amount of resources. Our control represents the intrinsic growth rate of the species and measures the availability of the resources. Analysis and numerical results will be presented. Joint work with W. Ding, H. Finotti, Y. Lou and Q. Ye. (Received September 14, 2011)

1077-35-927 **Lokenath Debnath*** (debnathl@utpa.edu), Mathematics Department (MAGC 3.602), 1201 West University Drive, Edinburg, TX 78540. *The Nonlinear Klein-Gordon Equation and Average Variational Principle.*

The average variational principle is used to derive the nonlinear Klein-Gordon equation. Some comments will be made about the relativistic and non relativistic Klein-Gordon equations. (Received September 14, 2011)

1077-35-938 **Lei Z. Cheng*** (zhang86@math.purdue.edu), 150 N. University Street, West Lafayette, IN 47907. *Static and Dynamic Features of Liquid Crystal Films.*

We analyze a model based on the energies introduced by de Gennes and Chen-Lubensky to find the chevron structure arising from the cooling from the Sm-A liquid crystal to the nonchiral Sm-C phase in a surface-stabilized cell with planar boundary conditions. We show that the chevron is the thermodynamic equilibrium structure by analytically minimizing the energy using the methods in calculus of variation and the notion of $\Gamma-$convergence. There are two distinct stable director states with the same free energy. This feature of bistability is widely used in optical applications, where the cell is switched between the stable states, i.e., between a dark and a bright state, which happens when an external electric field is added. We analyze how the molecules switch from one stable state to the other under an electric field by considering an initial value problem for the gradient flow for this non-linear second order energy. This work is joint with D. Phillips. (Received September 22, 2011)

1077-35-940 **Stephen Robinson*** (sbr@wfu.edu) and **Pavel Drabek**. *On the Variational Characterization of the Fucik Spectrum.* Preliminary report.

We present a new variational characterization of points in the Fucik Spectrum for the p-Laplacian on smooth bounded domains assuming Dirichlet boundary data. (Received September 14, 2011)

1077-35-941 **Zhiwu Lin** and **Chongchun Zeng*** (zengch@math.gatech.edu). *Unstable manifolds and L^2 nonlinear instability of Euler equations.*

We consider a steady state v_0 of the Euler equation in a fixed bounded domain in R^n. Suppose the linearized equation has an exponential dichotomy with a finite dimensional unstable subspace. By rewriting the Euler equation as an ODE on an infinite dimensional manifold in H^k, $k > \frac{n}{2} + 1$, the unstable manifold of v_0 is constructed under certain conditions on the Lyapunov exponents of the vector field v_0. This in turn shows the nonlinear instability of v_0 in the sense that small H^k perturbations can lead to L^2 derivation of the solutions. (Received September 14, 2011)

1077-35-987 **Heather Finotti**, Department of Mathematics, University of Tennessee, 227 Ayres Hall, 1403 Circle Drive, Knoxville, TN 37996, **Suzanne Lenhart** (lenhart@math.utk.edu), Department of Mathematics, University of Tennessee, 227 Ayres Hall, 1403 Circle Drive, Knoxville, TN 37996, and **Tuoc Van Phan*** (phan@math.utk.edu), Department of Mathematics, University of Tennessee, 227 Ayres Hall, 1403 Circle Drive, Knoxville, TN 37996. *Optimal Control of Advection Direction on Reaction-Diffusion Population Models.*

We investigate optimal control of the convective coefficient in a class of non-linear parabolic partial differential equations, modeling a population with non-linear growth. This work is motivated by the question: Does movement toward a better resource environment benefit a population? Results on existence, uniqueness, and characterization of the optimal control will be presented along with numerical illustrations.

This is the joint work with H. Finotti, and S. Lenhart. (Received September 15, 2011)

1077-35-990 **Catherine Sulem*** (sulem@math.toronto.edu), Department of Mathematics, University of Toronto, Toronto, ON M5S2E4, Canada. *Water waves over a rough bottom in the shallow water regime.*

This is a study of the Euler equations for free surface water waves in the case of varying bathymetry, considering the problem in the shallow water scaling regime. In the case of rapidly varying periodic bottom boundaries this is a problem of homogenization theory. In this setting, we derive a new model system of equations, consisting of the classical shallow water equations coupled with nonlocal evolution equations for a periodic corrector term. Solutions of the latter can exhibit the effect of Bragg resonance with the periodic bottom, which leads to secular growth and can influence the time interval of validity of the theory. We justify the derivation of our model with a rigorous analysis of the scaling limit and the resulting error terms. The principal issue is that the shallow water limit and the homogenization process must be performed simultaneously. Our model equations and the error analysis are valid for both the two- and the three-dimensional physical problems.

This is a joint work with Walter Craig and David Lannes. (Received September 15, 2011)

1077-35-1037 **Michael Shearer*** (shearer@ncsu.edu), Department of Mathematics, NC State University, Raleigh, NC 27695, and **Kim Spayd** and **Zhengzheng Hu**. *Two Phase Flow in Porous Media: the Saffman-Taylor Instability Revisited.*

Plane waves for two phase flow in a porous medium are modeled by the one-dimensional Buckley-Leverett equation, a scalar conservation law. We analyze linearized stability of sharp planar interfaces to two-dimensional perturbations, which involves a system of PDE. Numerical simulations of the full nonlinear system, including dissipation, illustrate the analytical results. We also discuss a modified Buckley-Leverett equation, in which the capillary pressure is rate-dependent, thereby adding a BBM-type dispersive term. This equation sustains undercompressive planar waves, but they are all unstable to two-dimensional perturbations. (Received September 15, 2011)

1077-35-1040 **Tai-Ping Liu** and **Yanni Zeng*** (ynzeng@uab.edu). *Shock Wave Stability for Conservation Laws with Physical Viscosities.*

We study the nonlinear stability of shock waves for conservation laws with physical viscosities. Suppose that the initial data is a small perturbation of a weak shock. We show that the solution to the Cauchy problem converges to a translated shock profile. Detailed pointwise estimates on the convergence are obtained. The strength of the perturbation and that of the shock are assumed to be small, but independent. Our assumptions on the viscosity matrix are general so that our results apply to the Navier-Stokes equations for the compressible fluid and the full system of magnetohydrodynamics, including the cases of multiple eigenvalues in the transversal fields, as long as the shock is classical. Our analysis depends on accurate construction of the approximate green's function. The form of the ansatz for the perturbation is carefully constructed and is sufficiently tight so that we can close the nonlinear term through the Duhamel principle. (Received September 15, 2011)

1077-35-1049 **Constantine M. Dafermos*** (Constantine_Dafermos@brown.edu), Division of Applied Mathematics, Brown University, Providence, RI 02912. *Applications of Generalized Characteristics.*

The lecture will present applications of the method of generalized characteristics to the study of the large time behavior of solutions of hyperbolic balance laws and to the theory of solutions of the Hunter-Saxton equation. (Received September 15, 2011)

1077-35-1055 **Alrazi M Abdeljabbar*** (alrazia@yahoo.com), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, PHY 114, Tampa, FL 33620. *Wronskian and Paffian solutions to nonlinear partial differential equations.*

In the past several decades, many powerful and systematic methods have been developed in soliton theory for solving nonlinear differential equations, which include the inverse scattering method, Darboux transformation, Bäcklund transformation, Hirota method, the Wronskian determinants technique, and the Pfaffian technique.
The Wronskian and Pfaffian technique has been applied to a variety of soliton equations such as KdV,MKdV,NLS, derivative NLS,KP and sine-Gordon equations. Within Wronskian and Paffian formulations, soliton solutions and rational solutions are usually expressed as some kind of logarithmic derivatives of Wronskian and Pfaffian type determinants and the determinants involved are made of functions satisfying linear system of differential equations. This connection between nonlinear problems and linear ones utilizes linear theories in solving soliton equations.
In our presentation, we are going to speak about this method and its applications to a generalized (3+1)-dimensional KP equation, the Jimbo-Miwa equation, a (2+1)-dimensional Boussinesq system with variable coefficients. A necessary and sufficient criterion for the existence of linear subspaces of solutions to Hirota bilinear equations established by W. X. Ma and E. G. Fan will be discussed as well. (Received September 15, 2011)

1077-35-1081 **Chunquan Tang***, ctang@iastate.edu, and **Gary M Lieberman**. *Mixed Boundary Value Problem for Quasilinear Elliptic Equations.* Preliminary report.

The gradient bound of a nonlinear mixed boundary-value problem for a class of equations in the domains with boundary curvature conditions is studied. A particular case of it is the following capillary problem:

$$\begin{aligned} \operatorname{div}\Big(\frac{Du}{\sqrt{1+|Du|^2}}\Big) &= 0, && \text{in } \Omega,\\ u &= \psi(x), && \text{on } \partial_1\Omega,\\ \frac{Du}{\sqrt{1+|Du|^2}}\cdot\gamma(x) &= \cos\beta, && \text{on } \partial_2\Omega. \end{aligned}$$

Here $\gamma(x)$ is the unit inner normal vector on the boundary $\partial_2\Omega$. Suppose θ is any one of angles formed by $\partial_1\Omega$ and $\partial_2\Omega$. It is shown that, among other conditions, when $\theta < \frac{\pi}{2} - |\frac{\pi}{2} - \beta|$, a global gradient bound exists. (Received September 16, 2011)

1077-35-1084 **Ping Liu***, Y.Y.Tseng Functional Analysis Research Center, and School of Mathematical Science, Harbin Normal University, Harbin, Heilongjia 150025, Peoples Rep of China, and **Junping Shi** and **Yuwen Wang**. *Abstract analytical bifurcation theory and its applications.*

We review several old and new abstract bifurcation theorems, based on implicit function theorem. Some examples are shown to demonstrate the applications of these results. (Received September 16, 2011)

1077-35-1093 **Gino Biondini*** (biondini@buffalo.edu), SUNY Buffalo, Math Dept, Buffalo, NY 14260, and **Gregor Kovacic**. *On the Maxwell-Bloch equations with non-zero boundary conditions.*

The inverse scattering transform for the Maxwell-Bloch equations with non-zero boundary conditions for the electric field is presented. The direct problem is formulated on a two-sheeted, genus-zero Riemann surface. The symmetries and the evolution of the scattering data are obtained, the inverse problem is formulated as a Riemann-Hilbert problem, and explicit formulae are obtained for the reflectionless solutions. Throughout, the similarities and differences with the case of zero boundary conditions are pointed out. (Received September 16, 2011)

1077-35-1101 **Sarath Sasi*** (ss885@msstate.edu). *Alternate Stable States in Ecosystems.*

We consider the existence of multiple positive solutions to the steady state reaction diffusion equation with Dirichlet boundary conditions of the form:

$$\begin{cases} -\Delta u = \lambda[u - \dfrac{u^2}{K} - c\dfrac{u^2}{1+u^2}], \quad x \in \Omega,\\ \quad u = 0, \quad x \in \partial\Omega. \end{cases}$$

Here $\Delta u = div(\nabla u)$ is the Laplacian of u, $\frac{1}{\lambda}$ is the diffusion coefficient, K and c are positive constants and $\Omega \subset \mathbb{R}^N$ is a smooth bounded region with $\partial\Omega$ in C^2. This model describes the steady states of a logistic growth model with grazing in a spatially homogeneous ecosystem. It also describes the dynamics of the fish population with natural predation. In this paper we discuss the existence of multiple positive solutions leading to the occurrence of an S-shaped bifurcation curve. We also introduce a constant yield harvesting term to this model and discuss the existence of positive solutions including the occurrence of a Σ-shaped bifurcation curve in the case of a one-dimensional model. We prove our results by the method of sub-super solutions and quadrature method. (Received September 16, 2011)

1077-35-1110 **Mark J Ablowitz**, **Sarbarish Chakravarty** and **Barbara Prinari*** (bprinari@uccs.edu), Department of Mathematics, University of Colorado at Colorado Springs, 1420 Austin Bluffs Pkwy, Colorado Springs, CO 80918. *Coupled Maxwell-Bloch equations with inhomogeneous broadening for a 3-level system.* Preliminary report.

The phenomenon that describes the effect of a coherent medium response to an incident electric field, to which the medium is totally transparent and which undergoes lossless propagation, is known as self-induced transparency (SIT). The initial value problem for the propagation of a pulse through a resonant two-level optical medium was solved by Inverse Scattering Transform (IST) in [1,2]. It is possible to formulate the SIT equations in the framework of the IST also in the case of a three-level system, as in [3]. While the associated scattering problem is the same as for the coupled nonlinear Schrödinger equation, the time evolution depends on asymptotic values of the material polarizability envelopes and is highly nontrivial. This talk will address the solution of the initial value problem for the SIT equations for three level systems, for generic preparation of the medium, and describe its soliton interactions.

References

[1] M.J. Ablowitz, D.J. Kaup, A.C. Newell, J. Math. Phys. **15**, 1852 (1974)

[2] I.R. Gabitov, A.V. Mikhailov, V.E. Zakharov, Theor. Math. Phys. **63**, 328 (1985)

[3] J.A. Byrne, I.R. Gabitov, G. Kovačič, Physica D **186**, 69 (2003)

(Received September 16, 2011)

1077-35-1111 **Fang Zeng*** (fangzeng1985@gmail.com), Department of Mathematical Sciences, Delaware State University, Dover, DE 19901, **Jiguang Sun** (jsun@desu.edu), Department of Mathematical Sciences, Delaware State University, Dover, DE 19901, and **Fioralba Cakoni** (cakoni@math.udel.edu), Department of Mathematical Sciences, University of Delaware, Newark, DE 19716. *An inverse electromagnetic scattering problem for cavity.*

We consider the inverse electromagnetic scattering problem of determining the shape of a perfectly conducting cavity from measurement of scattered electric field due to electric dipole sources on a surface inside the cavity. We prove a reciprocity relation for the scattered electric field and a uniqueness theorem for the inverse problem. Then the near field linear sampling method is employed to reconstruct the shape of the cavity. Preliminary numerical examples are provided to show the viability of the method. (Received September 16, 2011)

1077-35-1151 **Justin C Tzou*** (jtzou@northwestern.edu), Northwestern University, 2145 Sheridan Road, Evanston, IL 60208, **Yana Nec**, Department of Mathematics, University of British Columbia, 1984 Mathematics Road, Vancouver, B.C. V6T 1Z2, Canada, and **Michael J Ward**, Department of Mathematics, University of British Columbia, 1984 Mathematics Road, Vancouver, B.C. V6T 1Z2, Canada. *Slow Drift and Fast Asynchronous Oscillatory Instabilities of Spike Patterns in a One-Dimensional Singularly Perturbed Brusselator Model.*

Much effort has been devoted to determining whether or not equilibrium and quasi-equilibrium spike patterns of a singularly perturbed reaction diffusion system can undergo oscillatory instabilities in which spike amplitudes oscillate out of phase (asynchronously). Studies of activator-inhibitor models, such as the Gray-Scott (GS), with asymptotically small activator diffusivity on finite (Ward et al.) and infinite (Doelman et al.) domains have either predicted dominant synchronous instabilities as a control parameter is increased, or in the case of the GS model, dominant asynchronous instabilities but which are then numerically observed to be unstable in the weakly nonlinear regime. For the Brusselator on finite domain, we show that for a certain range of inhibitor diffusivity, the dominant oscillatory instability is asynchronous. In contrast to the GS model, we present numerical validation of asynchronous amplitude oscillations for both equilibrium and quasi-equilibrium solutions, the latter of which is characterized by dynamically triggered instabilities due to spike locations. We propose explanations for this previously unobserved behavior. We also offer an alternative analysis of small eigenvalues that is significantly simpler than but equivalent to previous analyses. (Received September 16, 2011)

1077-35-1160 **Jacek Szmigielski*** (szmigiel@math.usask.ca), Department of Mathematics and Statistics, University of Saskatchewan, 106 Wiggins Road, Saskatoon, SK S7N 5E6, Canada. *Multipeakons in the Degasperis-Procesi Equation I.* Preliminary report.

Peakons are singular solutions to nonlinear wave equations whose dynamics can be studied using ordinary differential equations (ODEs). When the underlying nonlinear partial differential equations (PDEs) are integrable the study of peakons can be greatly enhanced by the use of isospectral deformations techniques. Degasperis-Procesi equation (DP) is an integrable PDE exhibiting wave-breaking which, in the peakon sector, can be interpreted as a mechanical collision of particles (multipeakons) described by a system of ordinary differential equations. The multipeakon solution exhibits an intricate dynamics which is nontrivially correlated with the spectral properties of an accompanying boundary value problem. This talk is the first of two talks on the topic of DP multipeakons, the second talk to be given by Lingjun Zhou (Tongji University, Shanghai, China). In the first talk I will describe the forward and inverse problems that accompany multipeakon solutions. I will discuss a few more intricate aspects of the problem such as the correlation between the existence of the asymptotic (in time) dynamics and the underlying reality of the spectrum of the boundary value problem. This is joint work with Lingjun Zhou. (Received September 17, 2011)

1077-35-1177 **Allen M. Tesdall*** (allen.tesdall@csi.cuny.edu), Department of Mathematics, College of Staten Island, City University of New York, Staten Island, NY 10314, and **John K. Hunter** (jkhunter@ucdavis.edu), Department of Mathematics, University of California, Davis, Davis, CA 95616. *Self-similar solutions for the diffraction of weak shocks.*

We formulate a problem for the unsteady transonic small disturbance equations that describes the diffraction of a weak shock near a point where its strength approaches zero and the shock turns into an expansion wave.

Physically, this problem corresponds to the reflection of a weak shock wave by a semi-infinite screen at normal incidence. We formulate the equations in self-similar variables, and obtain numerical solutions using high resolution finite difference schemes. Our solutions appear to show that the shock dies out at the sonic line, a phenomenon which has not been previously observed. (Received September 17, 2011)

1077-35-1187 **Peter D. Miller*** (millerpd@umich.edu), Department of Mathematics, East Hall, 530 Church St., Ann Arbor, MI 48109. *On the Modified Nonlinear Schrödinger Equation in the Semiclassical Limit.*

The modified nonlinear Schrödinger (MNLS) equation is a completely integrable system that appears to be a perturbation of the focusing nonlinear Schrödinger (NLS) equation. However, the perturbation is singular and it turns out that one of its effects is that for certain initial data the problem behaves more like a perturbed defocusing NLS equation than a perturbed focusing NLS equation. This effect is particularly dramatic in the semiclassical limit, in which it can be seen that the modulational instability of the unperturbed problem completely disappears in the perturbed problem for certain initial conditions. This is joint work with Jeffery DiFranco. (Received September 17, 2011)

1077-35-1203 **Alexander Pankov*** (alexander.pankov@morgan.edu), Mathematics Department, Morgan State University, 1700 E Cold Spring Lane, Baltimore, MD 21251. *G-convergence approach to homogenization of nonlinear difference operators.*

We introduce the notion of G-convergence for certain natural classes of multi-dimensional difference operators and discuss basic results concerning it. As an application we consider homogenization problem for such operators. Also we point out some open problems. (Received September 17, 2011)

1077-35-1222 **Walter Craig*** (craig@math.mcmaster.ca), Department of Mathematics and Statistics, McMaster University, Hamilton, Ontario L8S 4K1, 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 $S'(T) \subseteq S(T)$ 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 one 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 18, 2011)

1077-35-1223 **Walter Craig*** (craig@math.mcmaster.ca), Department of Mathematics and Statistics, McMaster University, Hamilton, Ontario L8S 4K1, Canada. *Birkhoff normal forms and scattering for the NLS on R^d.* Preliminary report.

Hamiltonian systems are subjected to normal forms transformations in order to remove nonresonant terms from the equations of motion. For Hamiltonian PDE posed on the torus T^d this has proved useful for KAM theory, and for the purpose of understanding the long time behavior of solutions. However when considered on all of R^d there is the possibility that all of the resonant terms can be removed as well. I will discuss a circle of ideas to this effect. This represents work in progress with Y. Wang and A. Selvitella. (Received September 18, 2011)

1077-35-1240 **Plamen Stefanov*** (stefanov@math.purdue.edu). *Thermoacoustic and Photoacoustic Tomography with a variable continuous or discontinuous sound speed.*

We will review recent theoretical and numerical result on Thermoacoustic and Photoacoustic Tomography obtained in collaboration with Jianliang Qian, Gunther Uhlmann and Hongkai Zhao. We will present necessary and sufficient conditions for uniqueness, and such conditions for stability for full or partial boundary measurements and a smooth speed. For observation on the whole boundary, we present an explicit inversion formula of Neumann series type. We will discuss similar results for a piecewise smooth speed modeling brain imaging. We will illustrate the theoretical results with many numerical reconstructions. (Received September 18, 2011)

1077-35-1279 **Gang Wang*** (gwang@condor.depaul.edu), Mathematical Sciences Department, DePaul University, Chicago, IL 60614, **Jerry L Bona** (bona@math.uic.edu), Department of Mathematics, Statistics and Com, University of Illinois at Chicago, Chicago, IL , and **Jonathan Cohen** (jcohen@math.depaul.edu), Mathematical Sciences Department, DePaul University, Chicago, IL 60614. *Global Well Posedness For a System of KDV-Type Equations with Quadratic Nonlinearities.* Preliminary report.

Consider coupled KdV-type systems

$$u_t + u_{xxx} + P_x(u,v) = 0$$
$$v_t + v_{xxx} + Q_x(u,v) = 0$$

where $u = u(x,t), v = v(x,t)$ and $x, t \in R$. Here, subscripts denote partial differentiation and P and Q are quadratic polynomials in the variables u and v. For the pure initial-value problem in which $u(x,t)$ and $v(x,t)$ are both specified at $t = 0$ viz

$$u(x,0) = u_0(x) \text{ and } v(x,0) = v_0(x)$$

for $x \in R$, we show under suitable conditions on P and Q, global well posedness of this problem is established for initial data in the L^2-based Sobolev spaces $H^s(R) \times H^s(R)$ for any $s > -\frac{3}{4}$. (Received September 18, 2011)

1077-35-1283 **Marcello Lucia*** (marcello.lucia@csi.cuny.edu), Mathematics Department, 2800 Victory Blvd, New York, NY 10314, and **Dirk Horstmann**. *Steady-states for a chemotaxis system.*

We consider a model that has been proposed by Keller and Segel to describe the aggregation of a population of cells. We show that below a critical mass, the solution converges to a unique steady-state. This is a joint work with D. Horstmann. (Received September 18, 2011)

1077-35-1303 **Lingjun Zhou*** (zhoulj@tongji.edu.cn), 1239 Siping Road, Department of Mathematics, Tongji University, Shanghai, 200092, Peoples Rep of China. *Multipeakons in the Degasperis-Procesi Equation II.*

Degasperis-Procesi equation (DP) is an integrable PDE admitting singular solutions consisting of sharp peaks, which are called peakons. The dynamics of the peakons can be studied using ODEs. If the solution admits both peakons and antipeakons, the solution will usually blow up as peakons collide with anti-peakons. The type of the sigularities can be understood by the analytic property of the ODE solution. In this talk, I will describe the behaviour at the collisions. It is shown that peakons and antipeakons can only collide in pairs and there are no multiple collisions. Specially, simultaneous collsion can happen for some initial condition. This is joint work with Jacek Szmigielski. (Received September 19, 2011)

1077-35-1327 **Jingbo Dou**, Department of Mathematics, University of Oklahoma, Norman, OK 73019, and **Meijun Zhu*** (mzhu@ou.edu), Department of Mathematics, University of Oklahoma, Norman, OK 73019. *On one dimensional nonlinear equations with negative exponents.*

In this talk I will present various existence results for nonlinear differential equations related to L_p Minkowski problem in the plane as well as to Micro-Electromechanical System (MEMS) model. In particular, the case of $p < -2$ for L_p Minkowski problem with sign-changed data is addressed. Some new inequalities on periodic functions are also obtained. This is a joint work with Jingbo Dou. (Received September 19, 2011)

1077-35-1442 **Magdy G, Asaad*** (mgamil@mail.usf.edu), 13373 Arbor pointe circle, apt 102, Tampa, FL 33617. *The Grammian and Pfaffian solutions to the (3+1)-dimensional non-linear partial differntial equations.*

The Pfaffian technique is used to handle the (3+1)-dimensional *KP*, *BKP*, *Jimbo-Miwa* and *Ma-Fan* equations. New exact solutions in the Pfaffian and Grammian forms are derived by means of Pfaffian derivative formulas and identities. A group of sufficient conditions consisting of linear partial differential equations with variable-coefficients is presented. Bilinear Bäcklund transforms are furnished for the equations. As an application of the BTs, new Pfaffian solutions, traveling wave solutions and rational solutions are explicitly computed. Examples of Pfaffian solutions are made and a few particular solutions are plotted.
(Received September 19, 2011)

1077-35-1458 **Yuji Kodama*** (kodama@math.ohio-state.edu). *Real Grassmannian and KP solitons.*

I will talk about certain structures of real Grassmann variety in connection with KP solitons, which include the Deodhar type decomposition and the integral cohomology of the Grassmannian. (Received September 19, 2011)

1077-35-1498 **Rachad Zaki*** (rachad.zaki@kustar.ac.ae). *Homogenization in periodically perforated domains.*

The mathematical theory of Homogenization describes the asymptotic behavior of composite materials with heterogeneities of small size compared to the global dimension of the domain. In order to describe such materials, several scales are needed; one macroscopic scale for the global behavior, and at least one microscopic scale for the heterogeneities. Several methods are currently being used for that purpose, mainly the multiple scale method, the method of oscillating test functions of Tartar known by some as the energy method, and the two-scale convergence method. We will focus on a more recent method known as the periodic unfolding method. After introducing the standard techniques of Homogenization, we will present the main results of the periodic unfolding method in the case of domains that are periodically perforated, and we will look at some applications with different types of conditions (Dirichlet, Neumann, Robin) on the boundary of the holes. (Received September 20, 2011)

1077-35-1501 **Sergei Avdonin*** (s.avdonin@alaska.edu), Department of Mathematics, UAF, Fairbanks, AK 99775-6660. *Boundary Control Approach to Inverse Problems on Graphs.*

The Boundary Control (BC) method is based on the deep connections between control theory for PDEs and inverse problems of mathematical physics and offers a powerful alternative to previous identification techniques based on spectral or scattering methods. It allows to give a unified exposition of the classical Gelfand–Levitan and Krein theories, and the recently proposed Simon and Remling approaches.

In this talk we describe applications of the BC method to inverse problems on graphs. Differential equations on graphs are used to describe many physical processes such as mechanical vibrations of multi-linked flexible structures usually composed of flexible beams or strings, propagation of electro-magnetic waves in networks of optical fibers, heat flow in a wire mesh, and also electron flow in quantum mechanical circuits.

We proposed a new version of the BC method which combines the spectral and dynamical approaches to inverse problems for PDEs on graphs and developed a constructive procedure for the recovery graph's parameters. This procedures is recursive – it allows recalculating the inverse data from the original graph to smaller graphs. Because of its recursive nature, this procedure may serve as a base for developing effective numerical algorithms. (Received September 20, 2011)

1077-35-1529 **Pierre M Germain***, pgermain@cims.nyu.edu. *"Global solutions for the Euler-Maxwell equation".*

I will present a result giving global smooth solutions of the Euler-Maxwell equations for data sufficiently close to the equilibrium state of zero velocity, and constant density. The proof relies on a combination of the energy method, and the space-time resonance method. This is joint work with Nader Masmoudi. (Received September 20, 2011)

1077-35-1547 **Leonid Berlyand*** (berlyand@math.psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802, and **Houman Owhadi**. *Flux norm approach to finite-dimensional homogenization approximation with non-separated scales and high contrast.*

The homogenization of PDEs with periodic or random ergodic coefficients and well-separated scales is well understood. In a joint work with H. Owhadi (Caltech) we consider the most general case of arbitrary L^∞ coefficients, which may contain infinitely many scales that are not necessarily well-separated. Specifically, we study scalar and vectorial divergence-form elliptic PDEs with such coefficients. We establish two finite-dimensional homogenization approximations that generalize the *correctors* in classical homogenization. We introduce a flux norm and establish the error estimate in this norm with an explicit and *optimal* error constant *independent of the contrast* and regularity of the coefficients. A proper generalization of the notion of a cell problem is the key issue in our consideration. (Received September 20, 2011)

1077-35-1589 **Ian T Tice*** (ian.t.tice@gmail.com), Universite Paris-Est Creteil, LAMA, 61 Avenue du General de Gaulle, 94010 Creteil Cedex, France. *Global well-posedness and decay for the viscous surface wave problem without surface tension.*

We study the incompressible, gravity-driven Navier-Stokes equations in three dimensional domains with free upper boundaries and fixed lower boundaries, in both the horizontally periodic and non-periodic settings. The effect of surface tension is not included. We employ a novel two-tier nonlinear energy method that couples the boundedness of certain high-regularity norms to the algebraic decay of lower-regularity norms. The algebraic decay allows us to balance the growth of the highest order derivatives of the free surface function, which then allows us to derive a priori estimates for solutions. We then prove local well-posedness in our energy space, which yields global well-posedness and decay. The novel LWP theory is established through the study of the linear Stokes problem in moving domains. This is joint work with Yan Guo. (Received September 20, 2011)

1077-35-1630 **Lorena Bociu** (lvbociu@ncsu.edu), NC , and **Daniel Toundykov*** (dtoundykov2@unl.edu), NE. *Attractor for a non-dissipative von Karman plate with damping in free boundary conditions.*

I will discuss a plate equation suggested by a certain flow-structure interaction model: a von Karman plate with a first-order non-dissipative term in the interior, and subject to boundary damping acting through free boundary conditions. The resulting dynamical system does not possess a strict Lyapunov function on the "natural" energy space; as a result the boundedness of the energy, let alone existence of an absorbing ball, is a priori unknown. It will be shown that despite the lack of monotonicity and absence of interior dissipation this nonlinear flow may converge to a global compact attractor. (Received September 20, 2011)

1077-35-1632 **Gigliola Staffilani*** (gigliola@math.mit.edu), Room 2-246, 77 Massachusetts Avenue, Cambridge, MA 02139, and **Kay Kirkpatrick** and **Enno Lenzmann**. *On the continuum limit for discrete NLS with long-range lattice interactions.*

We consider a general class of discrete nonlinear Schrödinger equations (DNLS) on the lattice $h\mathbb{Z}$ with mesh size $h > 0$. In the continuum limit when $h \to 0$, we prove that the limiting dynamics are given by a nonlinear Schrödinger equation (NLS) on $\mathbb{R}$ with the fractional Laplacian $(-\Delta)^\alpha$ as dispersive symbol. In particular, we obtain that fractional powers $\frac{1}{2} < \alpha < 1$ arise from long-range lattice interactions when passing to the continuum limit, whereas NLS with the non-fractional Laplacian $-\Delta$ describes the dispersion in the continuum limit for short-range lattice interactions (e. g., nearest-neighbor interactions).

Our results rigorously justify certain NLS model equations with fractional Laplacians proposed in the physics literature. Moreover, the arguments given in our paper can be also applied to discuss the continuum limit for other lattice systems with long-range interactions. (Received September 20, 2011)

1077-35-1644 **Alfred S. Carasso***, 100 Bureau Drive, Gaithersburg, MD 20899. *Non Standard Parabolic Equations and Image Reconstruction.* Preliminary report.

Fractional and logarithmic diffusion equations can be constructed by appropriate Bochner randomization of the time variable in Brownian motion and the related heat conduction equuation. This talk will discuss recent NIST work using such equations in image denoising and deblurring. Significant applications to state of the art imaging, both at the nanoscale and at the cosmological scale, will be demonstrated. (Received September 20, 2011)

1077-35-1646 **Danut Arama*** (darama@luc.edu). *On a Variational Approach for Water Waves.*

We study locally the formation of an angle at the crest of a wave of maximum height. Our approach is variational and uses free boundary techniques developed by Alt, Caffarelli, and Friedman. (Received September 20, 2011)

1077-35-1651 **Maarten de Hoop*** (mdehoop@purdue.edu), **Lingyun Qiu** and **Otmar Scherzer**. *Local Analysis of Inverse Problems: Hölder Stability and Iterative Reconstruction.*

We consider a class of inverse problems defined by a nonlinear map from parameter or model functions to the data. We assume that solutions exist. The space of model functions is a Banach space which is smooth and uniformly convex; however, the data space can be an arbitrary Banach space. We study sequences of parameter functions generated by a nonlinear Landweber iteration and conditions under which these strongly converge, locally, to the solutions within an appropriate distance. We express the conditions for convergence in terms of Hölder stability of the inverse maps, which ties naturally to the analysis of inverse problems. We discuss the application to the Helmholtz equation and the Dirichlet-to-Neumann map as the data. (Received September 20, 2011)

1077-35-1665 **Barbara Lee Keyfitz*** (bkeyfitz@math.ohio-state.edu), Mathematics Department, The Ohio State University, 231 West 18th Avenue, Columbus, OH 43210. *Conservation Laws - Not Exactly a la Noether.*

Emmy Noether's famous theorem connects "conservation laws" with symmetries, and so perhaps the first thing that a speaker should do in a talk bearing her name is to explain that the relation between that theorem and the research area of hyperbolic conservation laws is not very close. That done, I will describe the main features of conservation law theory, beginning with the role of weak solutions (which break symmetry), and elements of the theory in a single space variable, which is now in a reasonably satisfactory state, and concluding with an outline of the current state of the theory for multidimensional conservation laws. Here there are a few results, most of them very recent. (Received September 20, 2011)

1077-35-1701 **Justin Holmer*** (holmer@math.brown.edu) and **Quanhui Lin**. *Phase-driven interaction of widely separated nonlinear Schrödinger solitons.*

We show that, for the 1d cubic NLS equation, widely separated equal amplitude in-phase solitons attract and opposite-phase solitons repel. Our result gives an exact description of the evolution of the two solitons valid until the solitons have moved a distance comparable to the logarithm of the initial separation. Our method does not use the inverse scattering theory and should be applicable to nonintegrable equations with local nonlinearities that support solitons with exponentially decaying tails. The result is presented as a special case of a general framework which also addresses, for example, the dynamics of single solitons subject to external forces. (Received September 20, 2011)

1077-35-1713 **Zhaosheng Feng*** (zsfeng@utpa.edu), Department of Mathematics, 1201 W. University Drive, University of Texas-Pan American, Edinburg, TX 78539. *Lie symmetries to the parabolic system.*

In this talk, we are concerned with a class of parabolic system including the Burgers-Huxley equation and the generalized Fisher equation by means of the Lie symmetry method. Through analyzing the associated determining system nontrivial infinitesimal generators, properties of proper solutions are established under the certain parametric conditions. (Received September 20, 2011)

1077-35-1725 **Richard J. Marchand*** (richard.marchand@sru.edu), Slippery Rock, PA, **Timothy J. McDevitt**, Elizabethtown, PA , and **Roberto Triggiani**, Charlottesville, VA. *Structural decomposition, spectral analysis, and exponential stability for a third order PDE arising in high-intensity ultrasound.*

We consider a third order (in time) PDE that arises in high-intensity ultrasound. Structural and spectral properties will be established for the model along with precise and explicit energy exponential decay in terms of model parameters. Numerical computations of the associated spectrum confirm the theoretical results. (Received September 20, 2011)

1077-35-1729 **John Gemmer*** (jgemmer@math.arizona.edu) and **Shankar Venkataramani**. *Periodic Rippling in Hyperbolic Non-Euclidean Plates.*

Non-Euclidean plates are thin elastic sheets in which the preferred intrinsic geometry of the mid-surface corresponds to a surface with nonzero Gaussian curvature. These sheets model the complex geometries generated by locally growing or swelling soft tissue.

We present a study of free non-Euclidean discs with constant negative Gaussian curvature curvature. The equilibrium configuration taken by these sheets are solutions to a modified version of the Föppl Von-Kàrmàn (FvK) equations in which strain is measured as the deviation of the surface from being a local isometric immersion of the hyperbolic plane. We show that solutions to the FvK equations with a periodic profile can be constructed. These solutions qualitatively resemble experimental results and and correspond to local minimum of the free elastic energy. (Received September 20, 2011)

1077-35-1747 **Paolo Piovano*** (ppiovano@andrew.cmu.edu). *Evolution of elastic thin films with curvature regularization via minimizing movements.*

We consider the evolution equation with curvature regularization that models the motion of a two-dimensional thin film by evaporation-condensation on a rigid substrate. The mismatch between the crystalline lattices of the two materials forces the film to be strained. We prove short time existence, uniqueness and regularity of the solution using De Giorgi's minimizing movements to exploit the L^2-gradient flow structure of the fourth order parabolic equation. This seems to be the first analytical result for the evaporation-condensation case in the presence of elasticity. (Received September 20, 2011)

1077-35-1765 **Jiahong Wu*** (jiahong@math.okstate.edu), Department of Mathematics, 401 Mathematical Sciences, Oklahoma State University, Stillwater, OK 74078. *The surface quasi-geostrophic and related equations.*

Fundamental issues such as the global regularity problem concerning the surface quasi-geostrophic (SQG) and related equations have attracted a lot of attention recently. Signicant progress has been made in the last few years. This talk summarizes some current results on the critical and supercritical SQG equations and presents very recent work on the generalized SQG equations. These generalized equations are active scalar equations with the velocity fields determined by the scalars through general Fourier multiplier operators. The SQG equation is a special case of these general models and it corresponds to the Riesz transform. We obtain global regularity for equations with velocity fields logarithmically singular than the 2D Euler and local regularity for equations with velocity fields more singular than those corresponding to the Riesz transform. The results are from recent papers in collaboration with D. Chae and P. Constantin, and with D. Chae, P. Constantin, D. Cordoba and F. Gancedo. (Received September 20, 2011)

1077-35-1771 **Rushun Tian*** (rushun.tian@aggiemail.usu.edu), Department of Mathematics and Statistics, Utah State University, Logan, UT 84322, and **Zhi-Qiang Wang**. *Multiple Solitary Wave Solutions of Nonlinear Schrödinger Systems.*

We study the solitary wave solutions of the following system of nonlinear Schrödinger equations,

$$\begin{cases} -\Delta U_j + U_j = \mu U_j^3 + \beta U_j \sum_{k\neq j} U_k^2, & \text{in } \Omega, \\ U_j > 0 \text{ in } \Omega, U_j = 0 \ \text{ on } \partial\Omega, & j = 1, \cdots, N. \end{cases}$$

Here $\mu > 0$ and $\beta < 0$ are constants; Ω is a smooth and bounded (or unbounded if Ω is radially symmetric) domain in $\mathbb{R}^n$, $n \leq 3$.

Using a Lusternik-Schnirelmann type theory and a Z_N-index, we prove the existence of multiple Z_N-orbits of solutions on different energy levels. The parameter β plays an important role in this process, and its value is used to estimate the number of solution orbits. (Received September 20, 2011)

1077-35-1784 **Aaron Hoffman***, Olin College, 1000 Olin Way, Needham, MA 02492. *Stability analysis via Backlund transform in completely integrable PDE.*

The many symmetries of completely integrable PDE give rise to classical techniques such as the Backlund transform for generating a new solution from a known solution. The Backlund transform is particularly useful in the study of soliton and multi-soliton solutions as the zero solution is related to a soliton via Backlund transform and in general the (n-1)-soliton is related to the n-soliton via Backlund transform. In recent years, the Backlund transform has been used to obtain stability results for solitons and multi-solitons across a wide range of completely integrable systems. We discuss recent stability results for the Toda lattice and the sine-Gordon equation. (Received September 20, 2011)

1077-35-1808 **Sergei Avdonin*** (s.avdonin@alaska.edu), Department of Mathematics, UAF, Fairbanks, AK 99775-6660, and **Jonathan Bell** (jbell@umbc.edu), Dept. of Mathematics, UMBC, Baltimore, MD 21250. *Determining Physical Parameters for a Neuronal Cable Model Defined on a Tree Graph.*

Dendrites of nerve cells have membranes with spatially distributed densities of ionic channels and hence non-uniform conductances. A neuron's dendritic tree is described by a parabolic type equation with spatially distributed conductance in its coefficients defined on each edge of a tree graph domain. We suppose that the Kirchhoff-Neumann conditions are satisfied at all internal nodes expressed a current conservation condition. Our goal is to recover the unknown conductance on the graph and its topology from boundary observations of the current and voltage.

Only recently has investigations of inverse problems on graphs been under investigation, and this largely has not involved the peculiarities imposed by biological constraints. Also, there is almost no numerical implementation of theoretical results on inverse problems on graphs in the literature. Our research is concerned with both theory and algorithm development.

Our approach is based on the boundary control method. We prove the uniqueness theorem and propose a constructive procedure for recovering the parameters of the tree. Our procedure is recursive; it allows recalculating efficiently the inverse data from the original tree to smaller trees, 'pruning' leaves step by step down to the rooted edge. (Received September 21, 2011)

1077-35-1835 **Slim Ibrahim*** (ibrahims@uvic.ca), Department of Mathematics and Statistics, Victoria, BC , Canada, and **Nader Masmoudi**, Courant Institute, NY. *On the wellposedness of the Navier-Stokes-Maxwell system.*

We investigate the local wellposedness (and global for small data) of a full system of Magneto-Hydro-Dynamic equations. Our results cover both the space dimensions two and three and constitute a refinement of earlier results. (Received September 21, 2011)

1077-35-1836 **Katharine Ott*** (katharine.ott@uky.edu), 715 Patterson Office Tower, Lexington, KY 40506, and **Irina Mitrea**. *The regularity problem for the Lamé system on curvilinear polygons in two dimensions.*

In this talk I will discuss sharp well-posedness results for the regularity problem for the Lamé system of elastostatics in the class of curvilinear polygons in two dimensions. The key technical ingredient is obtaining invertibility properties for the boundary version of the single layer potential operator S associated with the Lamé system acting from $L^p(\partial\Omega)$ onto $L^p_1(\partial\Omega)$, $1 < p < \infty$, whenever Ω is an infinite sector in two dimensions of aperture $\theta \in (0, 2\pi)$. This is joint work with I. Mitrea. (Received September 21, 2011)

1077-35-1840 **Yuliya Gorb*** (gorb@math.uh.edu), Department of Mathematics, University of Houston, Houston, TX 77204-3008. *Multiscale Modeling and Simulation of Fluid Flows in Deformable Porous Media.*

The main focus of this study is on fluid flows in deformable elastic media and associated multiscale problems. Many upscaling methods are developed for flows in rigid porous media or deformable elastic media assuming infinitely small fluid-solid interface displacements relative to the pore size. Much research is needed for the most general and least studied problem of flow in deformable porous media when the fluid-solid interface deforms considerably at the pore level. In this talk, we introduce a general framework for numerical upscaling of the deformable porous media in the context of a multiscale finite element method. This method allows for large interface displacements and significant changes in pore geometry and volume. (Received September 21, 2011)

1077-35-1850 **Vincent Jugnon*** (vjugnon@math.mit.edu), **Habib Ammari**, **Josselin Garnier** and **Elie Bretin**. *Coherent Interferometry Algorithms for Photoacoustic Imaging.*

We develop new Coherent Interferometry (CINT) algo- rithms to correct the effect of an unknown cluttered sound speed (random fluctuations around a known constant) on photoacoustic images. By back-projecting the correla- tions between the pre-processed pressure measurements, we show that we are able to provide statistically stable photo-acoustic images. The pre-processing is exactly in the same way as when we use the circular or the line Radon inversion to obtain photo- acoustic images. Moreover, we provide a detailed stability and resolution analysis of the new CINT-Radon algorithms. We also present numerical results to illustrate their performance and to compare them with Kirchhoff-Radon migration functionals. (Received September 21, 2011)

1077-35-1885 **Michael Hinz*** (Michael.Hinz.1@uni-jena.de), Department of Mathematics, 196 Auditorium Rd., University of Connecticut, U-3009, Storrs, CT 06269, and **Alexander Teplyaev**. *Vector equations on fractals.*

Starting from recent definitions of 1-forms via tensor products and energy norms, we propose some analogs of classical notions from vector analysis and utilize them to investigate some vector equations on fractals. (Received September 21, 2011)

1077-35-1888 **Mihail Sharov***, msharov@masonlive.gmu.edu, Woodbridge, VA 22191. *Tear-film dehydration of a soft contact lens.* Preliminary report.

The main focus of this research is to explore the factors that cause evaporative dehydration of tear film when a soft contact lens is present. Evaporation of the tear film is affected by various environmental conditions, such as relative humidity and wind speed. It also depends significantly on the time period of blink cycles, since the eyelid provides a new tear film to the surface of the eye during blinks. Every blink cycle has different duration and some blinks are not complete. I plan to improve a previously created model in order to incorporate this blink cycle variability and thus mimic more realistic blinking conditions. (Received September 21, 2011)

1077-35-1893 **Leonardo Kosloff*** (lkosloff@fau.edu) and **Tomas Schonbek**. *On the Laplacian, and fractional Laplacian, in an Exterior Domain.*

We see that the generalized Fourier transform due to A.G. Ramm for the case of $n = 3$ space dimensions remains valid, with some modifications, for all space dimensions $n \geq 2$. We use the resulting spectral representation of the exterior Laplacian to study exterior problems. In particular the *Fourier splitting method* developed by M.E. Schonbek extends easily to the study of this type of problems, as we illustrate for the dissipative 2 dimensional quasi-geostrophic equation in the critical case. (Received September 21, 2011)

1077-35-1895 **Amir Moradifam*** (amir@math.toronto.edu), 40 St.George st., Toronto, M5S2E4, and **Adrian Nachman** and **Alexandru Tamasan**, .. *Conductivity imaging from one interior measurement in the presence of perfectly conducting and insulating inclusions.*

We consider the problem of recovering an isotropic conductivity outside some perfectly conducting or insulating inclusions from the interior measurement of the magnitude of one current density field $|J|$. We prove that the conductivity outside the inclusions, and the shape and position of the perfectly conducting and insulating inclusions are uniquely determined (except in an exceptional case) by the magnitude of the current generated by imposing a given boundary voltage. We have found an extension of the notion of admissibility to the case of possible presence of perfectly conducting and insulating inclusions. This makes it possible to extend the results on uniqueness of the minimizers of the least gradient problem $F(u) = \int_\Omega a|\nabla u|$ with $u|_{\partial\Omega} = f$ to cases where u has flat regions (is constant on open sets). This is a joint work with Adrian Nachman and Alexandru Tamasam. (Received September 21, 2011)

1077-35-1902 **James Cameron*** (jcameroa@masonlive.gmu.edu), 6105 Backlick Road, Springfield, VA 22150, and **Charles Daly** and **Padmanabhan Seshaiyer**. *Mathematical Modeling and Analysis of a Nonlinear Large Deformation Plate Model with Applications to Micro Air Vehicles.* Preliminary report.

In this work we consider the development of a computational methodology to study stability and nonlinear dynamics of large deformation plate models. The main application is the computational modeling of flexible wing designs for Micro Air Vehicles. Using a geometrically nonlinear Green strain-displacement formulation, a materially linear constitutive stress-strain formulation, and a Hamiltonian energy approach, we develop the governing differential equations for the axial and transverse displacements of the plate. We also develop an appropriate energy norm for a class of boundary conditions and prove a stability estimate. The model developed will be numerically validated for benchmark applications. (Received September 21, 2011)

1077-35-1904 **Chongsheng Cao***, Dept. of Math., Florida International University, Miami, FL 33199, and **Jiahong Wu**, Dept. of Math., Oklahoma State University, OK. *global wellposedness of 2D anisotropic Boussinesq equations.*

Boussinesq equations are mathematical models of buoyancy driven flows. In this talk we first introduce the 2D Boussinesq equations, then, we establish the global in time existence of classical solutions to the 2D anisotropic Boussinesq equations with vertical dissipation. (Received September 21, 2011)

1077-35-1927 **Necibe Tuncer***, necibe-tuncer@utulsa.edu. *Pattern Formation For Reaction Diffusion Systems On Arbitrary Surfaces.*

We develop and analyze two numerical methods to approximate solutions of reaction diffusion systems defined on arbitrary surfaces. In particular, we are interested in reaction diffusion systems that model pattern formation on arbitrary surfaces. Such systems have numerous applications; examples include patterns on seashells and tropical fish, and butterfly wing pigmentation. One of the two methods we propose is based on radially projected finite elements, and the second method is based on projected surface finite elements. The power of both of these numerical methods are that they are easy to implement, and all computations are done in logically rectangular coordinates. (Received September 21, 2011)

1077-35-1932 **Mimi Dai*** (mdai@slugmail.ucsc.edu), 828 Koshland Way, Santa Cruz, CA 95064, and **Jie Qing** and **Maria Schonbek**. *Asymptotic Behavior of Solutions to the Liquid Crystals Systems in $\mathbb{R}^3$.*

On bounded domain, the asymptotic behavior of solutions to systems of nematic liquid crystals, with constant fluid density has been studied by several papers. In this paper we establish an asymptotic behavior result for nematic liquid crystals system with constant fluid density in the whole space $\mathbb{R}^3$ assuming that initial data is small. The main ingredient to derive decay is Fourier splitting method introduced by M. Schonbek. (Received September 21, 2011)

1077-35-1939 **Venky P Krishnan*** (vkrishnan@math.tifrbng.res.in). *Microlocal analysis of an ultrasound operator with circular source and receiver trajectories.*

In this talk, we consider a problem motivated by ultrasound reflection tomography. In our model, the ultrasound emitter and receiver move at a constant distance apart along a circle. We analyze the microlocal properties of the transform that arises from this model. As a consequence, we show the unique recovery of a function from this transform under an assumption of smallness of its support. This is joint work with Gaik Ambartsoumian of University of Texas at Arlington and Eric Todd Quinto of Tufts University. (Received September 21, 2011)

1077-35-1983 **Anahit Galstyan*** (agalstyan@utpa.edu), Department of Mathematics, University of Texas-Pan American, 1201 West University Drive, Edinburg, TX 78539. *Similarity solutions for some model equations appearing in the gas dynamics.*

In this talk we will discuss the issue of global existence of the solutions of the Cauchy problem for one-dimensional semilinear weakly hyperbolic equations, appearing in the boundary value problems of gas dynamics. We give some sufficient conditions for the existence of the global weak solutions. We wil present the necessary condition for the existence of the similarity solutions for the one-dimensional semilinear Gellerstedt-type equation. Our approach is based on the fundamental solution of the operator and the Lp-Lq estimates for the linear Gellerstedt equations. (Received September 21, 2011)

1077-35-1990 **Daniel T Onofrei*** (onofrei@math.uh.edu), **Giles Auchmuty** and **Yuliya Gorb**. *On a novel idea for the local characterization for solutions of multiscale elliptic problems.*

In this talk we will introduce a new approach for the understanding of various multiscale phenomena modeled by elliptic PDE's. We will show a strategy for the closed form local characterization of solutions for general deterministic but non-periodic multiscale elliptic problems and will discuss about potential applications of our results. (Received September 21, 2011)

1077-35-1991 **Robert L. Pego*** (rpego@cmu.edu), **Tetsu Mizumachi** and **José Raúl Quintero**. *Asymptotic stability of solitary waves in a water wave model with indefinite variational structure.* Preliminary report.

We study asymptotic stability properties for solitary waves in the Benney-Luke model equation for water waves. One feature that this model shares with the full water wave problem is that solitary wave profiles are critical points of an energy-momentum functional that is infinitely indefinite and not useful for estimates. (Received September 21, 2011)

1077-35-1996 **Linlin Su*** (lsu@wpi.edu), Department of Mathematical Sciences, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609, and **Roger Lui**. *Advance of Advantageous Genes in a Three-Allele Population Genetics Model.* Preliminary report.

Assume that certain gene resides at an autosomal locus and occurs in three forms: A_1, A_2 and A_3, called alleles. Let p_i be the frequency of allele A_i. Then, assuming that population density is spatially independent, and Hardy-Weinberg equilibrium holds, it can be shown that p_i's satisfy a reaction-diffusion system of two equations involving the frequencies of two of the alleles (noting that p_i's add up to 1). We investigate the propagation of advantageous genes by studying traveling wave solutions to the system. Our work is motivated by the work of Fisher (1937), the work of Kolmogoroff, Petrovsky and Piscounoff (1937), and the work of Aronson and Weinberger (1975, 1978) on the study of the two allele problem where a single reaction-diffusion equation is studied. (Received September 21, 2011)

1077-35-2011 **Marcel Filoche*** (marcel.filoche@polytechnique.edu), Physique de la Matière Condensée, Ecole Polytechnique, CNRS, 91128 Palaiseau, France, and **Svitlana Mayboroda** (svitlana@math.umn.edu), School of Mathematics, University of Minnesota, 127 Vincent Hall, 206 Church St. SE, Minneapolis, MN 55455. *The landscape of Anderson localization in a disordered medium.*

Wave localization occurs in all types of vibrating systems, in acoustics, mechanics, optics, or quantum physics. It arises either in systems of irregular geometry (weak localization) or in disordered systems (Anderson localization). We present here a general theory that explains how the system geometry and the wave operator interplay to give rise to a "landscape" whose valleys split the system into weakly coupled subregions. Very generally, the valley system of the localization landscape, that are the boundaries of the subregions, consists in a network of interconnected surfaces of codimension 1. It is shown that not only the subregions predict the spatial distribution of the vibrational eigenmodes, but also that the valley system allows one to understand the transition from localized to delocalized modes when the frequency increases.

This theory holds in any dimension, for any domain shape, and for all operators deriving from an energy form. In particular, Anderson localization is shown to be explained by this same mathematical frame. It can be understood as a special case of weak localization in a very rough landscape and a highly complex, possibly fractal, valley network. (Received September 21, 2011)

1077-35-2013 **Jerry L. Bona**, **Jonathan Cohen*** (jcohen@depaul.edu) and **Gang Wang**. *Global Well Posedness for a system of KdV-type Equations with Coupled Quadratic nonlinearities.*

In this talk, coupled systems

$$u_t + u_{xxx} + P(u,v)_x = 0,$$
$$v_t + v_{xxx} + Q(u,v)_x = 0,$$

of KdV-type are considered, where $u = u(x,t), v = v(x,t)$ and $x, t \in \mathbb{R}$. Here, subscripts connote partial differentiation and P and Q are quadratic polynomials in the variables u and v. Attention is given to the pure initial-value problem in which $u(x,t)$ and $v(x,t)$ are both specified at $t = 0$, *viz.*

$$u(x,0) = u_0(x) \text{ and } v(x,0) = v_0(x)$$

for $x \in R$. Under suitable conditions on P and Q, global well posedness of this problem is established for initial data in the L^2-based Sobolev spaces $H^s(\mathbb{R}) \times H^s(\mathbb{R})$ for any $s > -\frac{3}{4}$. (Received September 21, 2011)

1077-35-2039 **Qinghua Luo*** (qhluo@ou.edu), Department of Mathematics, University of Oklahoma, Norman, OK 73019. *Optimization Problem for Klein-Gordon Equation.*

We consider a damped Klein-Gordon equation with a variable diffusion coefficient. The goal is to derive necessary conditions for the optimal set of parameters minimizing the objective function J. First, we show that the solution map is continuous. Then the solution map is shown to be weakly Gâteaux differentiable on the admissible set P, implying the Gâteaux differentiability of the objective function. Finally we study the Fréchet differentiability of J and optimal parameters for these problems. Unlike the sine-Gordon equation, which has a bounded nonlinear term, Klein-Gordon equation requires stronger assumptions on the initial data. (Received September 21, 2011)

1077-35-2063 **Vitali G Vougalter*** (vitali@math.toronto.edu), University of Cape Town, Department of Math., and Applied Math., Private Bag, Rondebosch, 7701, South Africa. *On the existence of stationary solutions for some non-Fredholm integro-differential equations.*

We show the existence of stationary solutions for some reaction-diffusion type equations in the appropriate H^2 spaces using the fixed point technique when the elliptic problem contains second order differential operators with and without Fredholm property (Received September 21, 2011)

1077-35-2065 **Bernard R Lipat*** (bernardlipat@yahoo.com), 156 Carlton Ave., Apt. 2, Jersey City, NJ 07306, and **Rusty Laracuenti** (rlaracuenti@gmail.com). *Modeling the Effects of the Fukushima Daiichi Nuclear Meltdown on the Marine Environment.* Preliminary report.

With the increasing frequency of nuclear power as a source of energy, understanding the effects of radioactivity on the marine environment is a problem whose solution is vital for a comprehensive approach to nuclear safety. In particular, the recent meltdown of the Fukushima Daiici Nuclear Power Plant provides a case study out of which we develop a mathematical model using numerical approximations of the diffusion equation with advection and decay to study the spread of radionuclides and their effects on the populations of the Pacific Bluefin Tuna (Thunnus orientalis) and the Pacific Pink Salmon (Oncorhynchus gorbuscha). (Received September 21, 2011)

1077-35-2119 **Jerry L Bona*** (bona@math,uic.edu), Dept. Math. Statistics & Computer Science, University of Illinois at Chicago, 851 S. Morgan Street MC 249, Chicago, IL 60607. *Comparisons between Uni-directional and Bi-directional Models for Surface Water Waves.*

Bi-directional models for surface water waves go back to the work of Saint-Venet and Boussinesq in the 19th century. There is a further, formal reduction of such models to simpler equations that encompass waves moving only in one direction. Investigated here are some rigorous results underlying the usual formalism for passing from one to the other. Work of Alazman, Albert, Chen, Scialom and Wu will be featured. (Received September 21, 2011)

1077-35-2120 **Shantia Yarahmadian*** (syarahmadian@math.msstate.edu). *Existence and stability of steady states of the microtubule formation in three states.* Preliminary report.

Further generalization of the Dogterom-Leibler model for microtubule dynamics to the case where the microtubules can be found in three states of growth, pause, and decay, is provided. Rates of elongation as well as the lifetimes of the elongating shortening phases are a function of GTP-tubulin concentration. We have considered the effect of nucleation rate in the form of a damping term which leads to new steady-states. For this model, we study existence and stability of steady states satisfying the boundary conditions at $x = 0$. Our stability analysis uses numerical and analytical Evans function computations as a new mathematical tool in the study of microtubule dynamics. (Received September 21, 2011)

1077-35-2135 **Andrej Cherkaev*** (cherk@math.utah.edu), 155 S 1400 E, JWB 225, Salt Lake City, UT 84112. *Bounds and optimal structures of three-material composites: Beyond the translation bound.* Preliminary report.

We consider a composite assembled from three isotropic materials with fixed volume fractions. A lower bound for the effective conductivity is found using a generalization of the Translation method that accounts for inequalities on the range of fields in the materials in an optimal structure. We show that special finite-rank laminates realize the bound in all but one parameter domains. For isotropic structures, we also find new type of optimal structures, wheels assembly. (Received September 21, 2011)

1077-35-2144 **Joshua Mann***, Morehouse College, Physics Department, Atlanta, GA 30314, and **Ronald E. Mickens** (rohrs@math.gatech.edu), Clark Atlanta University, Physics Department, Atlanta, GA 30314. *New Results for the Leah Cosine Function.*

We report on extensions of our previously reported work [1] on the properties of the Leah-cosine function, Lcn. This function is the solution to the initial-value problem

$$\frac{d^2x}{dt^2} + x^{1/3} = 0, \quad x(0) = 1, \quad \frac{dx(0)}{dt} = 0.$$

The new results include expressions for the first twenty Taylor series coefficients, and both upper and lower bounds for the perimeters of the closed curves in the x-y phase-plane, where $y \equiv dx/dt$.

[1] J. Mann et al., Abstracts of papers presented to the American Mathematical Society, Vol. 32 (#1, Winter 2011), pp. 138. (Received September 21, 2011)

1077-35-2146 **Peter Elbau*** (peter.elbau@oeaw.ac.at), RICAM, Austrian Academy of Sciences, Altenbergerstrasse 69, A-4040 Linz, Austria. *Reconstruction Formulas for Photoacoustic Sectional Imaging.*

In standard photoacoustic imaging, an object is analysed by illuminating it uniformly with a laser pulse which is absorbed by the material. The hereby induced pressure wave in the object is then observed with some sensors placed outside of the object. From these measurements, the absorption density of the object shall be reconstructed.

The idea behind photoacoustic sectional imaging is not to measure the whole object at once, but instead to focus the laser beam such that it illuminates only one slice of the object and then to reconstruct the absorption density in this illumination plane. In this talk, I would like to derive reconstruction formulas for this sort of measurements for different arrangements of detectors (considering point, line, and planar detectors) outside of the object. (Received September 21, 2011)

1077-35-2187 **George Avalos*** (gavalos@math.unl.edu), Department of Mathematics, University Nebraska-Lincoln, Lincoln, NE 68588. *Rational decay rates for fluid-structure interactive dynamics.*

In this talk we shall derive certain delicate decay rates for a partial differential equation (PDE) system which comprises (parabolic) Stokes fluid flow and a (hyperbolic) elastic structural equation. The appearance of such coupled PDE models in the literature is well-established, inasmuch as they mathematically govern many physical phenomena; e.g., the immersion of an elastic structure within a fluid. The coupling between the distinct hyperbolic and parabolic dynamics occurs at the boundary interface between the media. In previous work, we have established semigroup wellposedness for such dynamics, in part through a nonstandard elimination of the associated pressure variable. For this PDE model, we provide a uniform rational decay estimate for solutions corresponding to smooth initial data; viz., for initial data in the domain of the semigroup generator. The attainment of this result depends upon the appropriate use of a recently derived operator semigroup result. (Received September 21, 2011)

1077-35-2206 **Katarzyna Saxton*** (saxton@loyno.edu), Dept. of Mathematical Sciences, Loyola University, New Orleans, LA 70118. *Singularity Formation in Nonstrictly Hyperbolic Equations.*

We consider a 2 x 2 system for which, at some point (b, 0), the initial data intersect curves on which two characteristics coincide. Given that the system is genuinely nonlinear, one such curve on which the speed of both characteristics is zero will become the line x=b. We exam singularity formation along this line and prove that the solution breaks down in finite with or without damping. It is shown that, unlike the case for strictly hyperbolic systems, dissipation is not strong enough to preserve smoothness of small solutions globally in time. We will give an example of two further branches of curves starting at (b,0), in addition to the line x=b, where characteristics speeds are equal. The consequences of this phenomenon will be discussed. (Received September 21, 2011)

1077-35-2216 **Leonard Gross*** (gross@math.cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853. *Yang-Mills heat equation with $H_{1/2}$ initial data in three dimensions.* Preliminary report.

It is known that the Yang-Mills heat equation over a bounded open set in $\mathbb{R}^3$ with smooth boundary has long time solutions for Dirichlet, Neumann or Marini boundary conditions when the initial connection form is in Sobolev class H_1.

In this talk it will be shown how to extend the initial data space to Sobolev class $H_{1/2}$. The resulting solution space is then an infinite dimensional complete Riemannian manifold of class at least C^2.

Continuous dependence of the solution on the initial data is established. Three spatial dimensions is the critical dimension for $H_{1/2}$ initial data. (Received September 21, 2011)

1077-35-2217 **Marina Chugunova** and **Mary C. Pugh*** (mpugh@math.toronto.edu), Department of Mathematics, University of Toronto, 40 St George St, room 6290, Toronto, ON M5S 2E4, Canada, and **Roman Taranets**. *A new result in blow-up for long-wave unstable thin film equations.*

This talk will provide an introduction to long-wave unstable thin film equations of the form

$$u_t = -(u^n u_{xxx})_x - B(u^m u_x)_x.$$

The exponents n and m determine whether or not finite-time blow-up of the solution might occur. In this talk, we present new results for the critical ($n = m + 2$) and supercritical cases ($m > n + 2$) on the line. (Received September 21, 2011)

1077-35-2223 **Min Chen*** (chen45@purdue.edu), Dept of Mathematics, Purdue University, West Lafayette, IN 47906. *From Euler equation to Boussinesq system to KP equation.*

This talk is to demonstrate that the famous Kadomtsev-Petviashvilli II-type equation for water waves which are weakly three-dimensional and propagating predominantly in one-direction can be derived formally from the three-dimensional Boussinesq system (see Bona, Chen and Saut (2002)). The relationship between the dispersion relations of Euler equations, Boussinesq systems and KP equations are also analyzed. (Received September 21, 2011)

1077-35-2232 **Dhanapati Adhikari*** (dadhikari@marywood.edu), Department of Mathematics, Marywood University, 2300 Adams Avenue, Scranton, PA 18509, and **Jiahong Wu**. *The 2D Boussinesq equations with partial viscous dissipation.*

In this talk we consider the 2D Boussinesq equation with vertical diffusivity and viscosity only in the second equation of the velocity field, namely with $\kappa\theta_{yy}$ and $\nu\Delta v$. We prove that any solution starting with sufficiently smooth initial data remains regular on $[0, T]$, for any $T > 0$. (Received September 21, 2011)

1077-35-2243 **Maya Chhetri***, maya@uncg.edu, and **Petr Girg**. *Existence of Positive Solutions For a Class of Semipositone Systems with Exponential Growth in R^2.*

We will consider an elliptic system of the form

$$\left.\begin{array}{rl} -\Delta u = \lambda\, f(v) & \text{in} \quad \Omega \\ -\Delta v = \lambda\, g(u) & \text{in} \quad \Omega \\ u = 0 = v & \text{on} \quad \partial\Omega\,, \end{array}\right\}$$

where $\lambda > 0$ is a parameter and Ω is a convex bounded domain in R^2 with smooth boundary $\partial\Omega$. The nonlinearities $f, g : [0, \infty) \to R$ are C^1 functions that are superlinear at infinity, bounded above by exponential functions and satisfy $f(0) < 0$ and $g(0) < 0$. We will discuss the existence of positive solution for λ small. (Received September 21, 2011)

1077-35-2245 **N. Mavinga*** (mavinga@swarthmore.edu), Department of Mathematics and Statistics, Swarthmore College, Swarthmore, PA 19081, and **M. N. Nkashama** and **S. Robinson**. *Steklov-Fucik Spectrum and Nonlinear Elliptic Equations with Nonlinear Boundary Conditions.* Preliminary report.

We consider the (generalized) Steklov-Fucik spectrum for the Laplacian with a nonlinear flux boundary condition and prove the existence of solutions for nonlinear elliptic equations with nonlinear boundary conditions when both nonlinearities in the differential equation and on the boundary lie asymptotically between the first generalized Steklov-Robin eigenvalue-pair and one point on the first nontrivial curve of the generalized Steklov-Fucik spectrum in the plane. (Received September 22, 2011)

1077-35-2255 **N. Mavinga** (mavinga@swarthmore.edu), Department of Mathematics & Statistics, Swarthmore College, Swarthmore, PA 19081-1390, and **M. N. Nkashama*** (nkashama@uab.edu), Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294-1170. *Eigenvalue-curves and nonlinear boundary conditions for nonlinear elliptic equations.*

We show the existence of eigenvalue-curves connecting the Steklov spectrum to the Neumann-Robin spectrum for linear second order elliptic equations. We then consider nonlinear problems with nonlinear boundary conditions when the nonlinearities stay in some sense between two consecutive eigenvalue-curves. (Received September 21, 2011)

1077-35-2274 **Alejandro Sarria** and **Ralph Saxton*** (rsaxton@uno.edu). *Blow Up of Solutions to the Generalized Proudman Johnson Equation.* Preliminary report.

The inviscid Proudman Johnson equation provides a simple class of exact solutions for the incompressible, two-dimensional Euler equations and can be extended to allow similar classes of solutions to be constructed for higher dimensions. Further generalization leads to a rich variety in the evolution of solutions. In this talk, we will discuss background and new findings for the problem. (Received September 22, 2011)

1077-35-2275 **Yanqiu Guo*** (s-yguo2@math.unl.edu), University of Nebraska-Lincoln, Department of Mathematics, 203 Avery Hall, Lincoln, NE 68588, and **Mohammad A. Rammaha**. *Blow-up of Solutions to Systems of Nonlinear Wave Equations with Interior and Boundary Sources and Damping.*

We study a system of coupled nonlinear wave equations which features two completing forces, one force is damping and the other is a strong source of super-critical order. In this talk, I will present a result on the blow-up of weak solutions in finite time, provided the initial energy is negative. (Received September 22, 2011)

1077-35-2291 **Tuwaner Hudson Lamar*** (tlamar@morehouse.edu), Morehouse College, 830 Westview Drive, S.W., Atlanta, GA 30314. *Analysis of a 2n-th Order Differential Equation with Lidstone Boundary Conditions - The Existence of Positive Solutions.*

The existence of positive solutions is established for a class of even order differential equations with even order boundary conditions. Exact and time dependent solutions are analyzed for the case n = 2. The theory of the existence of positive solutions for all n is proven using a method that shows the associated integral operator for the differential equation has a fixed point.
(Received September 22, 2011)

1077-35-2309 **Lois Curfman McInnes*** (curfman@mcs.anl.gov), Mathematics and Computer Science Division, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, IL 60439. *Nonlinear Solvers in Large-Scale Computational Science: Challenges and Opportunities.*

Parallel implicit solution strategies have proven robust and efficient in resolving challenging nonlinearities in many large-scale PDE-based simulations. We discuss the use of preconditioned Newton-Krylov methods in the PETSc library for parallel applications in coupled core-edge plasma and multiphase reactive flow, and we introduce new work on capabilities for the solution of differential variational inequalities as motivated by heterogeneous materials modeling. We also discuss challenges and opportunities in developing robust, scalable, and extensible algorithms and software to support multimodel and multiphysics simulations on emerging high-performance architectures. (Received September 22, 2011)

1077-35-2321 **Peter Constantin***, Department of Mathematics, Princeton University, Fine Hall, Washington Road, Princeton, NJ 08544, and **Vlad Vicol**, Department of Mathematics, The University of Chicago, 5734 S. University Avenue, Chicago, IL 60637. *Nonlocal dissipation and the Euler Equations.*

We describe a general nonlinear maximum principle for nonlocal dissipative operators and apply it to prove global existence for families of perturbations of the incompressible 2D Euler equations. (Received September 22, 2011)

1077-35-2324 **Peter Constantin***, Department of Mathematics, Princeton University, Fine Hall, Washington Road, Princeton, NJ 08544, and **Vlad Vicol**, Department of Mathematics, The University of Chicago, 5734 S. University Avenue, Chicago, IL 60637. *Nonlinear Maximum Principle for Dissipative Nonlocal Operators and Applications: SQG.*

We will prove a nonlinear maximum principle for dissipative nonlocal operators that is simple, general and versatile. We will use it to give an instructive new proof of global existence of smooth solutions for critical dissipative SQG. (Received September 22, 2011)

1077-35-2332 **R. L. Jerrard***, rjerrard@math.toronto.edu, and **D. Smets**, smets@ann.jussieu.fr. *On Schrödinger maps from T^1 to S^2.*

We study aspects of Schrödinger maps from T^1 to S^2 in very weak topologies. For this equation, the space $H^{1/2}$ has critical scaling, and one can verify by explicit examples that the solution map is discontinuous in the H^s topology for all $s < 1/2$. We show that, perhaps surprisingly, the solution map is continuous in the topology of "L^2 modulo translation" at points u_0 in its domain (i.e., in the space of initial data) such that $u_0 \in H^3(T^1, S^2)$.
(Received September 22, 2011)

1077-35-2355 **Lorena Bociu*** (lvbociu@ncsu.edu). *On the linearization of a fluid-nonlinear elasticity interaction.*

We present a new linearized model for a three-dimensional fluid-structure interaction. The linearization that we obtained reveals new features, including the presence of the matrix of curvature terms on the common boundary. Thus our model takes into account the geometrical aspect of the problem, which is critical for a correct physical interpretation of the fluid-structure coupling. (Received September 22, 2011)

1077-35-2369 **Matthias Eller*** (mme4@georgetown.edu), Department of Mathematics, Georgetown University, 37th & O Street NW, Washington, DC 20057. *Carleman estimates for systems of partial differential equations.*

Classical Carleman estimates have been established to prove the unique continuation property for partial differential equations with non-analytic coefficients. Over the last 30 years these estimates have become powerful tools when applied to problems of parameter identification or to problems of boundary control. While various types of Carleman estimates have been established for scalar second-order equations, there are only very few results pertaining to systems of partial differential equations. In this talk we will give a brief survey on Carleman estimates for systems and present some new results pertaining to hyperbolic systems. (Received September 22, 2011)

1077-35-2370 **Vera Mikyoung Hur*** (verahur@math.uiuc.edu), 1409 W Green Street, University of Illinois at Urbana-Champaign, Department of Mathematics, Urbana, IL 60801. *On the modulational instability for the Benjamin-Ono equation.*

I will discuss the modulational stability and instability for a class of nonlinear dispersive equations, involving nonlocal dispersion operators, such as the Benjamin-Ono equation. In case the equation is equipped with Hamiltonian structure and thus periodic traveling-wave solutions arise as critical points of a constrained Hamiltonian, I will explain how the traditional Evans function based approach can be related to direct Bloch wave expansions. I will also make a connection of the spectral analysis to the Whitham's theory. This is joint work with Jared Bronski. (Received September 22, 2011)

1077-35-2373 **Gang Bao*** (baog@msu.edu), Wells Hall, Department of Mathematics, Michigan State University, East Lansing, MI 48824-1027. *Recent developments in inverse scattering.* Preliminary report.

This talk is concerned with the recent developments of our research group on inverse scattering in wave propagation. The speaker will discuss the model problem, mathematical challenges, and the most recent advances on this classic field that arises in a diverse set of scientific and application areas. Future opprotunities and challenges will also be highlighted. (Received September 22, 2011)

1077-35-2375 **Ronghua Pan*** (panrh@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30332. *On 2D viscous Boussinesq system on a bounded domain.*

2D viscous Boussinesq's system models atmospheric and oceanographic turbulence, and the field of Buoyancy driven flows. The system is one of the most commonly used simplified model equations for 3D incompressible Navier Stokes equation, sharing the same vortex stretching effect. In this talk, I will review some recent progress on the global well-posedness, and large time behavior of the system on a bounded domain. The talk is based on joint work with M. Lai, K. Zhao, and with S. Bianchini. (Received September 22, 2011)

1077-35-2379 **Sean A. Colbert-Kelly*** (scolbert@math.purdue.edu), Purdue University, Math Sci. Building, 150 N. University St., West Lafayette, IN 47907-2067, and **Daniel Phillips**. *Analysis of a Ginzburg-Landau Type Energy Model for Smectic C* Liquid Crystals with Defects.* Preliminary report.

This work investigates the properties of a smectic C* liquid crystal that contains defects within its structure, giving rise to distinct spiral formation textures, described by a Ginzburg-Landau Type model. Through this investigation, a detailed analysis of the energy model through the equilibrium configuration of the director field is provided. This investigation also demonstrates that a location for the vortices to minimize the energy exists and that these vortices are located away from the boundary. Through this investigation, a renormalized energy function that depends on the vortices, the boundary values, and the value inside the domain was constructed. It is proved that the limit, as ϵ tends to zero, of the energy functional minus the sum of the energy around the vortices is equal to this renormalized energy. (Received September 22, 2011)

1077-35-2380 **Alireza Aghasi*** (Alireza.Aghasi@tufts.edu), 161 College Ave, Tufts University, Medford, MA 02155, and **Eric Miller**, 161 College Ave, Tufts University, Medford, MA 02155. *Multiobjective Optimization Methods for Shape-Based Joint Inversion.*

The fundamental objective of many inverse problems is to extract information about a medium of interest by analyzing the measurements collected at the periphery based on a physical models linking the internal structure of the medium to the observed data. In the case of shape based inverse problems, the specific goal is to characterize the geometry and contrast of obstacle located in the medium. Of particular interest to us in this talk are inverse obstacle problems for which multiple sensing modalities are employed. We will focus on an approach to such joint inverse problems in which we extend our recent use of parametric level set representations concentrating on the reconstruction of subsurface chemical contaminant plumes contamination using two physical modalities, i.e., the Electrical Resistance Tomography and Hydrological observations. (Received September 22, 2011)

1077-35-2410 **Rakesh Rakesh***, Department of Mathematical Sciences, University of Delaware, Newark, DE 19716. *Uniqueness for a hyperbolic inverse problem with angular control of the coefficients.*

Let u(x,t) be the solution of the initial value problem $u_{tt} - \Delta_x u + q(x)u = \delta(x,t)$ in $\mathbb{R}^3 \times [0,T]$ with zero initial data. Let S be the unit sphere in $\mathbb{R}^3$ and $C = S \times [0,T]$ the space time cylinder with axis along the t axis. We show that the map $F : q \mapsto (u, u_r)|_C$ is injective if T is large enough and q is restricted to a class of potentials whose angular derivatives are dominated by their radial derivatives. Additional results may also be available based on work currently in progress. This is based on work done with Paul Sacks. (Received September 22, 2011)

1077-35-2421 **Geoffrey Robert Wienefeld Dillon*** (geoffrey.dillon@ttu.edu), Texas Tech University, Department of Mathematics, Broadway and Boston, Lubbock, TX 79409-1042. *Schur Complements and Block Preconditioners for Coupled Diffusion Systems.* Preliminary report.

Discretization of systems of coupled PDE under finite elements or finite differences gives rise to block-structured algebraic systems. Expensive to solve, these systems require effective preconditioning. Many of these preconditioners are based on block LU factorizations. In such factorizations, one obtains the Schur complement by eliminating one field in terms of the other. Preconditioners constructed in this manner require the inverse of the Schur complement, which is very expensive to compute. We study a particular simple strategy for approximating the Schur complement that has some general applicability, giving examples both of the resulting block preconditioner and solving the Schur complement system for some coupled PDE. (Received September 22, 2011)

1077-35-2433 **Changchun Wang*** (cwang@math.tamu.edu), 1100 Hensel Dr. Apt Y3L, College Station, TX 77840. *On theory and numerical method for computing eigen-solutions of nonlinear elliptic equation with Neumann boundary condition.* Preliminary report.

In order to numerically solve nonlinear elliptic eigen solution problems, a new formulation is developed by focusing the study of the problems on their variational energy profile and using the implicit function approach. Then a modified local minmax method is devised to compute the solutions in the order of their eigenvalues. The nonlinear Neumann boundary value eigen solution problems are very different from their Dirichlet counterparts and the linear ones. In particular, the former has, in addition to those sign-changing solutions, a positive constant solution which may bifurcate to many positive solutions. So a result based on Morse index approach is established to identify bifurcation points and to help computing positive solutions. Numerical results will be presented to illustrate the theory and method. This research is supported in part by NSF DMS-0713872/0820327/1115384. (Received September 22, 2011)

1077-35-2443 **Karen Yagdjian*** (yagdjian@utpa.edu), 1201 West University Drive, Edinburg, TX 78539. *Sign-changing solutions of the semilinear hyperbolic equations.*

In this talk we discuss global in time solutions (not necessarily small) of some model semilinear hyperbolic equations. We reveal qualitative behavior of the global solutions, and, in particular, we formulate sufficient conditions for the global solutions to be sign-changing. These conditions guarantee existence of the zeros of global solutions in the interior of their supports. The application of these results to the equations, which have been studied in particle physics and inflationary cosmology, implies a creation of the so-called bubbles. (Received September 22, 2011)

1077-35-2446 **Jaffar Ali***, Dept. Math & Chem, Florida Gulf Coast University, 10501 FGCU Blvd. S., Fort Myers, FL 33967, and **Peng Feng**. *A remark on the entire solutions for a class of elliptic system with linear gradient terms.* Preliminary report.

In this talk, we discuss the existence of positive entire large radial solutions to the nonlinear elliptic system with gradient terms. (Received September 22, 2011)

1077-35-2458 **Irina Mitrea*** (imitrea@temple.edu), Department of Mathematics, Temple University, 1805 N. Broad Street, Philadelphia, PA 19122. *Regularity properties of Green functions in non-smooth domains.*

I this talk I will discuss recent results regarding regularity properties of Green functions associated with elliptic differential operators of second and higher order in Lipschitz domains. This analysis includes the case of second and higher order elliptic systems with constant coefficients, the bi-Laplacian, and the Stokes system. (Received September 22, 2011)

1077-35-2478 **Magdalena Czubak*** (czubak@math.binghamton.edu). *Estimates and wellposedness for magnetic Schrödinger equations and related systems.* Preliminary report.

We discuss some recent work on wellposedness, scattering and blowup for a Schrödinger equation with electromagnetic potentials and for the Chern-Simons-Schrödinger system. (Received September 22, 2011)

1077-35-2501 **Barbara Lee Keyfitz** and **Charis Tsikkou*** (tsikkou@math.ohio-state.edu), Department of Mathematics, The Ohio State University, 231 West 18th Avenue, Columbus, OH 43210. *A system of conservation laws with no classical Riemann solution. Existence of Dafermos profiles for singular shocks.*

We consider a system of two equations derived from isentropic gas dynamics. We show that there is no classical Riemann solution and that singular shocks have Dafermos profiles. (Received September 22, 2011)

1077-35-2520 **T. Zhang*** (zhang_t@math.psu.edu) and **Y. Zheng** (yzheng1@yu.edu). *Structure of solutions near sonic line for pressure gradient equation.*

We consider the two-dimensional pressure gradient system in the self-similar plane and show that a local smooth solution exists extending from a sonic line towards the hyperbolic region with given boundary conditions on the sonic line. Characteristics are only Hölder continuous at the sonic line. We introduce a new coordinate system, that involves the state variable pressure p as well as the self-similar ones, so that the characteristics become smooth and terms of singularity are shifted to within the lower order terms in the characteristic form of the equation. We establish the existence of a local smooth solution by showing that an iteration sequence converges under a new metric. (Received September 22, 2011)

1077-35-2535 **Sarah King*** (saking@ncsu.edu). *A Multi-Moment CIP Method for Hyperbolic Equations.*

We propose a numerical method for solving hyperbolic equations based on the method of characteristics and multi-moment approximation of functions. Exact update formulas are derived for for the solution and solution derivative with variable wave speed using the method of characteristics. Then an extension of the Constrained Interpolation Profile (CIP) method is used for time integration. The CIP method is numerically stable and for certain vector fields that develop singularities in the solution, the method captures the singularity. We will apply the method to the transport and advection equations and provide extensions to higher dimensions. (Received September 22, 2011)

1077-35-2558 **Margo S Levine*** (mlevine@seas.harvard.edu), **Emil Y Sidky** and **Xiaochuan Pan**. *Consistency Conditions for Cone-Beam CT Data Acquired with a Linear Source Trajectory.*

A consistency condition is developed for computed tomography (CT) projection data acquired from a linear X-ray source trajectory. The condition states that integrals of normalized projection data along detector lines parallel to the X-ray path must be equal. The projection data is required to be untruncated only along the detector lines parallel to the X-ray path, a less restrictive requirement compared to Fourier conditions that necessitate completely untruncated data. The condition is implemented numerically on simple image functions, a discretization error bound is estimated, and detection of motion inconsistencies is demonstrated. The results show that the consistency condition may be used to quantitatively compare the quality of projection data sets obtained from different scans of the same image object. (Received September 22, 2011)

1077-35-2568 **Baofeng Feng*** (feng@utpa.edu), Department of Mathematics, The University of Texas-Pan American, Edinburg, TX 78541, **Kenichi Maruno**, Department of Mathematics, The University of Texas-Pan American, Edinburg, TX 78541, and **Yasuhiro Ohta**, Department of Mathematics, Kobe University, Rokko, Kobe, Japan. *Bilinearization of the Degasperis-Procesi equation.*

It is known that both the Camassa-Holm (CH) equation and the Degasperis-Procesi (DP) equation can be viewed as shallow water wave models. The short wave model of the DP equation is also known as the Ostrovsky-Hunter equation or the Vakhnenko equation, describing high-frequency waves in a relaxing medium. In the present talk, we will give bilinear equations for the DP equation and its short wave model. To be more specific, we will show that the Vakhnenko equation can be derived from a 3-reduction of C-type KP hierarchy through a hodograph transformation. The situation of the Dapasperis-Procesi equation is more complicated. By proving one of the tau-functions to be the product of two pfaffians, we will show that the DP equation is a pseudo 3-reduction of the C-type KP hierarchy. As a by-product, the multi-soliton solutions including multi-loop solutions for the Dapasperis-Procesi equation and the Vakhnenko equation are given in terms of pfaffians. (Received September 22, 2011)

1077-35-2575 **Mickael D. Chekroun*** (mchekroun@atmos.ucla), 405 Hilgard Ave/7127 Math Sciences Bldg, Los Angeles, CA 90095-15, and **Lionel Roques**, **Michel Cristofol**, **Samuel Soubeyrand** and **Michael Ghil**. *Parameter estimation for energy balance models with memory.* Preliminary report.

We study parameter estimation for one-dimensional energy balance models with memory (EBMMs) based on given localized and noisy temperature measurements. Our results apply to a wide range of nonlinear PDEs with integral memory terms. First, we show that a space-dependent parameter can be determined uniquely everywhere in the PDE's domain, using only temperature information in a small subdomain. This result is valid only when the data correspond to exact measurements of the temperature.

We propose a method for estimating a model parameter of the EBMM using more realistic, error-contaminated temperature data derived, for example, from ice cores or marine-sediment cores. Our approach is based on a so-called mechanistic-statistical model, which combines a deterministic EBMM with a statistical model of the observation process. Estimating a parameter in this setting is especially challenging because the observation process induces a strong loss of information. Aside from the noise contained in past temperature measurements, an additional error is induced by the age-dating method, whose accuracy tends to decrease with a sample's remoteness in time. Using a Bayesian approach, we show that obtaining an accurate parameter estimate is still possible in certain cases. (Received September 22, 2011)

1077-35-2582 **Hongyu Liu***, Department of Mathematics and Statistics, University of North Carolina, Charlotte, NC 28223. *Enhanced Near-cloak by FSH Lining.*

We consider regularized approximate cloaking for the Helmholtz equation. Various cloaking schemes have been recently proposed and extensively investigated. The existing cloaking schemes in literature are (optimally) within $|\ln\rho|^{-1}$ in 2D and ρ in 3D of the perfect cloaking, where ρ denotes the regularization parameter. In this work, we develop a cloaking scheme with a well-designed lossy layer right outside the cloaked region that can produce significantly enhanced near-cloaking performance. In fact, it is proved that the proposed cloaking scheme could (optimally) achieve ρ^N in $\mathbb{R}^N$, $N\geq 2$, within the perfect cloaking. It is also shown that the limit of the proposed lossy layer corresponds to a sound-hard layer. We work with general geometry and arbitrary cloaked contents of the proposed cloaking device. Numerical examples are given to demonstrate the sharpness of our estimates. (Received September 22, 2011)

1077-35-2584 **Gunther Uhlmann*** (gunther@math.washington.edu). *The Calderon Problem with Partial Data.*

We discuss some recent advances on the problem of determining the conductivity of a medium by making voltage and current measurements on part of the boundary. (Received September 22, 2011)

1077-35-2599 **Maxim Zyskin*** (Maxim.Zyskin@utb.edu). *Integrable n-field model on a triangular domain.*

We obtain solution of a class of boundary value problems for intgerable n-field equation on a triangular domain, using non-conventional methods. Lower energy bound is obtained by algebraic methods; matching upper energy bound is obtained by an explicit construction (Received September 22, 2011)

1077-35-2619 **Jerry L Bona** and **Hongqiu Chen*** (hchen1@memphis.edu), University of Memphis, Deparmtent of Mathematical Sciences, Memphis, TN 38152. *Initial-boundary value problem for coupled nonlinear dispersive equations.* Preliminary report.

We consider the following system of nonlinear dispersive equations

$$\begin{cases} u_t + u_x - u_{xxt} + (Au^2 + Buv + Cv^2))_x = 0, \quad x \in [0, L],\, t \geq 0 \\ v_t + v_x - v_{xxt} + (Du^2 + Euv + Fv^2)_x = 0, \quad x \in [0, L],\, t \geq 0 \\ u(0,t) = a(t), \quad u(L,t) = b(t) \\ u(0,t) = c(t), \quad u(L,t) = d(t) \\ u(x,0) = u_0(x), \quad v(x,0) = v_0(x), \quad x \in [0, L] \end{cases}$$

where $L > 0$ is given number, $u = u(x,t), v = v(x,t)$ are functions defined on $[0, L] \times \mathbb{R}^+$ and $A, B, \cdots F \in \mathbb{R}$ are constants. We discuss conditions to have the problem well-posed both locally and globally in time. (Received September 22, 2011)

1077-35-2628 **Jerry L BONA** and **Hongqiu CHEN*** (hchen1@memphis.edu), University of Memphis, Deparmtent of Mathematical Sciences, Memphis, TN 38152. *Initial value problem for coupled nonlinear dispersive equations.*

We consider the following system of nonlinear dispersive equations

$$\begin{cases} u_t + u_x - u_{xxt} + (Au^2 + Buv + Cv^2))_x = 0, x \in \mathbb{R}, t \geq 0 \\ v_t + v_x - v_{xxt} + (Du^2 + Euv + Fv^2)_x = 0, x \in \mathbb{R}, t \geq 0 \\ u(x,0) = u_0(x),\, v(x,0) = v_0(x), x \in \mathbb{R} \end{cases}$$

where $u = u(x,t), v = v(x,t)$ are functions defined on $\mathbb{R} \times \mathbb{R}^+$ and $A, B, \cdots F \in \mathbb{R}$ are constants. We show that the problem is well-posed (in time) on $H^s \times H^s$ for any $s \geq 0$. Moreover, when $A, B, \cdots, F$ satisfy some simple algebraic condition, the problem is well-posed globally in time. (Received September 22, 2011)

1077-35-2655 **Shelly M McGee*** (mcgee@findlay.edu), Department of Mathematics, 1000 N Main St, Findlay, OH 45840. *A sixth-order compact finite difference method for Navier-Stokes in cylindrical coordinates.* Preliminary report.

A model will be proposed to simulate the Navier-Stokes equation for incompressible fluid flow in a cylindrical channel using a sixth-order compact finite difference method. The finite difference discretization will be combined with the semi-implicit method for pressure link equations revised (SIMPLER). Blood flow will be simulated using the model. (Received September 22, 2011)

1077-35-2678 **Kyungwoo Song*** (kyusong@khu.ac.kr), 1504 Belfer Hall, Yeshiva University, 2495 Amsterdam Ave., Manhattan, New York, NY 10033, and **Yuxi Zheng** (yzheng1@yu.edu), 519 Belfer Hall, Yeshiva University, 2495 Amsterdam Ave., Manhattan, New York, NY 10033. *A semi-hyperbolic region for the pressure gradient system.*

We consider solutions in regions including a semi-hyperbolic area in a self-similar plane. We give a talk on new results or developments on semi-hyperbolic patches using a pressure gradient system, which is a simple model of the two-dimensional compressible Euler system. (Received September 22, 2011)

1077-35-2694 **Maxim Zyskin*** (Maxim.Zyskin@utb.edu). *Fundamental differential form and boundary value problems for PDEs.*

We describe constructive realization of Ehrenpreis fundamental principle, in terms of fundamental differential form. We use such form to obtain Ehrenpreis representation of solutions of boundary value problems for linear constant coefficient PDEs. We apply this method to solve and analyze boundary value problems with applications. (Received September 22, 2011)

1077-35-2704 **John P Albert*** (jalbert@ou.edu), 601 Elm Ave., Rm. 423, Norman, OK 73019, and **Santosh Bhattarai** (sbhattarai@ou.edu), 601 Elm Ave, Rm 423, Norman, OK 73019. *Concentration compactness and KdV-NLS solitary waves.*

We prove existence and dynamic stability of solutions which represent the coupling of solitary waves to ground states for a system of coupled KdV and nonlinear Schrodinger equations. The proof involves establishing the joint subadditivity in both constraint variables of a two-parameter family of constrained variational problems. The method is simpler and leads to more general results than that employed previously by Albert and Angulo in [Proc. Roy. Soc. Edinburgh Sect. A 133 (2003), no. 5, 987–1029]. (Received September 22, 2011)

1077-35-2719 **Edriss S. Titi*** (etiti@math.uci.edu), Department of Mathematics, The University of California, Rowland Hall, Irvine, CA 92697-3875. *Navier-Stokes, Euler, and other relevant equations.*

In this talk I will survey the status of, and the most recent advances concerning, the questions of global regularity of solutions to the three-dimensional Navier-Stokes and Euler equations of incompressible fluids. Furthermore, I will also present recent global regularity results concerning certain three-dimensional geophysical flows, including the three-dimensional viscous "primitive equations" of oceanic and atmospheric dynamics. (Received September 22, 2011)

1077-35-2723 **Silvia Jiménez*** (silviajimenez@wpi.edu), Dept. of Mathematical Sciences, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609, and **Bogdan Vernescu**. *Nonlinear Neutral Inclusions: Assemblages of Disks and Ellipsoids.* Preliminary report.

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 disks and ellipsoids. (Received September 22, 2011)

1077-35-2737 **Maya Chhetri**, **Sarah Raynor*** (raynorsg@wfu.edu) and **Stephen Robinson**. *Existence of Multiple Positive Solutions to Some Semipositone Systems.*

In this talk we use the method of upper and lower solutions combined with degree theoretic techniques to prove the existence of multiple positive solutions to some semipositone, superlinear elliptic systems with Dirichlet boundary conditions, under suitable conditions on the nonlinearities. Our techniques apply generally to subcritical, superlinear problems with a certain concave-convex shape to their nonlinearity. (Received September 22, 2011)

1077-35-2769 **John K Hunter*** (jkhunter@ucdavis.edu), Department of Mathematics, University of California at Davis, Davis, CA 95616, and **Mihaela Ifrim**, Department of Mathematics, University of California at Davis, Davis, CA 95616. *Enhanced Lifespan of Smooth Solutions of a Burgers-Hilbert Equation.*

We consider an initial value problem for an inviscid Burgers-Hilbert equation that models the motion of vorticity discontinuities in the two-dimensional flow of an inviscid, incompressible fluid. We use a normal form transformation, consisting of a near-identity transformation of the independent spatial variable, to remove the quadratic nonlinearity and prove the existence of small, smooth solutions on cubically nonlinear time-scales. For vorticity discontinuities, this result means that there is a cubically nonlinear time-scale before the onset of filamentation. (Received September 22, 2011)

1077-35-2787 **Stephen C Anco*** (sanco@brocku.ca), Department of Mathematics, Brock University, Canada. *Integrability of geometric evolution equations using Hasimoto variables.* Preliminary report.

Wave maps and Schrodinger maps are examples of geometric nonlinear evolution equations for a map from space-time into a Riemannian manifold or a Hermitian manifold. In this talk, I will describe a formulation of such equations using Hasimoto-type variables that arise from the introduction of a moving parallel frame. As applications, integrable mKdV versions of Schrodinger maps will be obtained, and the bi-Hamiltonian structure for these maps will be derived geometrically in the case when the manifold is a symmetric space or a Lie group. (Received September 22, 2011)

1077-35-2813 **Michael I Weinstein*** (miw2103@columbia.edu), 212 SW Mudd Building, Columbia University, New York, NY 10027. *Carrier Shocks and Coherent Structures in the Nonlinear Maxwell Equation.*

We consider the 1-dimensional propagation of E&M waves in a weakly nonlinear and low-contrast spatially periodic medium with no energy dissipation, in which dispersion enters only through the spectral band dispersion associated with the periodic structure. Numerical simulations show that for wave-packet data, very long-lived spatially localized coherent soliton-like structures emerge, whose character is that of a slowly varying envelope of a train of shocks. This violates the oft-assumed nearly monochromatic wave packet structure governed by the nonlinear coupled mode eqns (NLCME). We systematically derive a fully consistent set of nonlocal integro-differential equations governing the coupled evolution of backward and forward propagating waves. These equations incorporate all infinitely many resonances and may be expressed as a system of infinitely many coupled mode equations, which we call the extended nonlinear coupled mode eqns (xNLCME).

Numerical simulations of xNLCME capture both large scale features and the fine scale carrier shocks of the nonlinear periodic Maxwell equations. Finally, we explore the existence of spatially localized states corresponding to broad band solitons of xNLCME. This is joint work with G. Simpson and D. Pelinovsky. (Received September 22, 2011)

1077-35-2814 **Bogdan Vernescu*** (vernescu@wpi.edu), Department of Mathematical Sciences, 100 Institute Rd., Worcester, MA 01609. *Mathematical Problems in Metal Processing.*

Modeling of metal processes like wire drawing, flat rolling, extrusion, rolling or sintering lead to a wealth of interesting mathematical problems. We will talk about the mathematics involved in modeling a few of these problems. (Received September 22, 2011)

1077-35-2819 **Jay Lawrence Hineman***, 719 Patterson Office Tower, University of Kentucky, Lexington, KY 40506. *Well-Posedness of Liquid Crystal Flow in L^3_{uloc}.* Preliminary report.

We analyze uniformly locally L^3 integrable (L^3_{uloc}) solutions of the hydrodynamic flow of the nematic liquid crystals in three dimensions. This model is a simplified version of the equations derived by Ericksen and Leslie. Weak solutions with small L^3_{uloc} norm are shown to be smooth. As a consequence, the local (or global) well-posedness in L^3_{uloc} (or small L^3_{uloc}) is established. (Received September 22, 2011)

1077-35-2848 **Jing Li*** (li_j@math.psu.edu), Department of Mathematics, Pennsylvania State University, 109 McAllister Building, State College, PA 16802, and **Xingfu Zou**. *Modeling spatial spread of infectious diseases with a fixed latent period in a spatially continuous domain.*

In this talk, with the assumptions that an infectious disease in a population has a fixed latent period and the latent individuals of the population may diffuse, we formulate an SIR model with a simple demographical structure for the population living in a spatially continuous environment. The model is given by a system of reaction-diffusion equations with a discrete delay accounting for the latency and a spatially non-local term caused by the mobility of the individuals during the latent period. We address the existence, uniqueness, and positivity of solution to the initial-value problem for this type of system. Moreover, we investigate the traveling wave fronts of the system and obtain a critical value c^* which is a lower bound for the wave speed of the traveling wave fronts. Although we can not prove that this value is exactly the minimal wave speed, numerical simulations seem to suggest that it is. Furthermore, the simulations on the PDE model also suggest that the spread speed of the disease indeed coincides with c^*. We also discuss how the model parameters affect c^*. (Received September 22, 2011)

1077-35-2855 **Qingshan Chen**, **Max Gunzburger** and **Mauro Perego*** (mperego@fsu.edu), Tallahassee, FL 32304. *Well-posedness results for a nonlinear Stokes problem arising in Glaciology.*

In this talk we present well-posedness results for a nonlinear, incompressible Stokes problem that models the flow of ice in glaciers and ice sheets, e.g., Greenland and Antarctica. An important feature of the problem, in addition to the highly nonlinear rheology, are boundary conditions which describe the Coulomb-like friction at the ice-bedrock interface. Results available in the literature for similar nonlinear Stokes problems do not fully account for boundary conditions typical of glaciology. Difficulties in the analysis of the Stokes model are generated by the fact that boundary conditions can possibly depend on the normal stress. In this case, led by arguments typical in the linear elasticity context, we prove an existence result for nonlocal friction boundary conditions. Moreover, we prove that Coulomb friction problem can be approximated by differentiable boundary conditions that render numerical simulations more affordable. (Received September 22, 2011)

1077-35-2867 **Anton Dzhamay*** (adzham@unco.edu), School of Mathematical Sciences, University of Northern Colorado, 501 20th Street, Greeley, CO 80639. *Combinatorics of matrix refactorizations and discrete integrable systems.*

Many interesting questions in the theory of discrete integrable systems, such as Lax representations, Yang-Baxeter maps, and dynamics of discrete Painlevé equations, can be formulated in terms of refactorization transformations of rational matrix functions. One way to better understand such transformations is to study the non-trivial relations that the eigenvectors of these matrix functions must satisfy. We give a geometric representation of some of these relations and consider their applications. In particular, we show how to encode, in a very natural way, the generating functions of refactorization transformations (i.e., the Lagrangians of the corresponding discrete integrable systems) in some simple cases. (Received September 22, 2011)

37 ► Dynamical systems and ergodic theory

1077-37-172 **Joseph H. Silverman***, Mathematics Department - Box 1917, Brown University, Providence, RI 02912, and **Michael Zieve**, Mathematics Department, University of Michigan, Ann Arbor, MI. *Algebra, Geometry, and Dynamics of Pseudo-Real Maps.* Preliminary report.

Let L/K be a separable quadratic extension of fields, for example $\mathbb{C}/\mathbb{R}$, and let $\mathrm{Gal}(L/K) = \{1, \sigma\}$. A rational map $\phi(z) \in L(z)$ is *L/K-pseudo-real* if there is a fractional linear transformation $f(z) \in L(z)$ such that $\phi^\sigma = f^{-1} \circ \phi \circ f$. With an eye towards dynamical appliations, in this talk I will explain how a $\mathbb{C}/\mathbb{R}$ pseudo-real map induces an algebraic map on the real projective plane $\mathbb{RP}^2$ and will discuss how this generalizes to general pseudo-real maps. (Received August 07, 2011)

1077-37-174 **Joseph H. Silverman***, Mathematics Department - Box 1917, Brown University, Providence, RI 02912. *Number Theoretic Properties of Difference Equations Associated to Hénon Maps.* Preliminary report.

A classical Hénon map is an automorphism $\phi : \mathbb{A}^2 \to \mathbb{A}^2$ of the form $\phi(x, y) = (y+1-ax^2, bx)$. This Hénon map is equivalent to the polynomial difference equation $x_{n+1} = 1-ax_n^2+bx_{n-1}$. Hénon maps are examples of regular affine automorphisms, which are automorphisms $\phi : \mathbb{A}^N \to \mathbb{A}^N$ whose extension to a rational map $\Phi : \mathbb{P}^N \to \mathbb{P}^N$ has the property that at least one of Φ or Φ^{-1} is defined at every point of $\mathbb{P}^N$. In this talk I will discuss number theoretic properties of Hénon difference equations and more general regular affine automorphisms. (Received August 07, 2011)

1077-37-427 **Sevak Mkrtchyan*** (sm29@rice.edu), Department of Mathematics - MS 136, Rice University, Houston, TX 77005. *Entropy of Schur-Weyl measures.*

Relative dimensions of the isotypic components of the N-th order tensor representations of the symmetric group on n letters give a Plancherel-type measure, called the Schur-Weyl measure, on the space of Young diagrams with n cells and at most N rows. We obtain logarithmic, order-sharp bounds for the maximal dimensions of the isotypic components of the tensor representations, and prove that the typical dimensions, after appropriate normalization, converge to a constant with respect to the family of Schur-Weyl measures in the limit when $N/\sqrt{n}$ converges to a constant. By analogy with the Shannon-Macmillan-Breiman theorem this constant represents the entropy of the Schur-Weyl measures.

We also obtain a new proof of Biane's theorem which states that scaled random Young diagrams with respect to the Schur-Weyl measure converge to a limit shape.

The main results were conjectured by G. Olshanski. Analogous results for the Plancherel measure were obtained by Vershik and Kerov (order-sharp bounds), and Bufetov (convergence to a constant). (Received August 31, 2011)

1077-37-438 **Hong-Kun Zhang*** (hongkun@math.umass.edu), Department of Math. & Stat., University of Massachusetts Amherst, Amherst, MA 01003. *Billiards under small twists.*

Lorentz gas is a simple model of diffusive billiards in studying the transport precess of electrons in an ionized metal. Since the key aim in statistical mechanics is to characterize the diffusion matrix that appear in the CLT. We study 2d periodic Lorentz gas in the presence of a twist force on the scatterers. In this system, billiard orbits are still geodesics between collisions, but do not reflect elastically when reaching the boundary. When the horizon is finite, i.e. the free flights between collisions are bounded, the resulting current J is proportional to the strength of the twist force. We prove the existence of a unique SRB measure, for which the Pesin entropy formula and Young's expression for the fractal dimension are valid. The classical CLT is verified and the diffusion matrix is calculated according to a formula involves the twist function. (Received September 01, 2011)

1077-37-464 **Adam Doliwa*** (doliwa@matman.uwm.edu.pl). *Quantum pentagon equation, Hirota's discrete KP equation, and projective geometry over division rings.*

An incidence geometry interpretation of the Hirota equation and of its integrability (understood as the multidimensional consistency) will be presented. Such a description makes also visible the A_N affine Weyl group symmetry of the system of the Hirota equations for N discrete variables. The Veblen configuration, which provides the geometric interpretation of the Hirota equation, allows to define a birational map $S : D^2 \times D^2 -- > D^2 \times D^2$, where D is an arbitrary division ring (skew field). The Desargues configuration, which is responsible for the 4-dimensional consistency of the Hirota equation, explains why S satisfies the functional dynamical pentagon equation $S_{12}S_{23} = S_{23}S_{13}S_{12}$ on $D^2 \times D^2 \times D^2$. It turns out that in an appropriate gauge the (commutative version of the) map preserves a natural Poisson structure - the quasiclassical limit of the Weyl commutation relations. This allows to construct the corresponding solution of the quantum pentagon equation. (Received September 02, 2011)

1077-37-540 **Yakov B. Pesin*** (pesin@math.psu.edu), Department of Mathematics, Eberly College of Science, Penn State University, University Park, PA 16803. *Essential coexistence of completely hyperbolic and completely non-hyperbolic behavior.*

I will describe an example of a C^∞ volume preserving topologically transitive diffeomorphism of a compact smooth Riemannian manifold which is ergodic (indeed is Bernoulli) on an open and dense subset U of not full measure and has zero Lyapunov exponent on the complement of U. This can be viewed as a version of a "discrete" KAM theory phenomenon in the volume preserving category. (Received September 06, 2011)

1077-37-678 **Sergey Tikhomirov*** (sergey.tikhomirov@gmail.com), Arnimallee 3, 14195 Berlin, Germany. *Holder shadowing on finite intervals.*

We study the Holder shadowing property for diffeomorphisms of a compact manifold. We proved that if any d-pseudotrajectory of diffeomorphism f can be d^α shadowed by an exact trajectory on intervals of length $1/d^\alpha$ for $\alpha > 1/2$ then f is in fact structurally stable.

We discuss connections of this problem with Katok's question: "Does any diffeomorphism Holder conjugated to Anosov must be Anosov by itself?" and Hammel-Grebogi-Yorke conjecture on shadowability of Henon map.

The main technique is consideration of inhomogeneous linear equation

$$v_{k+1} = A_k v_k + w_{k+1},$$

where A_k are differential of the diffeomorphism along an exact trajectory and w_k is an arbitrarily bounded sequence. (Received September 09, 2011)

1077-37-717 **Joseph H Silverman** (jhs@math.brown.edu) and **Bianca Viray*** (bviray@math.brown.edu). *On a uniform bound for the number of exceptional linear subvarieties in the dynamical Mordell–Lang conjecture.*

Let $\phi : \mathbb{P}^n \to \mathbb{P}^n$ be a morphism of degree $d \geq 2$ defined over $\mathbb{C}$. The dynamical Mordell–Lang conjecture says that the intersection of an orbit $\mathcal{O}_\phi(P)$ and a subvariety $X \subset \mathbb{P}^n$ is usually finite. We consider the number of linear subvarieties $L \subset \mathbb{P}^n$ such that the intersection $\mathcal{O}_\phi(P) \cap L$ is "larger than expected." When ϕ is the d^{th}-power map and the coordinates of P are multiplicatively independent, we prove that there are only finitely many linear subvarieties that are "super-spanned" by $\mathcal{O}_\phi(P)$, and further that the number of such subvarieties is bounded by a function of n, independent of the point P and the degree d. More generally, we show that there exists a finite subset S, whose cardinality is bounded in terms of n, such that any $n+1$ points in $\mathcal{O}_\phi(P) \smallsetminus S$ are in linear general position in $\mathbb{P}^n$. (Received September 11, 2011)

1077-37-764 **Enrique Pujals*** (enrique@impa.br), Dona Castorina 110, Rio de Janeiro, RJ 22460-320, Brazil. *Partial Hyperbolicity in the Hamiltonian and geometrical context.*

We will discuss a series of result in partially hyperbolic dynamics with applications to hamiltonian and symplectic dynamics. In particular, we will consider the case of partially hyperbolic geodesic flows. (Received September 12, 2011)

1077-37-803 **David Aulicino*** (aulicino@math.umd.edu). *Classifying Teichmueller Disks with Completely Degenerate Kontsevich-Zorich Spectrum.*

The moduli space of genus g Riemann surfaces is the space of all complex structures on a closed orientable surface of genus g up to orientation preserving diffeomorphisms. The Teichmueller geodesic flow is the flow on the cotangent bundle of the Teichmueller space of surfaces defined by the direction of minimal dilatation and it descends to the cotangent bundle of the moduli space under the action of the mapping class group. It is well-known that the Lyapunov spectrum of this flow is determined by g numbers $1 = \lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_g \geq 0$. The Kontsevich-Zorich conjecture, proven by Forni and Avila-Viana, showed that generically all the inequalities are strict with respect to the canonical absolutely continuous measures. However, Forni found an example of a measure on the genus three moduli space, and Forni-Matheus found a measure in genus four, with completely degenerate spectrum, i.e. $1 = \lambda_1 > \lambda_2 = \cdots = \lambda_g = 0$. We prove that these are the only such measures in genus three and four. Furthermore, there are no such measures for $g = 2$ and $g \geq 13$. Finally, if there are no square-tiled surfaces in genus five that determine a measure with completely degenerate spectrum, then there are no examples for $g \geq 5$. (Received September 12, 2011)

1077-37-937 **Danijela Damjanovic*** (dani@rice.edu). *Partially hyperbolic actions on nilmanifolds.*

This talk will be about the last remaining case in a large program initiated by Katok and Spatzier on local rigidity of hyperbolic and partially hyperbolic algebraic abelian higher rank actions. It concerns actions by automorphisms of nilmanifolds. I will talk about local rigidity for such actions on 2-step free nilmanifolds. (Received September 14, 2011)

1077-37-944 **Tom Farrell** and **Andrey Gogolev*** (agogolev@math.binghamton.edu). *Anosov diffeomorphisms constructed from* $\boldsymbol{\pi}_k(\mathrm{Diff}(\mathbf{S^n}))$.

Farrell and Jones constructed codimension one Anosov diffeomorphisms on manifolds that are homeomorphic to tori but have exotic smooth structures. We use a different method to construct Anosov diffeomorphisms of higher codimension on manifolds that are homeomorphic to infranilmanifolds yet have irreducible exotic smooth structures. (Received September 14, 2011)

1077-37-1005 **Tuhin Sahai*** (sahait@utrc.utc.com), 411 Silver Lane, MS 129-85, East Hartford, CT 06118. *Designing Scalable Algorithms for Complex Networks.*

Complex networks such as building systems, UAV swarms and communication networks are of paramount importance to modern day applications and particularly challenging from an analysis perspective.

For scalable analysis of large networks, our approach first uses a novel decentralized clustering approach, based on propagating waves in the graph, for partitioning the system of differential equations. The partitioned system is then simulated using adaptive waveform relaxation, an efficient approach for the distributed simulation of differential algebraic equations. We demonstrate the efficacy of this two step approach for simulating large models of building systems and electrical circuits.

Polynomial Chaos based methods are used extensively for propagating uncertainty through smooth dynamical systems. Though useful for systems of small to moderate dimension, the curse of dimensionality restricts the applicability of these methods to high dimensional dynamical systems. We show how our simulation framework can also be used to propagate uncertainty through large dynamical systems. (Received September 15, 2011)

1077-37-1115 **Robert G. Niemeyer*** (niemeyer@math.ucr.edu), 900 Big Springs Rd., Surge Building, Riverside, CA 92512, and **Michel L. Lapidus** (lapidus@math.ucr.edu), 900 Big Springs Rd., Riverside, CA 92512. *Properties of compatible sequences of periodic orbits of prefractal approximations of the Koch snowflake fractal billiard.*

We give a construction of Cantor orbits and hybrid periodic orbits of a prefractal approximation of the Koch snowflake fractal billiard. We show that there exists a countably infinite collection of directions for which a compatible sequence of periodic orbits exists. We discuss properties of certain compatible sequences of orbits and describe other self-similar fractal billiard tables for which a number of our results hold. We then speculate on the criterion for our results holding on a general self-similar fractal billiard table. We finish by describing an analogy between a region with varying indecies of refraction and cells of a prefractal approximation to the Koch snowflake fractal billiard. (Received September 16, 2011)

1077-37-1189 **Andrey Gogolev**, **Boris Kalinin*** (kalinin@jaguar1.usouthal.edu) and **Victoria Sadovskaya**. *Local rigidity for Anosov automorphisms.*

We consider an irreducible Anosov automorphism L of a torus $\mathbb{T}^d$ such that no three eigenvalues have the same modulus. We prove that L is locally rigid, that is, L is smoothly conjugate to any C^1-small perturbation f for which the derivatives of the return maps at the periodic points are conjugate to those of L. We show that toral automorphisms satisfying the above assumptions are generic in $SL(d, \mathbb{Z})$. (Received September 17, 2011)

1077-37-1199 **Xavier Buff**, **Adam Epstein** and **Sarah Koch*** (kochs@math.harvard.edu), Department of Mathematics, Science Center, Harvard University, 1 Oxford Street, Cambridge, MA 02138. *Twisted matings of polynomials.* Preliminary report.

Given two suitable polynomials of degree d, $p : \mathbb{C} \to \mathbb{C}$ and $q : \mathbb{C} \to \mathbb{C}$, we can form the mating of the polynomials $S^2 \to S^2$ by gluing together the Julia sets of p and q in a dynamically meaningful way. If the mating is equivalent to a rational map $\mathbb{P}^1 \to \mathbb{P}^1$, we say that the geometric mating of the polynomials exists. In this talk we define *twisted matings* of polynomials, and we prove that for the basilica polynomial $P(z) = z^2 - 1$, for any $n > 0$, all of the twisted matings of $P^{\circ n}$ with itself are classified by the periodic cycles of $z \mapsto z^2$, of length n. (Received September 17, 2011)

1077-37-1258 **Victoria Sadovskaya*** (sadovska@jaguar1.usouthal.edu). *Cohomology of $GL(2, \mathbb{R})$-valued cocycles over hyperbolic systems.*

We discuss cohomology of group-valued cocycles over Anosov diffeomorphisms. Central questions in this area are whether a measurable conjugacy between two cocycles is continuous, and whether conjugacy of the periodic data implies conjugacy of the cocycles. We concentrate on $GL(2, \mathbb{R})$-valued cocycles and address these questions as well as the problem of classification up to a continuous conjugacy. (Received September 18, 2011)

1077-37-1329 **Vaughn Climenhaga** (vclimenh@math.utoronto.ca) and **Daniel J Thompson*** (thompson@math.psu.edu). *Uniqueness of Equilibrium States: Constructive Techniques in a Non-Uniform, Non-Markov Setting.*

This work establishes uniqueness of equilibrium states for

1) a large class of shift spaces which includes every beta-shift; 2) a large class of potential functions which strictly includes those with the Bowen property.

As an application, our method yields new results in the theory of thermodynamic formalism for piecewise monotonic interval maps. Our method allows us to handle a variety of systems without a Markov structure, and it covers a class of potentials that are well behaved away from a 'small' set; for example, an indifferent fixed point or a point of discontinuity. Under a mild additional hypothesis, we establish (weighted) equidistribution results for the periodic orbits of the space. Our results can also be formulated so that they apply to some higher dimensional examples of geometric interest. (Received September 19, 2011)

1077-37-1330 **Skyler C Simmons***, 275 TMCB, Brigham Young University, Provo, UT 84602. *Invariant Sets of Hyperbolic Toral Automorphisms.*

Recently, open dynamical systems, which present the possibility of orbits "falling out" of the system and contributing nothing to the overall dynamics, have been gaining attention. Open systems in billiards have been the prototypical example. In this presentation, we consider open systems for hyperbolic toral automorphisms, and present results related to cardinality, connectivity, and dimension. These results are extended to general Anosov maps whenever possible. (Received September 19, 2011)

1077-37-1352 **Thomas Barthelmé*** (thomas.barthelme@math.unistra.fr), IRMA, 7 rue René-Descartes, 67084 STRASBOURG, France. *Isotopy class for orbits of skewed $\mathbb{R}$-covered Anosov flows.*

Skewed $\mathbb{R}$-covered Anosov flows are a type of flow on closed 3-manifolds such that the stable and unstable foliations are well-behaved (their leaf spaces are homeomorphic to $\mathbb{R}$). The geodesic flow of a negatively-curved surface for instance is of that type, but there are many different examples in all kinds of 3-manifolds. When the manifold is hyperbolic, any free-homotopy class of a periodic orbit contains infinitely many other periodic orbits. We study isotopy classes inside these free homotopy classes and related questions. (Received September 19, 2011)

1077-37-1362 **Sarah Day*** (sday@math.wm.edu), Department of Mathematics, College of William and Mary, P.O.Box 8795, Williamsburg, VA 23187, and **Benjamin Holman** (bholman@math.arizona.edu), Program in Applied Mathematics, University of Arizona, 617 N. Santa Rita Ave., P.O.Box 210089, Tucson, AZ 85721. *Quantifying Patterns in a Coupled-Patch Population Model.*

Coupled patch models of population dynamics combine local dynamics on patches with rules for dispersal of the population between patches. When an appropriate threshold is applied, population values give rise to patterns (in space) and may evolve in a complicated manner in time. I will discuss joint work with Benjamin Holman in which we study coupled Ricker maps and the complicated patterns they produce. We use computational homology, and in particular the computation of Betti numbers, to measure the patterns and their evolution in time. (Received September 19, 2011)

1077-37-1419 **Nicolai Haydn**, **Matthew Nicol*** (nicol@math.uh.edu), **Tomas Persson** and **Sandro Vaienti**. *A note on dynamical Borel-Cantelli lemmas for non-uniformly hyperbolic dynamical systems.*

Suppose (T, X, μ) is a dynamical system and (B_i) is a sequence of sets in X. We consider whether $T^i x \in B_i$ i. o.for μ a.e. $x \in X$. If $T^i x \in B_i$ i. o. for μ a.e. x we call the sequence (B_i) a Borel–Cantelli sequence. If the sets $B_i := B(p, r_i)$ are nested balls of radius r_i about a point p then the question of whether $T^i x \in B_i$ i. o. for μ a.e. x is often called the shrinking target problem.

We show, under certain assumptions on the measure μ, that for balls B_i if $\mu(B_i) \geq i^{-\gamma}$, $0 < \gamma < 1$, then a sufficiently high polynomial rate of decay of correlations for Lipschitz observables implies that the sequence is Borel–Cantelli. If $\frac{C_1}{i} \leq \mu(B_i) \leq \frac{C_2}{i}$ then exponential decay of correlations implies that the sequence is Borel–Cantelli. We give conditions in terms of return time statistics which quantitative Borel-Cantelli results for sequences of balls such that $\mu(B_i) \geq \frac{C}{i}$. Corollaries are that for Sinai planar dispersing billiards sequences of nested balls $B(p, 1/i)$ are Borel–Cantelli. We give applications to certain non-uniformly hyperbolic dynamical systems. (Received September 19, 2011)

1077-37-1444 **Michael Field*** (mikefield@gmail.com). *Mixing rates for flows.*
Although it is often assumed that hyperbolic theory is (now) well understood, rather little is still known about mixing for hyperbolic flows that do not satisfy strong geometric conditions (for example, contact Anosov flows). Nothing seems to be known about hyperbolic basic sets that are not attractors, repellors or suspensions of subshifts of finite type (or products of known examples). In this talk, we review some results about exponential mixing for suspension flows and compare with previous results on rapid mixing. (Received September 19, 2011)

1077-37-1460 **Jianyu Chen*** (j_chen@math.psu.edu), 723 W Cherry Ln Apt 1, State College, PA 16803, and **Huyi Hu** and **Yakov Pesin**. *A KAM phenomenon for volume-preserving flows.*
The persistence of invariant tori is not only common in Hamiltonian systems, but also in the volume-preserving systems. Outside those so-called "elliptic islands" , it is very possible that there is a "chaotic sea" with (nonuniformly) completely hyperbolic behavior. There are already several examples with this phenomenon in the category of volume-preserving diffeomorphisms. I shall present a volume-preserving flow of this type. More precisely, the flow is ergodic and has nonzero Lyapunov exponents on an open dense subset of not full measure, and has zero exponents on the complement consisting of codimension-2 invariant submanifolds. Moreover, the flow is indeed just a linear flow when restricted on each invariant submanifold. (Received September 19, 2011)

1077-37-1474 **Phillip O Williams*** (pwilliams@tkc.edu). *Towards a Dynamical Analogue of Szpiro's Conjecture.*
Szpiro's Conjecture says that the minimal discriminant of an elliptic curve over a number field is bounded in terms of its conductor. The analogue of this in the function field case has long since been proven, but the number field case is much more difficult, and is closely related to the ABC-conjecture.

The proper formulation of a dynamical analogue to Szpiro's conjecture, if such a formulation exists, is still very much an open project, and there are several promising ideas. We will assess the current state of the problem, discussing what the desirable features of such a conjecture might be, and what has been tried so far. Most generally, one would hope that such a conjecture would be approachable in the function field case and related to the ABC-conjecture in the number field case. The author along with Szpiro and Tepper have shown one natural formulation of the conjecture to be false in its full generality, in both the number field and function field cases. We will discuss ideas for repairing this, as well as another promising alternative approach recently suggested by Petsche.
(Received September 19, 2011)

1077-37-1540 **Juan Rivera-Letelier*** (riveraletelier@math.brown.edu). *Ergodic theory of p-adic rational maps.*
The topological entropy is one of the most important invariants of a topological dynamical system. It has been known since the late 1970s that the topological entropy of a rational map acting on the Riemann sphere is equal to the logarithm of its degree. However, this is not true for a p-adic rational map acting on Berkovich's projective line: the topological entropy could be zero and it is difficult to compute in general. We show a rigidity result for a p-adic rational map whose equidistribution measure does not charge the wildly ramified locus: if the topological entropy is not equal to the logarithm of its degree (as in the complex case), then the rational map possesses a smooth invariant metric. This is a work in progress with Charles FAVRE. (Received September 20, 2011)

1077-37-1545 **Abraham Freiji*** (afreiji@uab.edu), FOT 1020, 1530 3RD Ave S, Birmingham, AL 35294-3410, and **Hassan M Fathallah-Shaykh** (hfathall@uab.edu), FOT 1020, 1530 3RD Ave S, Birmingham, AL 35294-3410. *Limit Cycles, Bistability, and Global Stability by Two-Element Negative Loops in Biological Networks,.*
Negative loops, present in almost all prokaryotic and eukaryotic networks, are key to generating molecular oscillations. Here, we study the dynamics of 2-element negative loop motifs modeled by a new nonlinear system of ODE. The results reveal that a 2-element negative loop with a single positive and constant input leads to globally stable critical points while an interconnection with a positive loop admits limit cycles, Hopf birfurcations, and bistability but no tristability. The system of ODE, related to the Lotka-Volterra equations, offers insights on how the architecture of the network impacts its dynamics. (Received September 20, 2011)

1077-37-1549 **Hassan M Fathallah-Shaykh*** (hfathall@uab.edu), FOT 1020, 1530 3RD Ave S, Birmingham, AL 35294-3410, and **Abraham Freiji** (afreiji@uab.edu), FOT 1020, 1530 3RD Ave S, Birmingham, AL 35294-3410. *Global Asymptotic Stability in a Model of Biological Networks.*

Global asymptotic stability (GAS) is a key feature of the dynamical behavior of biological networks. We construct a suitable Lyapunov function for a system of ODEs, related to the Lotka-Voltera model, which models molecular networks and derive a sufficient condition for GAS. In particular, an n-dimensional system with interaction matrix $\boldsymbol{A}$ and a unique interior equilibrium is GAS if there exists a diagonal positive matrix $\boldsymbol{D}$ such that $\boldsymbol{DA} + \boldsymbol{A}^T\boldsymbol{D}$ is negative definite. This theorem is applied to derive conditions for GAS of negative feedback loop chains with or without feedback. The results are illustrated by numerical examples. (Received September 20, 2011)

1077-37-1552 **Anna L Mazzucato*** (alm24@psu.edu). *Ensemble Dynamics and Bred Vectors.*

We present some recent developments in the theory of "bred vectors". These are obtained by an appropriate rescaling of the forward evolution of an initial perturbation under a discrete non-linear system. Bred vectors are a widely used tool to assess sensitivity to initial conditions in weather forecasting models. We explore the role of bred vectors in studying dynamical systems by introducing the new concept of "ensemble bred vector", which is based on the notion of ensemble dynamics of initial perturbations, and showcase its distinctive features with two examples: one is the 3-equation Lorenz system, the other is a model of thermohaline circulation based on the Cahn-Hilliard equation. This is joint work with Nusret Balci, Juan M. Restrepo, and George R. Sell. (Received September 20, 2011)

1077-37-1598 **P. Christopher Staecker*** (cstaecker@fairfield.edu). *Dynamics of random selfmaps of surfaces with boundary and graphs.*

We use Wagner's algorithm to estimate the number of periodic points of certain selfmaps on compact surfaces with boundary. When counting according to homotopy classes, we can use the asymptotic density to measure the size of sets of selfmaps. In this sense, we show that "almost all" such selfmaps have periodic points of every period, and that in fact the number of periodic points of period n grows exponentially in n. We further discuss this exponential growth rate and the topological and fundamental-group entropies of these maps.

Since our approach is via the Nielsen number, which is homotopy and homotopy-type invariant, our results hold for selfmaps of any space which has the homotopy type of a compact surface with boundary.

This is joint work with Seungwon Kim, Kyungsung University, Busan, Korea. (Received September 20, 2011)

1077-37-1601 **Robert L. Devaney*** (bob@bu.edu), Math Dept., Boston University, Boston, MA 02215. *The Geometry of the Mandelbrot Set.*

In this lecture we show how the geometry of the boundary of the Mandelbrot set allows us to understand much of the dynamics of the quadratic polynomial $z^2 + c$. In particular, this boundary is by no means self-similar (and so not a fractal). We'll also see how the Fibonacci sequence and Farey addition arise in an interesting way in the Mandelbrot set. (Received September 20, 2011)

1077-37-1618 **Vaughn Climenhaga*** (vclimenh@math.toronto.edu) and **Daniel J Thompson**. *Unique equilibrium states using regular collections of times.*

Axiom A maps have the specification property, which Bowen used to prove uniqueness of equilibrium states for a broad class of potentials. This property often fails for partially hyperbolic maps and for uniformly expanding maps with discontinuities. We introduce a weaker version of the specification property that allows us to extend Bowen's results to many such maps. The same techniques allow us to treat a more general class of potentials than in the original result. (Received September 20, 2011)

1077-37-1905 **Jesse Berwald*** (jjberwald@wm.edu), **Tomas Gedeon** and **John Sheppard**. *Predicting Catastrophes In Dynamical Systems Using Machine Learning.*

Nonlinear dynamical systems, which include models of the Earth's climate, financial markets and complex ecosystems, often undergo abrupt transitions that lead to radically different behavior. The ability to predict such qualitative and potentially disruptive changes is an important problem with far-reaching implications. Even with robust mathematical models, predicting such critical transitions prior to their occurrence is extremely difficult. In this work we propose a machine learning method to study the parameter space of a complex system, where the dynamics is coarsely characterized using topological invariants. We show that by using a nearest neighbor algorithm to sample the parameter space in a specific manner, we are able to predict with high accuracy the locations of critical transitions in parameter space. (Received September 21, 2011)

1077-37-1964 **Elizabeth D Russell*** (elizabeth.russell@usma.edu), Department of Mathematical Science, Building 601, West Point, NY 10996. *Perturbations in the Quadratic Family with Multiple Poles.*

We consider the quadratic family of complex maps given by $q_c(z) = z^2 + c$ where c is chosen so that the critical point, 0, is periodic of period N. Then we introduce a singular perturbation by adding one pole to each point along the cycle. When $c = -1$ the Julia set is the well known basilica and the perturbed map is given by $f_\lambda(z) = z^2 - 1 + \lambda/(z^{d_0}(z+1)^{d_1})$. We will show that if λ is sufficiently small and the order of the poles satisfies a certain arithmetic condition, then the Julia set consists of the union of homeomorphic copies of the unperturbed Julia set, countably many Cantor sets of concentric closed curves, and Cantor sets of point components that accumulate on them. (Received September 21, 2011)

1077-37-2010 **Danilo Diedrichs*** (danilo-diedrichs@uiowa.edu), 2890 Coral Ct., #302, Coralville, IA 52241. *A Mathematical Model of the Unfolded Protein Response to Stress in the Endoplasmic Reticulum of Mammalian Cells.*

The unfolded protein response (UPR) is a cellular mechanism whose primary functions are to sense perturbations in the protein-folding capacity of the endoplasmic reticulum and to take corrective steps to restore homeostasis. Recent experimental results on mammalian cells show that the UPR is capable of producing qualitatively different outputs depending on the nature, strength, and persistence of the inducing stress. This study proposes a mechanistic framework (ODE model) based on biochemical rate equations to model the dynamics of the UPR as a network of interacting proteins and mRNAs. The model, calibrated by experimental data, includes the UPR's intrinsic feedback loops and allows for the integration of various forms of external stress signals. It can be used to predict the behavior and outcome (adaptation or apoptosis) of a cell when it is subjected to different forms of stress. Ramifications of a perturbation in the UPR can also be predicted, which is useful for the design of treatments of UPR-related diseases, such as diabetes and Parkinson's disease. (Received September 21, 2011)

1077-37-2019 **Rafail V. Abramov*** (abramov@math.uic.edu), University of Illinois at Chicago, 851 S. Morgan st. (M/C 249), Chicago, IL 60607. *Suppression of chaos at slow variables by rapidly mixing fast dynamics.*

Chaotic multiscale dynamical systems are common in many areas of science, one of the examples being the interaction of the low-frequency dynamics in the atmosphere with the fast turbulent weather dynamics. One of the key questions about chaotic multiscale systems is how the fast dynamics affects chaos at the slow variables, and, therefore, impacts uncertainty and predictability of the slow dynamics. We demonstrate that the linear slow-fast coupling with the total energy conservation property promotes the suppression of chaos at the slow variables through the rapid mixing at the fast variables, both theoretically and through numerical simulations. (Received September 21, 2011)

1077-37-2029 **Eugen Andrei Ghenciu*** (eghenciu@ecok.edu), 505 Stadium Dr. #B, Ada, OK 74820, and **Mario Roy**. *Gibbs states for non-irreducible countable Markov shifts.* Preliminary report.

We study Markov shifts over countable (finite or countably infinite) alphabets, i.e. shifts generated by incidence matrices. In particular, we derive necessary and sufficient conditions for the existence of a Gibbs state for a certain class of infinite Markov shifts. We further establish a characterization of the existence, uniqueness and ergodicity of invariant Gibbs states for this class of shifts. Our results generalize the well-known results for finitely irreducible Markov shifts. (Received September 21, 2011)

1077-37-2115 **Keith Burns*** (burns@math.northwestern.edu), Department of Mathematics, Northwestern University, 2033 Sheridan Rd, Evanston, IL 60208, **Howard Masur** (masur@math.uchicago.edu), Department of Mathematics, University of Chicago, 5734 S. University Ave., Chicago, IL 60637, and **Amie Wilkinson** (wikinso@math.northwestern.edu), Department of Mathematics, Northwestern University, 2033 Sheridan Rd, Evanston, IL 60208. *Ergodicity of the Weil Petersson geodesic flow.*

The Weil-Petersson metric is a Riemannian metric on the moduli space of a surface. It has negative curvature, but is incomplete. Analogy with the results of Hopf and Anosov for complete metrics of negative curvature suggested that the geodesic flow for the Weil-Petersson metric should be ergodic, but the incompleteness of the metric and insufficient knowledge of its geometry delayed a proof. We now know a great deal about the geometry of the Weil-Petersson metric, in large part due to the work of Scott Wolpert, and ergodicity of the geodesic flow has been proved by Burns, Masur and Wilkinson. The proof uses the results of Wolpert and the theory of nonuniformly hyperbolic dynamical systems, in the particular the work of Katok and Strelcyn. (Received September 21, 2011)

1077-37-2183 **Yakov I Berchenko-Kogan*** (yashabk@math.mit.edu), Department of Mathematics, MIT, 2-091, 77 Massachusetts Avenue, Cambridge, MA 02139. *Uncovering the Lagrangian from observations of trajectories.* Preliminary report.

Given discrete measurements of trajectories of an unknown dynamical system, we provide a method motivated by variational integrators for automatically modelling the system. We write the discrete Lagrangian as a quadratic polynomial with varying coefficients, and then use the discrete Euler-Lagrange equations to numerically solve for the values of these coefficients near the data points. This method correctly modelled the Lagrangian of a simple harmonic oscillator and a simple pendulum, even with significant measurement noise added to the trajectories. (Received September 21, 2011)

1077-37-2229 **William Gignac*** (wgignac@umich.edu), Department of Mathematics, 2074 East Hall, 530 Church St, Ann Arbor, MI 48109. *Equidistribution of Preimages in Berkovich Projective Space.*

In complex dynamics, in particular in the study iteration of holomorphic maps $f\colon \mathbb{P}^k \to \mathbb{P}^k$, an important result is that the iterated preimages $f^{-n}(x)$ of generic points $x \in \mathbb{P}^k$ equidistribute to the equilibrium measure on the Julia set of f. This result has recently been extended to the Berkovich projective line over nonarchimedean fields by Favre and Rivera-Letelier. In this talk I will discuss the problem of equidistribution of preimages in higher dimensional Berkovich projective spaces over trivially valued fields. (Received September 21, 2011)

1077-37-2302 **Tushar Das*** (tushardas.math@gmail.com). *Kleinian Limit Sets in Hilbert Space.*

We develop the theory of discrete groups acting by hyperbolic isometries on the open unit ball of an infinite-dimensional separable Hilbert space. We build appropriate analogs of thermodynamic formalism, ergodic theory and geometric measure theory to study the geometry of limit sets at the sphere at infinity.

The existence of fix-points of isometries and their structure will be discussed. We define the concepts of strongly discrete groups and convex-cobounded groups and characterize them in terms of radial points in the limit set and go on to characterize the groups whose limit sets are compact.

We will sketch some of the ideas that go into proving a generalization of the Bishop-Jones theorem, equating the Hausdorff dimension of the radial limit set with the exponent of convergence of the Poincare series associated to the group.

Classical Schottky groups (both fintely and infinitely generated) provide a rich abundance of examples and time permitting, we present a Sullivan-type Rigidity Theorem for the Schottky class.

This is joint work with Bernd Stratmann (Bremen) and Mariusz Urbanski (UNT). (Received September 22, 2011)

1077-37-2394 **Lucas Manuelli** (manuelli@princeton.edu) and **Jared Hallett*** (jared.hallett@gmail.com), Williamstown, MA 01267, and **Cesar E. Silva** (csilva@williams.edu). *On Li-Yorke Measurable Sensitivity.* Preliminary report.

The notion of Li-Yorke sensitivity has been studied extensively in the case of topological dynamical systems. We introduce a measurable version of Li-Yorke sensitivity, for nonsingular (and measure-preserving) dynamical systems, and compare it with various mixing notions. It is known that in the case of nonsingular dynamical systems, ergodic Cartesian square implies double ergodicity, which in turn implies weak mixing, but the converses do not hold in general, though they are all equivalent in the finite measure-preserving case. We show that for nonsingular systems, ergodic Cartesian square implies Li-Yorke measurable sensitivity, which in turn implies weak mixing. As a consequence we obtain that, in the finite measure-preserving case, Li-Yorke measurable sensitivity is equivalent to weak mixing. We also show that with respect to totally bounded metrics, double ergodicity implies Li-Yorke measurable sensitivity, and extend the known result that weak mixing implies measurable sensitivity for finite measure-preserving systems to the case of infinite measure-preserving systems. (Received September 22, 2011)

1077-37-2417 **Ilya Grigoriev** (ilyagr@stanford.edu), **Catalin Cătălin Lubin** (mci@cs.stanford.edu), **Amos Lubin** (incenate@gmail.com), **Nathaniel Ince** and **Cesar E. Silva*** (csilva@williams.edu), Mathematics Department, Williams College, Williamstown, MA 01267. *On μ-Compatible Metrics and Measurable Sensitivity.*

We introduce the notion of W-measurable sensitivity, which extends and strictly implies canonical measurable sensitivity, a measure-theoretic version of sensitive dependence on initial conditions. This notion also implies pairwise sensitivity with respect to a large class of metrics. We show that nonsingular ergodic and conservative dynamical systems on standard spaces must be either W-measurably sensitive, or isomorphic mod 0 to a minimal uniformly rigid isometry. In the finite measure-preserving case they are W-measurably sensitive or measurably isomorphic to an ergodic isometry on a compact metric space. (Received September 22, 2011)

1077-37-2518 **David Richeson** and **Jim Wiseman*** (jwiseman@agnesscott.edu), Agnes Scott College, Dept. of Mathematics, 141 E. College Ave., Decatur, GA 30030. *Ambiguous shifts: symbolic dynamics from open covers.*

We consider shifts in which elements of the alphabet may overlap nontransitively. Such shifts arise as models for discrete dynamical systems on spaces covered by a finite collection of open sets, in which case an orbit's itinerary may be ambiguously defined. We define a notion of entropy for ambiguous shifts, and show that it is equal to a limit of entropies of (standard) full shifts and gives a lower bound for the topological entropy of the original dynamical system. (Received September 22, 2011)

1077-37-2527 **Anthony Tongen*** (tongenal@jmu.edu), MSC 1911; Department of Mathematics and Stat, James Madison University, Harrisonburg, VA 22807, and **Roger J. Thelwell** and **David Becerra-Alonso**. *Reinventing the Wheel: The Chaotic Sandwheel.* Preliminary report.

The Malkus chaotic waterwheel, a tool to physically demonstrate Lorenzian dynamics, motivates the study of a chaotic sandwheel. We model the sandwheel in parallel with the waterwheel when possible, noting where methods may be extended and where no further analysis seems feasible at this point. Numerical simulations are used to compare and contrast the behavior of the sandwheel with the waterwheel. Simulations confirm that the sandwheel retains many of the elements of chaotic Lorenzian dynamics. However, bifurcation diagrams show the dramatic differences in the places where the order-chaos-order transitions occur. (Received September 22, 2011)

1077-37-2555 **Anatole Katok*** (katok_a@math.psu.edu), Department of Mathematics, Pennsylvania State University, University Park, PA 16802. *Actions of higher rank abelian groups: from measure rigidity to arithmeticity to topology.*

We will describe a recent progress in the "non-uniform measure rigidity" program started in 2007 and pursued in collaboration with Boris Kalinin and Federico Rodriguez Hertz in various combinations. We show that for a smooth action of discrete higher rank abelian group preserving an ergodic measure assumptions of general dynamical nature including linear algebra of Lyapunov exponents and entropy imply striking rigidity properties. In particular, the action, restricted to a subgroup of finite index, is isomorphic in the sense of ergodic theory to a finite factor of action by automorphisms of a torus. Under a maximal rank assumption strong conclusions on topology of the ambient manifold are also derived. Results presented in this talk are joint with Federico Rodriguez Hertz. (Received September 22, 2011)

1077-37-2591 **Allison L. Corish***, Department of Mathematics, College of William & Mary, P.O. Box 8795, Williamsburg, VA 23187-8795, **Sarah Day**, Department of Mathematics, College of William & Mary, P.O. Box 8795, Williamsburg, VA 23187-8795, and **M. Drew LaMar**, Department of Biology, College of William & Mary, 2137 Integrated Science Center, Williamsburg, VA 23187. *Global Dynamics of Pulse-Coupled Oscillators.* Preliminary report.

Networks of pulse-coupled oscillators can be used to model systems from firing neurons to blinking fireflies. Many past studies have focused on numerical simulations and locating the synchronous state of such systems. In this project, we construct a Poincare map for a system of three pulse-coupled oscillators and use rigorous computational techniques and topological tools to study asynchronous dynamics. We will present sample results, focusing on periodic behavior in the system. (Received September 22, 2011)

1077-37-2630 **Vadim Kaimanovich*** (vkaimano@uottawa.ca), 585 King Edward, Ottawa, ON K1N 6N5, Canada. *Fractals and hyperbolicity.* Preliminary report.

Various fractal sets can naturally be presented as boundaries of the associated Gromov hyperbolic graphs. The talk will be devoted to a discussion of ramifications of this idea. (Received September 22, 2011)

1077-37-2675 **Clinton P Curry** (ccurry@huntingdon.edu), Dept. of Mathematics- Huntingdon College, Montgomery, AL, **John C Mayer*** (mayer@math.uab.edu), Dept. of Math - UAB, Birmingham, AL 35294-1170, and **E. D. Tymchatyn** (tymchat@math.usask.ca), Dept. of Math, University of Sakatchewan, McLean Hall, Saskatoon, Sask. S7N 5E6, Canada. *Buried Points in Rational Julia Sets Have Full Geometric and Dynamical Measure.*

The Julia and Fatou sets of a rational function R on the Riemann sphere split the sphere into two fully invariant subsets, closed and open, respectively, the former unstable or chaotic in its rational dynamics, and the latter stable (but possibly empty). Assume the Fatou set is nonempty. In that case, a second, less well-known, split of the Julia set $J = J(R)$ itself is into the set of buried points $\mathrm{Bur}(J)$ and the set of non-buried points (the former possibly empty). A point in the Julia set is *buried* iff it is not on the boundary of any component of the Fatou set. If $\mathrm{Bur}(J)$ is nonempty, it is a dense G_δ subset of J, thus "fat" topologically. We prove in this talk that $\mathrm{Bur}(J)$ is also "fat" in measure. If μ denotes the measure of maximal entropy supported on J, then $\mathrm{Bur}(J)$, if nonempty. is of full μ-measure. If ν denotes conformal measure supported on J, then, in those cases where the conformal exponent is unique, again $\mathrm{Bur}(J)$, if nonempty, is of full ν -measure. (Received September 22, 2011)

1077-37-2716 **Rafe Jones*** (rjones@holycross.edu). *Fixed-point-free elements of iterated monodromy groups.* Preliminary report.

I will define the iterated monodromy group of a post-critically finite complex polynomial, and explain how it acts naturally on the tree T of preimages of a generic point. I'll then give a theorem showing that for nearly all non-Chebyshev polynomials, the set of group elements fixing at least one point on the boundary of T has Haar measure zero. Finally, I'll give a brief sketch of how these ideas relate to a natural question about the density of periodic orbits in dynamics over the algebraic closure of a finite field. (Received September 22, 2011)

1077-37-2833 **Jeffrey F. Brock*** (Jeff_Brock@brown.edu), Department of Mathematics, Brown University, Box 1917, Providence, RI 02912. *Recurrence and unique ergodicity for Weil-Petersson geodesics and their ending laminations.*

We investigate the role of the ending lamination associated to a Weil-Petersson geodesic ray in determining the trajectory of the ray. A Theorem of H. Masur guarantees that a Teichmüller geodesic that recurs to the thick part of Teichmüller space has associated vertical foliation that is uniquely ergodic – in contrast, we exhibit recurrent Weil-Petersson geodesic rays with ending laminations that are not uniquely ergodic. In this talk I will explore other relations, both well-understood and conjectural, between properties of the ending lamination and properties of the ray. (Received September 22, 2011)

1077-37-2905 **Lucy E. Spardy*** (les65@pitt.edu), 301 Thackeray Hall, Pittsburgh, PA 15205, and **Sergey N. Markin**, **Natalia A. Shevtsova**, **Boris I. Prilutsky**, **Ilya A. Rybak** and **Jonathan E. Rubin**. *A dynamical systems analysis of afferent control in a neuromechanical model of locomotion.*

We analyze a simplified model of mammalian locomotion where a spinal central pattern generator (CPG) is coupled to a biomechanical limb system, with afferent feedback to the spinal circuits and CPG closing the control loop. In this model, the CPG establishes a rhythm when a "supra-spinal" drive is present, and afferent feedback from a one-joint limb helps to stabilize the CPG operation and control the timing of phase switches. Increasing the drive intensity to the CPG yields an increase in locomotor speed by reducing the duration of the stance phase, at a relatively constant duration of the swing phase, a phase asymmetry observed in normal locomotion in cats. Transitions associated with changes in ground reaction force or motoneuron outputs abruptly alter the vector field in the limb dynamics phase plane. We show how the position of the locomotor oscillation trajectory relative to these transient vector fields and their critical points explain the model's ability to replicate this experimentally observed locomotor asymmetry. This analysis, along with observations gained from explaining the mechanism responsible for rhythm generation, allows us to establish a reduced model for which an argument for existence and uniqueness of a periodic orbit can be constructed. (Received September 22, 2011)

1077-37-2936 **Aimee S.A. Johnson** (aimee@swarthmore.edu) and **David M. McClendon*** (dmcclen1@swarthmore.edu), Department of Mathematics and Statistics, 500 College Ave., Swarthmore, PA 19081. *Speedups of ergodic $\mathbb{Z}^d$ actions.*

A *speedup* of a measure-preserving transformation (m.p.t.) (X, μ, T) is another m.p.t. (X, μ, S) where $S(x) = T^{p(x)}(x)$ for some measurable function $p : X \to \{1, 2, 3, ...\}$. Arnoux, Ornstein and Weiss showed that given any two ergodic m.p.t.s, there is a speedup of one which is isomorphic to the other. Recently, a relative version of this result dealing with ergodic group extensions was obtained by Babichev, Burton and Fieldsteel.

In this talk we discuss what is meant by a *speedup* of an action of d commuting m.p.t.s, and describe results which generalize the aforementioned ideas to ergodic actions of $\mathbb{Z}^d$. (Received September 23, 2011)

39 ► Difference and functional equations

1077-39-30 **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, Iasi 700506, Romania. *Positive solutions for a system of second order multipoint discrete boundary value problems.*

Sufficient conditions are given on λ, μ, f and g for which there exist positive solutions of the system of nonlinear second order difference equations, $\Delta^2 u_{n-1} + \lambda c_n f(u_n, v_n) = 0$, $\Delta^2 v_{n-1} + \mu d_n g(u_n, v_n) = 0$, $n \in \{1, \dots, N-1\}$, satisfying the multipoint boundary conditions, $\alpha u_0 - \beta \Delta u_0 = 0,\ u_N = \sum_{i=1}^{m-2} a_i u_{\xi_i},\ m \geq 3$, and $\gamma v_0 - \delta \Delta v_0 = 0,\ v_N = \sum_{i=1}^{p-2} b_i v_{\eta_i},\ p \geq 3$. The Guo-Krasnosel'skii fixed point theorem for positive operators on a cone is applied. (Received June 14, 2011)

1077-39-107 **James C Cameron*** (j_cameron@utexas.edu), **Luis Diego Granera**, **Peter Jaworski** and **Loren Santana**. *Discrete Models with Proportional Harvesting.*

Difference equations used to model populations are analyzed, and we show how to control stability and induce chaos using proportional harvesting. In particular, we use the Beverton-Holt and Ricker models with proportional harvesting to demonstrate that a harvested system can be more stable than its unharvested counterpart. We also use digraphs to analyze the periodic structure of continuous functions, and we provide necessary and sufficient conditions for a digraph to support a continuous or piecewise monotone function. (Received July 27, 2011)

1077-39-113 **Kenneth R. Ball*** (krball@ncsu.edu), Box 8205, NCSU Campus, Raleigh, NC 27695, and **Dmitry V. Zenkov**. *Difference equations for long-term simulation of mechanical systems.* Preliminary report.

The importance of preservation of various structures of mechanical systems by discrete models has long been acknowledged. It is possible to interpret the dynamics of a mechanical system as a variational problem. Discretizations of variational formulations – as opposed to discretizations of the corresponding differential equations of motion – lead to difference equations that acknowledge these structures and demonstrate good long-term behavior. In this talk we will discuss the extension of this strategy to systems with velocity constraints (such as non-slip conditions on carwheels) using suitable variational principles and show that the resulting difference equations correctly model the constraints. (Received July 27, 2011)

1077-39-301 **Mustafa R. S. Kulenovic*** (mkulenovic@mail.uri.edu), Department of Mathematics, The University of Rhode Island, Kingston, RI 02881, and **Orlando Merino** and **Mehmed Nurkanovic**, Tuzla, Bosnia-Herzegovina. *Global Dynamics of Certain Competitive System in the Plane.*

The competitive system of difference equations

$$x_{n+1} = \frac{a + x_n}{b + y_n}, \quad y_{n+1} = \frac{d + y_n}{e + x_n}, \quad n = 0, 1, \dots$$

where the parameters a, b, c and d are positive real numbers, and the initial conditions x_0 and y_0 are nonnegative real numbers is considered.

A complete classification of all possible dynamical behavior scenarios according to all different parameter configurations is obtained. (Received August 19, 2011)

1077-39-360 **George A Anastassiou*** (ganastss@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152. *Representations and Ostrowski type inequalities on Time scales.* Preliminary report.

Here we give univariate and multivariate representations of Montgomery type for hybrid functions on Time scales. Based on these we establish univariate and multivariate Ostrowski type inequalities on Time scales domains. These compare the average of a function to its values. The estimates involve the higher order delta and nabla derivatives and partial derivatives. We finish with applications on the time scales R and Z. (Received August 25, 2011)

1077-39-385 **Paul R Bouthellier*** (pbouthe@pitt.edu), 504 East Main Street, Titusville, PA 16354. *Studying the Solutions and Stability of Difference Equations with Time-Varying Coefficients.*

In most classes in differential equations and numerical analysis, the solution and stability of difference equations are only considered for equations with constant coefficients. However, in many areas, such as mathematical modeling for economic and engineering systems, time-varying systems are required. In this talk we shall consider the solution and stability of difference equations with time-varying coefficients. It will be shown, via interactive programs, how perturbations in the coefficients affect the solutions and stability of such systems. It often surprises students how fast small perturbations in the coefficients can build up. The projects we shall consider will allow students to see how small errors in the systems coefficients affect the systems over time and hence emphasize the need for accuracy in modeling, measuring, and programming. (Received August 28, 2011)

1077-39-470 **Frank J. Palladino*** (frank@math.uri.edu). *On Periodic Trichotomies.*
We discuss several general periodic trichotomy results in the literature. We discuss some open questions regarding periodic trichotomies and several patterns of periodic trichotomy behavior. (Received September 03, 2011)

1077-39-475 **Vlajko L Kocic*** (vkocic@xula.edu), Mathematics Department, Xavier Univesrity of Louisiana, 1 Drexel Dr., New Orleans, LA 70125. *Global Asymptotic Behavior of Some Periodically Forced Discrete Nonlinear Population Models.* Preliminary report.
We study the boundedness, the extreme stability, the existence, and the attractivity of periodic solutions of certain periodically forced nonlinear discrete population models. In addition, we investigate the attenuance and the resonance of such periodic solutions. (Received September 03, 2011)

1077-39-490 **Gerasimos E. Ladas*** (geladas@mail.uri.edu), University of Rhode Island, Department of Mathematics, Kingston, RI 02881. *Open Problems and Conjectures in Difference Equations.* Preliminary report.
We present some new results and we pose several open problems and conjectures on the global character of solutions of rational difference equatons and systems of rational difference equations. We are interested in patterns of boundedness, invariants, global stability results, periodic solutions, convergence to periodic solutions and periodic trichotomies. During the last two years with my collaborators and students we have discovered 15 patterns of boundedness for rational systems in the plane which (with a few conjectures about a small number of special cases) determine the boundedness character of each of the 2401 special ceses of rational systems in the plane. These patterns offer a fertile area of research in the global character of solutions of rational difference equations and systems. (Received September 04, 2011)

1077-39-539 **Fei Xue*** (xue@hartford.edu), Department of Mathematics, University of Hartford, West Hartford, CT 06117, and **Harry Gingold** (gingold@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26506-6310. *Asymptotic summation of right almost diagonal difference systems.*
We derived a new technique for the asymptotic summation of linear systems of difference equations $Y(t+1) = (D(t)+R(t))Y(t)$. A fundamental solution $Y(t) = \Phi(t)(I+P(t))$ is constructed in terms of a product of two matrix functions. The first function $\Phi(t)$ is a product of the diagonal part $D(t)$. The second matrix $I+P(t)$, is a perturbation of the identity matrix I. Conditions are given on the matrix $D(t)+R(t)$ that allow us to represent $I+P(t)$ as an absolutely convergent resolvent series without imposing stringent conditions on $R(t)$. (Received September 06, 2011)

1077-39-669 **Tyrus Berry*** (tyrus.berry@gmail.com), 4400 University Drive, Mail Stop 3F2, Fairfax, VA 22030, and **Tim Sauer**. *Convergence of periodically forced rank-type equations.*
We study periodically-forced rank-type difference equations, which evolve according to the kth largest output of m functions of the previous m terms of the sequence. We show that with appropriate contraction and more general hypotheses, such non-autonomous difference equations are shown to converge to a periodic limit, which is independent of the initial condition. The solution period is equal to the period of the forcing, and does not depend on how far back each term is allowed to look back in the sequence. (Received September 09, 2011)

1077-39-750 **Chris D Lynd*** (chris_lynd@my.uri.edu). *The Global Character of Solutions of Rational Systems in the Plane.*
We will present the global character of solutions for several rational systems of difference equations in the plane. (Received September 12, 2011)

1077-39-788 **Lynn Erbe**, **Raziye Mert** and **Allan Peterson*** (apeterson1@math.unl.edu), Math Dept, 237 Avery, University of Nebraska-Lincoln, Lincoln, NE 685880130. *Spectral parameter power series for Sturm-Liouville problems on time scales.* Preliminary report.
We will derive formulas for finding two linearly independent solutions of the Sturm-Liouville dynamic equation. We will give several examples. In particular the q-difference equation which has important applications in quantum theory will be presented. (Received September 12, 2011)

1077-39-794 **E Grove**, **G Ladas**, **E Lapierre*** (evelina@cox.net) and **W Tikjha**. *The Global Characteristics of a Family of Systems of Piecewise Linear Difference Equations.*

We give a detailed analysis, complete with open problems and conjectures, of the global character of the solutions of the piecewise linear difference equations

$$\begin{cases} x_{n+1} &= |x_n| + ay_n + b \\ \\ y_{n+1} &= x_n + c|y_n| + d \end{cases}, \quad n = 0, 1, \ldots$$

where the initial condition $(x_0, y_0) \in \mathbf{R}^2$ and the parameters $a, b, c, d \in \{-1, 0, 1\}$. (Received September 12, 2011)

1077-39-921 **M Predescu*** (mpredescu@bentley.edu). *On a nonlinear system of difference equations.*

This talk will present a nonlinear system of difference equations that appears in the mathematical biology literature. We will investigate the global stability and the boundedness character of solutions. We will consider rational dependent functions acting on each of the system parameters at a time. (Received September 14, 2011)

1077-39-968 **Lucia Di Vizio***, UMR 8100, CNRS, Université de Versailles-St Quentin, 45 avenue des États-Unis, 78035 Versailles cedex, France, and **Charlotte Hardouin**. *Descent for differential Galois theory of difference equations. Confluence and q-dependency.* Preliminary report.

First of all, we explain how different autors have succeded to descent the differential Galois theory for difference equations constructed by Hardouin-Singer from a differentially closed to an algebraically closed field.

In the second part of the paper, we show that the theory can be applied to deformations of q-series, to study the differential dependency with respect to $x\frac{d}{dx}$ and $q\frac{d}{dq}$. We show that the differential Galois group of the Jacobi Theta function can be considered as the galoisian counterpart of the heat equation. (Received September 15, 2011)

1077-39-975 **Gabriel Lugo** and **Frank J. Palladino*** (frank@math.uri.edu). *On the Dynamics of some Competitive Rational Systems in the Plane.*

We will discuss the dynamics of several different competitive rational systems in the plane. The parameter space will be divided into regions. We will discuss the qualitative behavior in each region. (Received September 15, 2011)

1077-39-1041 **Emmanouil Drymonis*** (mdrymonis@math.uri.edu), 5 Lippitt Road, Department of Mathematics, University of Rhode Island, Kingston, RI 02881. *Patterns of Boundedness of Rational Systems in the Plane.* Preliminary report.

We present the patterns of boundedness of some rational systems in the plane. We establish easily verifiable necessary and sufficient conditions, explicitly stated in terms of the parameters of the systems, which determine the boundedness character of all special cases of the systems. We also present several global stability results. (Received September 15, 2011)

1077-39-1070 **Adrian Stefan Carstea*** (carstea@gmail.com), Srg. Latea Gheorghe Street, #15, Bl.C71,Ap.18, Bucharest, Romania. *On the Q4-elliptic Painleve equation and rational elliptic surfaces.*

We discuss singularity structure and deautonomization of the (p,q)-reduction of the ABS-Q4 lattice equation. Also the action on the fibers of rational elliptic surfaces obtained by blowing ups is analized. Reductions and deautonomisations of Q3 and Q2 lattice equations are studied as well, showing the linearisable character of the corresponding mappings. (Received September 16, 2011)

1077-39-1087 **Mary Michael Forrester*** (forremm0@sewanee.edu). *Statistical functional equations in the plane.*

I will present some new results for statistical functional equations in the plane that generalize the mean value property of harmonic functions. The talk will focus on discretizations of these equations on uniform rectangular grids; an algorithm for the corresponding boundary value problem and existence and uniqueness results will be discussed. (Received September 16, 2011)

1077-39-1161 **M. R. S. Kulenovic*** (mkulenovic@mail.uri.edu), Lippitt Hall, Kingston, RI 02881, and **Ed Janowski**, Lippitt Hall, Kingston, RI. *Attractivity and Global Stability for Linearizable Difference Equations.*

Consider the difference equation

$$x_{n+1} = f(x_n, \ldots, x_{n-k}), \quad n = 0, 1, \ldots$$

where $k \in \{0, 1, \ldots\}$ and the initial conditions are real numbers. We use the linearization of this equation in the form

$$x_{n+l} = \sum_{i=1-l}^{k} g_i x_{n-i}, \quad n = 0, 1, \ldots$$

where $l \in \{1, 2, \ldots\}$ and the functions $g_i : R^{k+l} \to R$ to investigate the asymptotic behavior of the solutions of the considered equation. We illustrate our results with various examples of rational difference equations. Some of our results will lead to global dynamics of certain difference equations. (Received September 17, 2011)

1077-39-1237 **Saber N Elaydi*** (selaydi@trinity.edu), One Trinity Place, San Antonio, TX 78212, and **Rafael Luis**, Lisbon, Portugal. *When does local stability imply global stability in planar competition models?*

Our main objective is to show that, for certain planar discrete competition models, local stability implies global stability. In particular, we prove global stability of the positive fixed point for the classical Ricker competition model and for the logistic competition by utilizing a combination of analytic and topological tools specific to planar dynamical systems. In addition, the theory of critical curves will play a central role in our analysis. Our method for establishing global stability can be extended and generalized to include a large class of nonlinear planar maps. (Received September 18, 2011)

1077-39-1259 **Saber N Elaydi*** (selaydi@trinity.edu), One Trinity Place, San Antonio, TX 78212, and **George Livadiotis**, San Antonio, TX. *General Allee effect and semistability in planar difference equations.*

We present a general framework for the notion of Allee effect in planar dynamical systems. Here the basic assumption is that the extension equilibrium $(0, 0)$ is locally attracting. The boundary of the basin of attraction of $(0, 0)$ will be called the Allee curve, which corresponds to the Allee-point in one-dimensional dynamics. We show how a phase space core of only three or four equilibrium points is sufficient to describe the essential dynamics that characterize the notion of the Allee effect. The traditional three types of stability (Attractor,Repeller,Saddle) allow the existence of only one case of a $3-point$ core and three cases of a $4-point$ core. A richer dynamics occurs if we add to those three stability types the notion of semistability. This phenomenon may be present only if one of the eigenvalues of the Jacobian of the map is unity. We provide the sufficient conditions for the existence of a semistable equilibrium, using the center manifold theory. Then we show that the existence of semi-stable equilibrium points increases dramatically the number of the possible cases of $3-$ or $4-point$ cores. Several examples will be provided to illustrate our theory. (Received September 18, 2011)

1077-39-1260 **Yevgeniy Kostrov** and **Zachary Kudlak*** (zachary.kudlak@msmc.edu), Mount Saint Mary College, 330 Powell Avenue, Newburgh, NY 12550. *On Rational Difference Equations with Nonnegative Periodic Coefficients.* Preliminary report.

In this preliminary report, we investigate the boundedness and convergence of rational difference equations with nonnegative periodic coefficients. (Received September 18, 2011)

1077-39-1340 **Youssef N Raffoul*** (youssef.raffoul@notes.udayton.edu), youssef.raffoul@notes.udayton.edu, Dayton, OH 45469-2316. *Periodicity In General Delay Nonlinear Difference Equations Using Fixed Point Theory.*

Using Schaefer's fixed-point theorem, enabling us to show that if there is an a priori bound on all possible T-periodic solutions of

$$\Delta x(n) = F(n,\ x_n),$$

then there is a T-periodic solution. The a priori bound will be established by different methods including non-negative Lyapunov functionals. Examples illustrating the developed theory are provided.
(Received September 19, 2011)

1077-39-1389 **Kristen K Abernathy*** (abernathyk@winthrop.edu) and **Jesus Rodriguez**. *Existence of Solutions to Boundary Value Problems at Full Resonance.*

The focus of this talk is the study of nonlinear differential equations of the form

$$\dot{x_i}(t) = a_i(t)x_i(t) + f_i(\epsilon, t, x_1(t), \cdots, x_n(t)), \;\; i = 1, 2, \cdots, n,$$

subject to two-point boundary conditions

$$b_i x_i(0) + d_i x_i(1) = 0, \quad i = 1, 2, \cdots, n.$$

We formulate sufficient conditions for the existence of solutions based on the dimension of the solution space of the corresponding linear, homogeneous equation and the properties of the nonlinear term when $\epsilon = 0$. We present the case when the solution space of the corresponding linear, homogeneous equation is n-dimensional; that is, when the system is at full resonance. The argument we use relies on the Lyapunov-Schmidt Procedure and the Schauder Fixed Point Theorem. (Received September 19, 2011)

1077-39-1406 **Kevin Ahrendt** (kahrendt@gmail.com), **Lucas Castle*** (lucas.c.castle@gmail.com), **Holm Michael** (s-mholm3@math.unl.edu) and **Kathryn Yochman** (yochmake@rose-hulman.edu). *Nabla Discrete Fractional Calculus.*

We will first define positive and negative nabla fractional differences for functions defined on $N_a = \{a, a+1, a+2, \cdots\}$. The corresponding discrete nabla Laplace transform will be defined and we will prove several properties of these nabla Laplace transforms including the nabla Laplace transform of fractional Taylor monomials. The discrete nabla Mittag-Leffler function will be introduced and we will derive a variation of constants formula for solving nabla discrete fractional initial value problems. Finally we will show how to use our Laplace transform results to prove composition properties of nabla fractional differences. (Received September 19, 2011)

1077-39-1500 **Candace M. Kent*** (cmkent@vcu.edu), Dept. of Mathematics & Applied Mathematics, Virginia Commonwealth University, P.O. Box 842014, Richmond, VA 23284-2014, and **Witold Kosmala** (kosmalaw@bellsouth.net), Dept. of Mathematics, Appalachian State University, Boone, NC 28608. *On the Nature of Solutions of the Difference Equation* $x_{n+1} = x_n x_{n-3} - 1$.

We investigate the long-term behavior of solutions of the difference equation $x_{n+1} = x_n x_{n-3} - 1\,, n = 0\,, 1\,, \ldots\,,$ where the initial conditions $x_{-3}\,, x_{-2}\,, x_{-1}\,, x_0$ are real numbers. In particular, we look at the periodicity and asymptotic periodicity of solutions, as well as the existence of unbounded solutions. (Received September 20, 2011)

1077-39-1633 **Gerry Ladas*** (geladas@mail.uri.edu), Kingston, RI 02881. *Patterns of boundedness for systems of rational difference equations.*

We present 15 patterns of boundedness which describe the boundedness characterizations of all special cases of the rational system:

$$x_{n+1} = \frac{\alpha_1 + \beta_1 x_n + \gamma_1 y_n}{A_1 + B_1 x_n + C_1 y_n} \text{ and } y_{n+1} = \frac{\alpha_2 + \beta_2 x_n + \gamma_2 y_n}{A_2 + B_2 x_n + C_2 y_n}$$

with nonnegative parameters and nonnegative initial conditions.

The patterns have been established in all special cases except for the special case of May's Host-Parasitoid Model which still remains a conjecture.

We also present several thought provoking open problems and conjectures on the global character of solutions of this system and its extensions to higher order spaces.

During the last two years with my collaborators and students we have discovered 15 patterns of boundedness for rational systems in the plane which (with a few conjectures about a small number of special cases) determine the boundedness character of each of the 2401 special cases of rational systems in the plane. These patterns offer a fertile area of research in the global character of solutions of rational difference equations and systems. (Received September 20, 2011)

1077-39-1642 **Gabriel Lugo*** (glugo@math.uri.edu) and **Frank Palladino**. *Further Consequences of the m-M Theorem.* Preliminary report.

A lemma is presented that proves than an equilibrium globally asymptotically stable under appropriate hypotheses. This lemma is used to strengthen the consequences of the m-M theorem without additional hypotheses. (Received September 20, 2011)

1077-39-1925 **Jim M Cushing*** (cushing@math.arizona.edu), Department of Mathematics, 617 N Santa Rita, University of Arizona, Tucson, AZ 85721. *Systems of rational difference equations from population dynamics and global dynamics on the boundary of the positive cone.* Preliminary report.

I will present some (systems of) rational difference equations that arise in the study of life history strategies in population dynamics. These equations hold both the boundary and the interior of the positive cone invariant. A fundamental bifurcation that occurs gives rise to a dynamic dichotomy between equilibria in interior of the cone and synchronized period oscillations on the boundary of the cone. An understanding of the global dynamics on the boundary of the cone is fundamental to understanding this dynamic dichotomy and its biological implications. I will describe some known results about the boundary dynamics and present several open problems. (Received September 21, 2011)

1077-39-1948 **Anton Dzhamay** (adzham@unco.edu), 2250A Ross Hall, Greeley, CO CO80639, **Hidetaka Sakai** (sakai@ms.u-tokyo.ac.jp), 3-8-1, Komaba, Meguro-ku, Tokyo 135-8914, Japan, and **Tomoyuki Takenawa*** (takenawa@kaiyodai.ac.jp), 2-1-6 Etchu-jima, Koto-ku, Tokyo 135-8533, Japan. *Discrete Hamiltonian structure of Schlesinger transformations.*

The purpose of this talk is to describe the discrete Hamiltonian structure of the Schlesinger transformations. For a linear differential equation with only regular singularities, the Schlesinger Transformation is an isomonodromic transformation of the equations such that the eigenvalues of the coefficient matrices are changed by integers. It is known that most of the integrable ordinary difference equations of Painlev¥'e type except q or elliptic difference ones can be obtained as Schlesinger transformations. Our discrete Lagrangian and Hamiltonian are nothing but the generating functions of canonical transformations. (Received September 22, 2011)

1077-39-1999 **Timothy Sauer*** (tsauer@gmu.edu), Fairfax, VA 22030. *Chaos in expansive rank-type equations.* Preliminary report.

Rank-type difference equations evolve according to a rule that chooses at each step the kth largest of a set of functions of past values. Recent results establish that under the assumption that all functions are contractive, rank-type equations converge to a fixed point. At the opposite extreme, rank-type equations choosing from a set of expansive functions, the dynamics are much more diverse. We propose conditions in the expansive case under which solutions are bounded or chaotic, and offer some open problems. (Received September 21, 2011)

1077-39-2240 **Sukanya Basu*** (basus@gvsu.edu), Department of Mathematics, Grand Valley State University, Allendale, MI 49401-6495, **Auroop R. Ganguly** (a.ganguly@neu.edu), Dept. of Civil and Environmental Engineering, Northeastern University, Boston, MA 02115, and **Evan Kodra** (evan.kodra@gmail.com), Dept. of Civil and Environmental Engineering, Northeastern University, Boston, MA 02115. *A Discrete Dynamical Systems Model to Study the Interaction Between Arctic Sea-Surface Temperature and Sea-Ice Cover.*

We propose a mathematical model involving discrete dynamical systems to understand the interaction between sea-surface temperature and sea-ice cover over the Arctic Ocean. Observed data from multiple sensors will be used to validate the model. The implications and caveats of the future projections made by our model will be explored. (Received September 21, 2011)

1077-39-2885 **Charles L Lamb*** (clamb@math.ku.edu), Department of Mathematics, 405 Snow Hall, 1460 Jayhawk Blvd, Lawrence, KS 66045, and **Erik S Van Vleck**. *Neutral Equation of Mixed.*

We extend the linear Fredholm theory for mixed type functional differential equations (with both advances and delays) to neutral equations of mixed type. We consider a prototype problem consisting of coupling between two nerve fibers which results in a system of neutral type equations. We employ the developed linear theory in conjunction with Lyapunov-Schmidt and numerical results to show existence for small values of the coupling parameter. (Received September 22, 2011)

40 ► Sequences, series, summability

1077-40-1124 **Thomas J Osler*** (osler@rowan.edu), Mathematics Department, Rowan University, 201 Mullica Hill Road, GLASSBORO, NJ 08028. *The devil's series, did it fool Euler?* Preliminary report.

Euler ends his paper [1], with a very general series which we call the "devil's series". Any series which does not contain zero terms is a special case of this devil's series. We show that the sum of this series can be expressed as A + B. Euler gives only A as the sum of the devil's series and ignores B. There is a large class of series for which Euler's sum is correct. We locate this class of series. We end with a conjecture as to why Euler did not reveal the full sum of the series.

[1] Euler, L. , "Exercitatio analytica, cum imprimis seriei maxime generalis summatio traditur". (An analytic exercise, for which a most general summation of series is given.), E 685. Originally published in Nova Acta Academiae Scientarum Imperialis Petropolitinae 9, 1795, pp. 41-53. Opera Omnia: Series 1, Volume 16, pp. 266-281. On the web at http://eulerarchive.maa.org/ (Received September 16, 2011)

41 ► Approximations and expansions

1077-41-807 **Phan Nguyen*** (nnphan@nmsu.edu), Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003. *Piecewise C^1 Biorthogonal Multiwavelets on $[-1,1]$.*

A procedure is given for constructing biorthogonal multiwavelets from a family of biorthogonal multiscaling functions compactly supported on $[-1,1]$. The scaling vectors and the associated multiwavelets are piecewise C^1, symmetrical and possess approximation order three. The construction of scaling vectors is accomplished using fractal interpolation functions. The filters corresponding to scaling vectors possess certain properties which enable us to construct a new pair of biorthogonal scaling vectors and associated multiwavelets with different regularity and approximation order, related to the old ones by differentiation and integration. The new multiscaling functions and multiwavelets give rise to biorthogonal multiresolution analyses for the Sobolev space $H_0^2([0,1])$. The work is motivated by potential numerical applications in differential equations. (Received September 13, 2011)

1077-41-810 **Hongbo Li*** (hli@mmrc.iss.ac.cn), Zhong Guan Cun East Rd. 55, Beijing, 100190, Peoples Rep of China, **Ruiyong Sun** (sunruiyong@126.com), Zhong Guan Cun East Rd. 55, Beijing, 100190, Peoples Rep of China, **Shoubin Yao** (yaoshoubin@163.com), Zhong Guan Cun East Rd. 55, Beijing, 100190, and **Ge Li** (liyoucun@126.com), Zhong Guan Cun East Rd. 55, Beijing, 100190, Peoples Rep of China. *Approximate Rational Solutions to Rational ODEs Defined on Discrete Differentiable Curves.*

In this paper, a new concept is proposed for discrete differential geometry: *discrete n-differentiable curve*, which is a tangent n-jet on a sequence of space points. A complete method is proposed to solve ODEs of the form

$$\mathbf{n}^{(m)} = \frac{\mathbf{F}(\mathbf{r},\mathbf{r}',\ldots,\mathbf{r}^{(n)},\mathbf{n},\mathbf{n}',\ldots,\mathbf{n}^{(m-1)},u)}{G(\mathbf{r},\mathbf{r}',\ldots,\mathbf{r}^{(n)},\mathbf{n},\mathbf{n}',\ldots,\mathbf{n}^{(m-1)},u)},$$

where $\mathbf{F}$, G are respectively vector-valued and scalar-valued polynomials, where $\mathbf{r}$ is a discrete curve obtained by sampling along an unknown smooth curve parametrized by u, and where $\mathbf{n}$ is the vector field to be computed along the curve. Our Maple-13 program outputs an approximate rational solution with the highest order of approximation for given data and neighborhood size.

The method is used to compute rotation minimizing frames of space curves in CAGD. For one-step backward-forward chasing, a 6th-order approximate rational solution is found, and 6 is guaranteed to be the highest order of approximation by rational functions. The theoretical order of approximation is also supported by numerical experiments. (Received September 13, 2011)

1077-41-1107 **Youngmi Hur** and **Fang Zheng*** (fzheng2@jhu.edu), 100 Whitehead Hall, 3400 N Charles St., Baltimore, MD 21218. *Coset sum: an alternative to the tensor product in wavelet construction.*

A wavelet system is a collection of functions, which are generated from a set of functions known as *mother wavelets* by scaling and translation. It is a set of building blocks to represent signals or functions, and has proven to be very efficient in many application areas including Signal Processing. While much work has been done to construct 1-D wavelets, less focus has been given to multidimensional ones. The most prevailing and generic way to construct multidimensional wavelets is by taking the tensor product of 1-D wavelets, which is called the tensor product method. Despite of its simplicity and popularity, it has many drawbacks: the wavelets constructed by the tensor product are directional only along the coordinate directions; the supports of multidimensional wavelets are huge. We will talk about an alternative of tensor product, called the coset sum method, that overcomes these drawbacks and is still generic. This new method lifts 1-D wavelets to n-D ones by taking their summation over coset representatives of the quotient group $\mathbf{Z}^n/(2\mathbf{Z})^n$, where 2 is the scaling ratio in the wavelet system. We will also talk about an extension to other integer scaling ratios. (Received September 16, 2011)

1077-41-1163 **Willi Freeden*** (freeden@mathematik.uni-kl.de), Germany. *Approximation based on integral formulas for star-shaped surfaces.*

In the first part the presentation is concerned with the development and application of integral formulas on the sphere such that equidistribtution, best approximation, and spline interpolation as well as their interrelations become derivable by use of an explicitly available remainder representation (reflecting the (linearized) 'curvature energy' in terms of the Beltrami operator).

The second part deals with the extension of the spherical ideas and concepts to geophysically relevant star-shaped surfaces such as ellipsoid, geoid, (real) Earth's surface. (Received September 17, 2011)

1077-41-1277 **Xiangsheng Wang*** (xswang4@mail.ustc.edu.cn), Centre for Disease Modelling, Department of Mathematics and Statistics, York University, Toronto, Ontario M3J1P3, Canada, and **Jianhong Wu**, Centre for Disease Modelling, Department of Mathematics and Statistics, York University, Toronto, Ontario M3J1P3, Canada. *Asymptotic analysis in migration ecology and simple SIR epidemiology.*

I will use a SIR model and a seasonal bird migration model to illustrate the connection between asymptotic analysis and biological dynamics. (Received September 18, 2011)

1077-41-1310 **Doreen Fischer***, Geomathematics Group, University of Siegen, Walter-Flex-Str. 3, 57068 Siegen, Germany. *The Regularized Functional Matching Pursuit and its Application to Inverse Ill-posed Problems in Geomathematics.*

To recover the density of the Earth we invert Newton's gravitational potential which is an ill-posed problem. Thus, we need to develop a regularization method to solve it appropriately.
We apply the idea of a Matching Pursuit to recover a solution stepwise. At step $n + 1$, the next expansion function and the weight are selected to best match the data structure. However, all kinds of different functions may be taken into account to improve the solution stepwise. Moreover, this new approach generates models with a resolution that is adapted to the data density as well as the detail density of the solution.
For the area of South America, we present an extensive case study to investigate the performance and behavior of the new algorithm. Furthermore, we research the mass transport in the area of the Amazon where the proposed method shows great potential for further ecological studies, i.e. to reconstruct the mass loss of Greenland and Antarctica.
However, from gravitational data alone it is only possible to recover the harmonic part of the density. To get information about the anharmonic part as well, we need to include other data types, e.g. normal mode anomalies. We present first results of such a joint inversion. (Received September 19, 2011)

1077-41-1312 **Roger Telschow*** (telschow@mathematik.uni-siegen.de), Geomathematics Group, University of Siegen, Walter-Flex-Str.3, 57068 Siegen, Germany. *Sparse Approximation on the Sphere - A Matching Pursuit with a Kernel Based Dictionary.*

A nonlinear method using a dictionary to approximate functions on the sphere is derived. The elements of the dictionary added to the approximation are chosen with a matching pursuit algorithm while the dictionary consists of spherical harmonics of low degrees, to approximate global structures, and several radial basis functions such as the Abel-Poisson kernel to be added in areas with more details. The method, therefore, yields an expansion of the function to be approximated which is not only sparse but also adapts to the solution, i.e. chooses more basis functions in areas where the function is structured more heavily and only few basis functions in areas of low frequency. Numerical results are presented for both benchmark functions as well as satellite data. (Received September 19, 2011)

1077-41-1427 **Majid Bani-Yaghoub*** (mbani@math.tamu.edu). *Approximation techniques for traveling waves of a single species delay diffusive model with age-structure and nonlocality.* Preliminary report.

This study makes an effort to construct the traveling wave solutions of a single species Reaction-Diffusion model through a number of approximation techniques. In addition to a monotone iterative technique, the capabilities of an asymptotic expansion, an extended differential transform and a boundary layer technique are explored. While the latter techniques are limited to small values of the delay term or diffusion coefficients, the former has the difficulty of finding a plausible pair of upper and lower solutions. Employing specific birth functions and parameter values, the accuracy of the approximated wave solutions are numerically examined. In conclusion, the usefulness of each technique is highly depends on the form of the birth function and the parameter values of the model. (Received September 19, 2011)

1077-41-1819 **Helmut Schaeben*** (schaeben@tu-freiberg.de), Geophysics and Geoscience Informatics, TU Bergakademie Freiberg, Gustav-Zeuner-Strasse 12, 09596 Freiberg, Germany. *Mathematical Texture Anaylsis.*

Texture analysis here means sampling, analyzing, and interpreting crystallographic preferred orientation. Crystallographic orientations are basically cosets of SO(3). Texture has initially been described by the orientation probability density function modeling the frequency of crystallographic orientations by volume. Diffraction experiments with X-rays, Neutron or synchrotron radiation provide integral measurements of crystallographic orientation which can basically be modeled by the totally geodesic Radon transform for SO(3). Then the numerical inversion of the Radon transform applied to these discrete pole intensity data yields the orientation probability density function. Electron Back Scatter Diffraction (EBSD) experiments allow to sample individual crystallographic orientations with spatial reference. Non-parametric kernel density estimation is applied to estimate the orientation probability density function, while the spatial reference and modeling assumptions are used to reconstruct crystallographic grain boundaries and corresponding grains in terms of incidence and adjacency matrices. Once the grains are modeled, various misorientation functions can be investigated as well as their geometry and topology. (Received September 21, 2011)

1077-41-2300 **Christian Gerhards*** (gerhards@mathematik.uni-kl.de), TU Kaiserslautern, Geomathematics Group, Germany. *Spherical Multiscale Methods and Applications in Geomagnetic Modeling.*

Quantities like the Earth's crustal magnetic field desire local modeling approaches on spherical geometries to improve the spatial resolution of magnetic anomalies. A multiscale method with locally supported wavelet kernels is a well-suited method for this purpose. The kernels can be constructed from regularizations of weakly-singular functions like the Green function for the Beltrami operator or the single layer kernel. In this talk we deal with such multiscale approaches and problems arising in their application. (Received September 22, 2011)

42 ► Fourier analysis

1077-42-115 **Bassam H. Shayya*** (bshayya@aub.edu.lb), American University of Beirut, P.O. Box 11-0236 / Mathematics, Riad El-Solh, Beirut, 1107 2020, Lebanon. *Decay of spherical means of Fourier transforms and distance sets of measures.*

Suppose $\mu \in M(\mathbb{R}^n)$ is a measure with $\|\mu\| > 0$, σ is surface measure on the unit sphere $\mathbb{S}^{n-1} \subset \mathbb{R}^n$, and $\phi \in L^2(\mathbb{S}^{n-1})$ is a function with $\|\phi\|_{L^2(\mathbb{S}^{n-1})} > 0$. If

$$\int_0^\infty \int_{\mathbb{S}^{n-1}} |\widehat{\mu}(r\theta)|^2 d\sigma(\theta) r^{n-1} dr = \int_{\mathbb{R}^n} |\widehat{\mu}(\xi)|^2 d\xi < \infty,$$

then, as is well-known, $d\mu \ll dx$, and since $\|\mu\| > 0$, it follows that $|\operatorname{supp}\mu| > 0$. Now by the Cauchy-Schwarz inequality,

$$\Big| \int_{\mathbb{S}^{n-1}} \widehat{\mu}(r\theta)\phi(\theta) d\sigma(\theta) \Big|^2 \leq \|\phi\|^2_{L^2(\mathbb{S}^{n-1})} \int_{\mathbb{S}^{n-1}} |\widehat{\mu}(r\theta)|^2 d\sigma(\theta),$$

so it is natural to ask the question, what can we say about $\operatorname{supp}\mu$ under the weaker assumption

$$\int_0^\infty \Big| \int_{\mathbb{S}^{n-1}} \widehat{\mu}(r\theta)\phi(\theta) d\sigma(\theta) \Big|^2 r^{n-1} dr < \infty?$$

We give an answer to this question in the case $\phi \in C^\infty(\mathbb{S}^{n-1})$. We also give an application of our result to Falconer's distance set problem. (Received July 28, 2011)

1077-42-333 **Ravshan R Ashurov*** (ashurovr@gmail.com), University Putra Malaysia, Institute of Advanced Technology, 43400 Sedang, Selangor, Malaysia, and **Almaz A Butaev** (butaev.al@gmail.com), University Putra Malaysia, Institute of Advanced Technology, 43400 Serdang, Selangor, Malaysia. *On the Pinsky phenomenon and the Kahane theorem for nonspherical partial Fourier integrals.*

In this talk we discuss pointwise convergence of nonspherical Fourier integrals. In particular, we present how the phenomenon established by M.Pinsky for spherical Fourier integrals can be revealed in nonspherical case. Generalizing the Pinsky theorem for spherical Fourier integrals, we establish necessary and sufficient conditions for pointwise convergence of nonspherical Fourier integrals. Further we consider one result by J.Kahane according to which if piecewise smooth function in R^3 with an analytic surface of discontinuity exhibit the Pinsky phenomenon, then with necessity the surface of discontinuity is sphere and the point of divergence is the center of this sphere. We discuss the formulation of this question for nonspherical Fourier integrals and prove the corresponding version of Kahane's theorem. (Received August 23, 2011)

1077-42-399 **Caroline Sweezy** and **James Michael Wilson*** (jmwilson@uvm.edu), Dept of Mathematics, University of Vermont, Burlington, VT 05405. *Intrinsic square function and almost-orthogonality on homogeneous spaces.*

We describe a generalization of the intrinsic square function to homogeneous spaces. We show how it leads to an extension of an almost-orthogonality result, due to Frazier, Jawerth, and Weiss, to homogeneous spaces having minimal translation-invariant structure. (Received August 29, 2011)

1077-42-477 **Shigehiko Kuratsubo*** (kuratubo@cc.hirosaki-u.ac.jp), Hirono 1-17-6, Hirosaki-shi, Aomori-ken , Japan. *A relation between multiple Fourier series and lattice point problems.*

Lattice point problems are the branch of analytic number theory which is concerned with the number of integer points. These problems have a long history and very deep accumulations since E. Landau, J. G. Van der Corput, G. Voronoi and G. H. Hardy. Especially the researches of Czechoslovakian mathematician B. Novak (1938-2003) are very important. We are aiming to point out intrinsic relationship between lattice point problems and the convergence problems of multiple Fourier series. We will see a strong relation between these. The strongest motivation of this study was two preprints by M. Taylor. (Received September 03, 2011)

1077-42-670 **Christopher D Sogge*** (sogge@jhu.edu). *Problems related to the concentration of eigenfunctions.*

I shall go over recent work related to concentration phenomena for eigenfunctions. This includes my work with Hamid Hezari and Steve Zelditch on Yau's conjecture for the size of nodal sets, and related estimates for eigenfunctions. (Received September 09, 2011)

1077-42-726 **Boris Rubin*** (borisr@math.lsu.edu), Louisiana State University, Department of Mathematics, 303 Lockett Hall, Baton Rouge, LA 70803. *Funk, Cosine, and Sine Transforms on Stiefel and Grassmann Manifolds. The Fourier Transform Approach.*

The Funk, cosine, and sine transforms on the unit sphere are indispensable tools in integral geometry and interesting objects of harmonic analysis. Using the classical Fourier techniques we extend basic facts about these transforms to the more general context for Stiefel or Grassmann manifolds. The main topics are composition formulas, the Fourier functional relations for homogeneous distributions, analytic continuation, inversion formulas. (Received September 11, 2011)

1077-42-1056 **chang-pao chen*** (cpchen@wmail.hcu.edu.tw), Department of Applied Mathematics, Hsuan Chuang University, Hsinchu, 30092, Taiwan, **Jin-Wen Lan** (d937210@oz.nthu.edu.tw), Department of Mathematics, National Tsing Hua University, Hsinchu, 30013, Taiwan, and **Dah-Chin Luor** (dclour@isu.edu.tw), Department of Applied Mathematics, I-Shou University, Kaohsiung, 84008, Taiwan. *The Muckenhoupt-type estimations for the best constants in multidimensional modular inequalities over spherical cones.*

In this paper, we establish the Muckenhoupt-type estimation for the best constant C associated with the following multidimensional modular inequality over a spherical cone:

$$\left(\int_E \left\{\Phi\left(\int_{\tilde{S}_x} k(x,t)f(t)d\sigma(t)\right)\right\}^q d\mu\right)^{1/q} \le C\left(\int_E \left\{\Phi(f(x))\right\}^p d\nu\right)^{1/p},$$

where $f \in L^p_\Phi(d\nu)$ and $1 \le p, q \le \infty$. Similar results are also derived for the complementary integral operator. As a consequence, we give the n-dimensional weighted extensions of Levinson's modular inequality, extensions of Stepanov's and Heinig's results, generalizations of the Hardy-Knopp-type inequalities, and those for the Riemann-Liouville operator and the Weyl fractional operator. We also point out that our estimates are better than the known ones. (Received September 15, 2011)

1077-42-1083 **Nicholas Boros*** (borosnic@msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48823. *The L^p-Operator Norm of a Perturbation of the Martingale Transform.*

Given a sequence of martingale differences, Burkholder found the sharp constant for the L^p-norm of the corresponding martingale transform. We are able to determine the sharp L^p-norm of small "quadratic perturbations" of the martingale transform in L^p. By "quadratic perturbation" of the martingale transform we mean the L^p norm of the square root of the squares of the martingale transform and the original martingale (with small constant). The problem of perturbation of martingale transform appears naturally if one wants to estimate the linear combination of Riesz transforms (as, for example, in the case of Ahlfors–Beurling operator). Let $\{d_k\}_{k\ge 0}$ be a complex martingale difference in $L^p[0,1]$, where $1 < p < \infty$, and $\varepsilon_k \in \{\pm 1\}, \forall k$. If $\tau^2 \le p^* - 1$ and $n \in \mathbb{Z}_+$ then

$$\left\| \sum_{k=0}^n \begin{pmatrix} \varepsilon_k \\ \tau \end{pmatrix} d_k \right\|_{L^p([0,1],\mathbb{C}^2)} \le ((p^*-1)^2 + \tau^2)^{\frac{1}{2}} \left\| \sum_{k=0}^n d_k \right\|_{L^p([0,1],\mathbb{C})},$$

where $((p^*-1)^2+\tau^2)^{\frac{1}{2}}$ is sharp and $p^*-1 = \max\{p-1, \frac{1}{p-1}\}$. For $2 \le p < \infty$ the result is also true with sharp constant for $\tau \in \mathbb{R}$. (Received September 16, 2011)

1077-42-1239 **William O. Bray*** (bray@math.umaine.edu), Department of Mathematics and Statistics, University of Maine, Orono, ME 04469. *Estimates of Fourier Transforms.* Preliminary report.

In recent work (joint with M. Pinsky, JFA 2008, arXiv.math 2009), we developed weighted L^q estimates of the Fourier transform on Euclidean spaces and on rank one symmetric spaces of non-compact type. This talk presents a summary of these results as well as some variations and extensions. (Received September 18, 2011)

1077-42-1308 **Faruk F. Abi-Khuzam*** (farukakh@aub.edu.lb), Department of Mathematics, American University of Beirut, Beirut, Lebanon. *On the WAT conjecture on the Torus.*

Let $f \in L^{\infty}(T^d)$ with $\|f\|_{L^{\infty}(T^d)} \leq 1$, $\nu \in \mathbb{Z}^d, n, k \in \mathbb{Z}$ and put $b_{n,n-k} = \int_E f(x)^n e^{-2\pi i(n-k)\nu \cdot x} dx$, $E = \{x \in T^d : |f(x)| = 1\}$. Shayya conjectured that, if $\hat{f}(\xi) = 0$ for all ξ in a half-space S of lattice points, and $\nu \in -S$, and $\hat{f}(0) \neq 0$, then $\lim_{n\to\infty} b_{n,n-k} = 0, k \in \mathbb{Z}$. This is a higher dimensional version of an earlier conjecture of Nazarov and Shapiro, the truth of which would imply that any composition operator is weakly asymptotically Toeplitz on the Hardy space H^2. For $k = 0$, Shayya proved that the arithmetic means of $\{b_{n,n}\}$ decay like $\{\log N\}^{-1}$. We prove that the arithmetic means of $\{b_{n,n-k}\}$ decay like $\{\log N \log\log N\}^{-1}$ uniformly in $k \in \mathbb{Z}$. (Received September 19, 2011)

1077-42-1441 **Allan Greenleaf**, **Alex Iosevich** and **Eyvindur Ari Palsson*** (palsson@math.rochester.edu), UR Mathematics, 915 Hylan Building, RC Box 270138, Rochester, NY 14627. *On multilinear generalized Radon transforms.*

In the 80s and early 90s, Phong and Stein initiated the study of linear generalized Radon transforms. These operators have found applications in many branches of harmonic analysis, partial differential equations and other areas. In this talk we will motivate a definition of multilinear generalized Radon transforms based on a graph theoretic perspective. We will consider a multilinear spherical averaging operator as a model operator and present some results on the boundedness of the model operator along with applications to finite point configuration problems. The particular finite point configuration problems we consider are multipoint configuration versions of the Falconer distance problem, which in turn can be thought of as a continuous analog of the Erdős distance problem. (Received September 19, 2011)

1077-42-1602 **Amit Bernanis** (amitberm@post.tau.ac.il), 8 Levnon Street, 69978 Tel Aviv, Israel, **Amir Averbuch*** (amir@math.tau.ac.il), 8 Levnon Street, 69978 Tel Aviv, Israel, and **Ronald Raphel Coifman**, PO Box 208283, New Haven, CT 06520-8283. *Multiscale data sampling and function extension for data analysis and processing of large high dimensional data.*

Many kernel based methods, which are used for dimensionality reduction and data mining applications, involve an application of a SVD to a kernel matrix, whose dimensions are proportional to the size of the data. When data is accumulated over time, a method for function extension is required. We introduce a multiscale scheme for data sampling and function extension, which can be applied in any metric space, not necessarily a vector space. The scheme is based on mutual distances between data points. It makes use of a coarse-to-fine hierarchy of the multiscale decomposition of a Gaussian kernel. It generates a sequence of subsamples, which we refer to as adaptive grids, and a sequence of approximations to a given empirical function on the data, as well as their extensions to any newly-arrived data point. The subsampling is done by a special decomposition of the associated Gaussian kernel matrix in each scale in the hierarchical decomposition. In each scale, the data is sampled by an interpolative decomposition of a low-rank Gaussian kernel matrix that is defined on the data. Demonstration of the processing of large volumes of high-dimensional data will be given. (Received September 20, 2011)

1077-42-1727 **David Ferrone***, david.ferrone@uconn.edu. *Finite Biorthogonal Transforms and Multiresolution Analyses on Intervals.* Preliminary report.

A class of biorthogonal transformations for finite strings of data are described. These transformations are modifications of dual multiresolution analyses over the real line, and can be used to construct dual multiresolution analyses over an interval. Regularity and approximation properties of the resulting MRA's are explored. (Received September 20, 2011)

1077-42-2041 **W. R. Madych*** (madych@math.uconn.edu). *Approximate reconstruction from circular mean data via classical summability.* Preliminary report.

The reconstruction of images from data modeled by circular or spherical mean Radon transforms plays an important role in thermoacoustic and photoacoustic tomography and gives rise to interesting and challenging mathematical questions. We describe two variants of a classical summability type approximate reconstruction method that produce good numerical results and show that in the limit one specific case leads to exact reconstruction. Among the consequences of this development are certain inversion type formulas. In our considerations the detectors need not be restricted to a circle. This work was done in collaboration with Marcus Ansorg, Frank Filbir, and Ruben Seyfried at the Institute of Biomathematics and Biometry, Helmholtz Center Munich, Germany. (Received September 21, 2011)

1077-42-2052 **Sergei Treil*** (treil@math.brown.edu). *H^1 and dyadic H^1 in multiparameter settings.*

It is well-known that in the harmonic analysis in multi-parameter settings the iteration in the number of variables usually does not work: the multi-parameter BMO is not obtained by iterating one parameter case, for example.

I will discuss a situation where such iteration does work, namely a (known before) result connecting "real" H^1 and dyadic H^1. I'll present a very simple proof, which can be easily iterated to several variables.

I'll also discuss why BMO is a subset of the dyadic BMO in the multi-parameter case: this result can be obtained essentially by iterating the (trivial) one-parameter result. (Received September 21, 2011)

1077-42-2086 **Galia Dafni** and **Hong Yue*** (yueh@trine.edu), 1 University Ave., Angola, IN 46703.
Some characterizations of local bmo and h^1 on metric measure spaces.

We study, in the setting of a doubling metric measure space, the local bmo and Hardy space h^1 defined by Goldberg. We prove a John-Nirenberg type inequality for the local bmo space and the boundedness of the Hardy-Littlewood maximal function from bmo to bmo. In addition, we give characterizations of bmo and h^1 using alternative mean-oscillation and moment conditions. (Received September 21, 2011)

1077-42-2959 **Alex Iosevich*** (iosevich@math.rochester.edu). *Applications of linear and multi-linear generalized Radon transforms.*

We are going to prove some Lp-Sobolev bounds of multi-linear generalized Radon transforms and apply them to Falconer type problems in geometric measure theory and Hardy type problems on the distribution of lattice points in convex domains. (Received September 26, 2011)

43 ► Abstract harmonic analysis

1077-43-693 **Vignon S Oussa***, Department of Mathematics and Computer Sc, 220 N. Grand Blvd., St.Louis, MO 63103. *Explicit Construction of Normalized Tight Frames and Wavelets for a Class of 2-step Nilpotent Lie Groups.* Preliminary report.

We consider a class of 2-step connected and simply connected nilpotent Lie groups of the type $N = P \rtimes M$ where P and M are abelian Lie groups and M acts on P by automorphisms. We consider the left regular representation restricted to a multiplicity-free closed subspace of $L^2(N)$ which we denote by H. We show how to construct normalized tight frames associated with fields of multivariate Gabor systems. Furthermore, we also obtain an explicit construction of continuous wavelets associated with the left regular representation restricted to H. (Received September 10, 2011)

1077-43-877 **John J Benedetto*** (jjb@math.umd.edu), Norbert Wiener Center, Department of Mathematics, University of Maryland, College Park, MD 20742. *Frames and applied harmonic analysis.*

Frames are a generalization of orthonormal bases. They have natural applicability when noise reduction, numerical stability, or robust signal decomposition are desired. Examples range from quantum detection, to erasure problems on the internet, to antenna design for wireless communications. We describe three frame techniques. First, we construct number theoretic constant amplitude zero autocorrelation (CAZAC) sequences with optimal radar ambiguity function behavior. Second, we develop an effective low bit A/D coding theory. Third, we design a classification algorithm to analyze hyper-spectral imagery by means of the notion of frame potential energy. (Received September 13, 2011)

1077-43-916 **Sigurdur Helgason*** (helgason@mit.edu), 5 Benton Road, Belmont, MA 02478. *Orbital Integrals, applications and problems.*

On a Lorentzian manifold G/H of constant curvature K and dimension 2m we proved in 1959 an inversion formula for the H-orbital integrals. In continuation of this, Schlichtkrull and Schimmimg deduced that each operator L-K(2m - k)(k -1) (k= 3,5,... 2m-1, L the Laplacian) satisfies Huygens' principle. In an important paper (Springer Lect. Notes 1243) J.Orloff extended the above inversion formula to a non Riemannian symmetric space G/H of rank one. Under additional assumptions, similar conclusions follow for the Laplacian L + constant. On a Euclidean space the spherical average operator is well known to satisfy the Darboux Equation. We extend this to H-orbital integrals on the rank one space D/H mentioned above. We shall also discuss in special cases the relationship of the Plancherel formula for G and G/H to H-orbital integrals. (Received September 14, 2011)

1077-43-1085 **Gestur Olafsson*** (olafsson@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803, and **Angela Pasquale**. *The* $\cos^\lambda$*-transform and intertwining operators for* $SL(n,\mathbb{F})$.

The $\cos^\lambda$-transform and the related $\sin^\lambda$-transform have been widely studied the last few years because their role in harmonic analysis and convex geometry. What is less known is their connection to representation theory and intertwining operators. In this talk we connect topics from convex and integral geometry with well known topics in representation theory of semisimple Lie groups by showing that the $\cos^\lambda$ and $\sin^\lambda$-transforms on Grassmann manifolds are standard intertwining operators between certain generalized principal series representations induced from a maximal parabolic subgroup of $SL(n+1,\mathbb{F})$. The general results of Knapp and Stein and Vogan and Wallach then show that both transforms have meromorphic extension to $\mathbb{C}$ and are invertible for generic λ. Furthermore, known methods from representation theory combined with a Selberg type integral allow us to determine the K-spectrum of those operators. (Received September 16, 2011)

1077-43-1232 **Roland Knevel*** (knevelr@macs.biu.ac.il), Bar-Ilan University, Department of Mathematics, 52900 Ramat Gan, Israel. *Krein spaces and local deformation in representation theory of super Lie groups.*

Using the example of the super Heisenberg groups I will show how indefinit invariant sesquilinear forms and local deformations of unitary representations naturally enter the picture when constructing an injective Fourier transform from the L^2-functions on a super Lie group to the ones on its unitary dual. However, both concepts have to be defined properly. I will discuss the possibilities of a precise definition and the survival of classical results in these cases. (Received September 18, 2011)

1077-43-1236 **Azita Mayeli*** (amayeli@qcc.cuny.edu), Mathematics and Computer Science Department, S-245, 222-05 56th Avenue, Bayside, NY 11364. *Structure of shift-invariant subspaces for the Heisenberg group.* Preliminary report.

Let N be the Heisenberg group. In this talk we shall introduce the concept of shift-invariant subspaces in $L^2(N)$ and study their structure in terms of their associated range functions and fibers. As a consequence of this study, we shall show the characterization of frames and Riesz bases of these subspaces generated by shifts of a countable set of generators in terms of their behaviour on the fibers. We shall conclude this talk with addressing that the results are also extended to an advanced context, namely simply connected nilpotent Lie groups whose irreducible representations are in SI/Z - *square-integrability mod the center.*

This is a joint work with Bradley Currey and Vignon Oussa of St. Louis University. (Received September 18, 2011)

1077-43-1820 **Jens Gerlach Christensen*** (jens.christensen@tufts.edu), MA. *Decomposition of spaces of distributions using Gårding vectors.*

A general machinery for construction of Banach spaces of distributions from group representation is presented. Via a sampling theorem on reproducing kernel Banach spaces on Lie groups, we then decompose the spaces of distributions. It is then shown that the use of Gårding vectors is particularly convenient when the representation involved is square integrable. (Received September 21, 2011)

1077-43-2331 **Norbert N Youmbi*** (nyoumbi@francis.edu), 117 Evergreen Dr, Sullivan 114, Loretto, PA 15940. *Some Weak Convergence Theorems on Topological Semihypergroups.*

We extend the definition of concretization of hypergroups to semihypergroups, and use it to prove some results on weak convergence of the sequences or averages of convolution powers on semihypergroups. (Received September 22, 2011)

1077-43-2549 **Fulton Gonzalez*** (fulton.gonzalez@tufts.edu), Department of Mathematics, Tufts University, Medford, MA 02155. *Multitemporal Wave Equations on Symmetric Spaces: Mean Value Solutions.* Preliminary report.

Let $X = G/K$ be a Riemannian symmetric space with G semisimple. Let $\Gamma : \mathbb{D}(X) \to \mathbb{D}_W(\mathfrak{a})$ be the Harish-Chandra isomorphism, and let w denote the order of the Weyl group W. For $f_1, \ldots, f_w \in C^\infty(X)$, consider the multitemporal system

$$D_x\, u(x,H) = \Gamma(D)_H\, u(x,H) \qquad (D \in \mathbb{D}(X))$$

for $u \in C^\infty(X \times \mathfrak{a})$, with initial data

$$\partial(p_j)_H\, h(x,0) = f_j(x) \qquad (j = 1, \ldots, w).$$

We present mean value solutions in the case when the restricted root multiplicities are even. (Received September 22, 2011)

1077-43-2720 **Susanna Dann*** (danns@missouri.edu), 202 Mathematical Sciences Bldg, University of Missouri, Columbia, MO 65211, and **Gestur Olafsson**. *Paley-Wiener Theorems on R^n with respect to the spectral parameter.*

One of the important questions related to any integral transform on a manifold M or on a homogeneous space G/K is the description of the image of a given space of functions. If $M = G/K$, where (G, K) is a Gelfand pair, then the harmonic analysis is closely related to the representations of G and the direct integral decomposition of $L^2(M)$ into irreducible representations of G. R^n can be realized as the quotient $G/SO(n)$, where G is the orientation preserving Euclidean motion group. The pair $(G, SO(n))$ is a Gelfand pair. Hence this realization of R^n comes with its own natural Fourier transform derived from the representation theory of G. The representations of G that are in the support of the Plancherel measure for $L^2(R^n)$ are parametrized by R^+. After recalling the Fourier transform on Gelfand pairs, we describe the image of smooth compactly supported functions under the Fourier transform with respect to the spectral parameter. Then we discuss projective limits of these spaces. (Received September 22, 2011)

44 ► Integral transforms, operational calculus

1077-44-456 **Job J. Kuit*** (j.j.kuit@gmail.com), Dep. of Mathematics, University of Copenhagen, Universitetsparken 5, DK-2100 Copenhagen, Denmark. *Radon transformation on reductive symmetric spaces: support theorems.*

Let G be a semisimple Lie group and let $G = KAN$ be an Iwasawa decomposition of G. Let X be the Riemannian symmetric space G/K. A horosphere in X is an orbit in X of a subgroup of G that is conjugate to N. For a compactly supported smooth function ϕ on X, let $\mathcal{R}\phi$ be the function on the set of horospheres, that for a horosphere ξ is given by the integral of ϕ over ξ. The Radon transform $\mathcal{R}$ thus obtained is called the horospherical transform. In 1973 Helgason proved the following support theorem. Let V be a closed ball in X. If $\mathcal{R}\phi(\xi) = 0$ for every horosphere ξ such that $\xi \cap V = \emptyset$, then $\phi(x) = 0$ for $x \notin V$.

The notion of a horospherical transform has a generalization to the context of reductive (pseudo-Riemannian) symmetric spaces. We present a support theorem for a class of Radon transforms, including the horospherical transforms, on a reductive symmetric space. Our theorem generalizes the theorem by Helgason. (Received September 02, 2011)

1077-44-715 **Jan Boman*** (jabo@math.su.se), Department of Mathematics, Stockholm University, SE-10691 Stockholm, Sweden. *Local injectivity of weighted Radon transforms.*

Let $m(\xi, \eta, x)$ be a given positive function and consider the Radon transform

$$R_m f(\xi, \eta) = \int f(x, \xi x + \eta) m(\xi, \eta, x) dx$$

for continuous functions $f(x, y)$ that vanish for $y < x^2$. For which $m(\xi, \eta, x)$ is it true that

$$\begin{aligned} R_m f(\xi, \eta) = 0 \quad & \text{in some neighborhood of the origin} \\ & \text{implies} \\ f(x, y) = 0 \quad & \text{in some neighborhood of the origin.} \end{aligned}$$

We will discuss some old and new results on this and related problems. (Received September 11, 2011)

1077-44-724 **Yuri A. Antipov** and **Boris Rubin*** (borisr@math.lsu.edu), Department of Mathematics, Baton Rouge, LA 70803. *A Generalization of the Mader-Helgason Inversion Formulas for Radon Transforms.*

A new elegant inversion formula for the k-plane transform (k even) in the n-dimensional real Euclidean space was derived by S. Helgason in his recent book “Integral geometry and Radon transform”. Many years ago, in 1927, Ph. Mader derived interesting inversion formulas for the hyperplane Radon transform (k=n-1), which differ from the original ones by Radon and seem to be forgotten. We generalize these formulas to totally geodesic Radon transforms in any dimensions on arbitrary constant curvature space. (Received September 11, 2011)

1077-44-1319 **Nils Byrial Andersen*** (byrial@imf.au.dk), Department of Mathematics, Aarhus University, Ny Munkegade 118, Building 1530, DK-8000 Aarhus, Denmark. *Cusp Forms on hyperbolic spaces.*

Cusp forms on a group G can be defined as the kernel of certain Radon transforms on G. Cusp Forms on real reductive Lie groups G were introduced by Harish-Chandra, who also showed that they coincide precisely with the discrete part of the spectral decomposition of the space of square integrable functions on G.

Flensted-Jensen recently proposed a new family of Radon transforms and associated Cusp forms on Reductive Symmetric Spaces, which in the group case reduces to the definition of Harish-Chandra. We will in this talk discuss Cusp Forms on Hyperbolic Spaces, in particular the existence of non-cuspidal discrete series.

This is joint work with Mogens Flensted-Jensen and Henrik Schlichtkrull. (Received September 19, 2011)

1077-44-1773 **Lance Nielsen*** (lnielsen@creighton.edu), Department of Mathematics, Creighton University, 2500 California Plaza, Omaha, NE 68178. *Feynman's Operational Calculi: Using Cauchy's Integral Formula.*

We will express the disentangling (in the sense of Feynman's operational calculus) of a function of several non-commuting operators using Cauchy's Integral Formula in several complex variables. It will be seen that the disentangling of a given function f can be expressed as a contour integral around the boundary of a polydisk where the standard Cauchy kernel is replaced by the disentangled version of the Cauchy kernel expressed as an element of the disentangling algebra. This approach to Feynman's operational calculus allows for us to develop a "differential calculus" with disentanglings. (Received September 20, 2011)

1077-44-1933 **George K. Yang*** (georgiyang@gmail.com), 515 Nichol Rd, Nashville, TN 37209. *On Random Fields and Their Wavelet Transforms.*

We first introduce the theory of wavelet transforms of functions in $L^2(R)$ and in the space $S(R)$ of Schwartz functions, and extend the concept of wavelet transforms to tempered distributions. Then we treat the stochastic processes and random fields as tempered distributions in $S'(R)$, the dual space of the space $S(R)$. Using the above theory to stochastic processes and random fields, we find that the expected value of the wavelet transform of the difference of an observed signal process minus the true signal is equal to the wavelet transform of the mean function of the random noise process. Also, we show that the $L^2(\Omega \times R^2)$-norm of the wavelet transform of the difference of the same observed signal process minus the true signal is equal to the $L^2(\Omega \times R)$-norm of the random noise process. (Received September 21, 2011)

45 ► Integral equations

1077-45-1023 **Darko Volkov*** (darko@wpi.eu), 100 institute road, worcester, MA 01609. *A Numerical Boundary Eigenvalue Problem For Elastic Cracks in Free and Half Space.*

We present in this talk a numerical method for hypersingular boundary integral equations. This method was developed for planar crack problems: additional edge singularities are known to develop in that case. This study includes a rigorous error analysis proving the convergence of our numerical scheme. Three types of examples are covered: the Laplace equation in free space, the linear elasticity equation in free space, and in half space. (Received September 15, 2011)

46 ► Functional analysis

1077-46-108 **Matthew A. Fury*** (maf44@psu.edu), Division of Science and Engineering, Penn State Abington, 1600 Woodland Road, Abington, PA 19001. *Regularization for ill-posed parabolic evolution equations.*

We consider the ill-posed parabolic evolution equation $du(t)/dt = a(t)Du(t), 0 \leq t < T$ with initial data $u(0) = \chi$ in a Banach space X where $-D$ is the infinitesimal generator of a bounded holomorphic semigroup on X and $a \in C([0,T] : \mathbb{R}^+)$. In this setting, we prove the existence of a family of regularizing operators for the problem which allows us to approximate known solutions $u(t)$. This is achieved by considering the evolution system associated with an approximate well-posed problem. Our theory has applications to partial differential equations in $L^p(\mathbb{R}), 1 \leq p < \infty$ such as the backwards heat equation. (Received July 27, 2011)

1077-46-226 **Sarah E. Wright*** (swright@holycross.edu), Mathematics and Computer Science Dept., College of the Holy Cross, One College Street, Worcester, MA 01610. *Aperiodicity Conditions in Topological k-Graphs.*

By generalizing what we think of as a graph we increase the class of C*-algebras that can be viewed as graph-algebras. Two main generalizations are making the graphs multidimensional k-graphs (Kumjian and Pask) and giving the vertex and edge sets topologies (Katsura). Yeend combined these two generalizations and constructed topological k-graphs in his thesis. We'll see an introduction to each of these generalizations. Condition (L), "every cycle has an entry" first appeared in the literature in Kumjian, Pask, and Raeburn's paper on Cuntz-Krieger algebras of directed graphs. It provides a necessary condition for simplicity of the graph algebra. This condition has been generalized to the theory of topological graphs, k-graphs, and topological k-graphs. We'll see how these conditions present themselves in various examples as well as evidence of their importance in each of the theories. Each generalization of the aperiodicity condition, particularly those in the k-dimensional case, can be difficult to check for. We'll give some equivalent conditions to aperiodicity in topological k-graphs. We will also see examples of topological k-graphs in which one condition may be substantially easier to verify than the other conditions. (Received September 22, 2011)

1077-46-401 **Weihua Li*** (wli@colum.edu), **Don Hadwin**, **Qihui Li** and **Junhao Shen**. *MF-traces and a lower bound for the topological free entropy dimension in unital C*-algebras.*

We introduce the notions of MF-trace, MF-ideal and MF-nuclearity, and use these concepts to obtain upper and lower bounds for the topological free entropy dimension. We obtain an exact formula for the topological free entropy dimension in many cases. (Received August 29, 2011)

1077-46-469 **Ioana Ghenciu*** (ioana.ghenciu@uwrf.edu), River Falls, WI 54022, and **Paul W Lewis** (lewis@unt.edu). *Completely Continuous operators.* Preliminary report.

A Banach space X has the Dunford-Pettis property (DPP) provided that every weakly compact operator T from X to any Banach space Y is completely continuous (or Dunford-Pettis operator). It is known that X has the DPP if and only if every weakly null sequence in X is a Dunford-Pettis subset of X. In this paper we give equivalent characterizations of Banach spaces X such that every weakly Cauchy sequence in X is a limited subset of X. We prove that every operator $T : X \to c_0$ is completely continuous if and only if every bounded weakly precompact subset of X is a limited set. We show that in some cases, the projective and the injective tensor products of two spaces contain weakly precompact sets which are not limited. As a consequence, we obtain that for all infinite compact Hausdorff spaces K_1 and K_2, $C(K_1) \otimes_\pi C(K_2)$ and $C(K_1) \otimes_\epsilon C(K_2)$ contain weakly precompact sets which are not limited. (Received September 03, 2011)

1077-46-494 **Teffera M. Asfaw*** (tasfaw@mail.usf.edu), University of South Florida, Department of Mathematics and Statistics, Tampa, FL 33620-5700, and **Athanassios G. Kartsatos**. *A Browder topological degree theory for multi-valued pseudomonotone perturbation of maximal monotone operators.* Preliminary report.

Let X be a real reflexive locally uniformly convex Banach space with locally uniformly convex dual space X^*. Let G be a bounded open subset of X. Let $T : X \supset D(T) \to 2^{X^*}$ be maximal monotone, possibly with $0 \notin T(0)$, and $S : X \to 2^{X^*}$ bounded, pseudomonotone and such that $0 \notin \overline{(T+S)(D(T) \cap \partial G)}$. Following Browder, we construct a topological degree theory for the sum $T + S$, with the degree mapping, $d(T + S, G, 0)$ defined by

$$d(T+S,G,0) = \lim_{\varepsilon \downarrow 0^+} d_{S_+}(T+S+\varepsilon J, G, 0),$$

where d_{S_+} is the degree for bounded (S_+)-perturbations of maximal monotone operators. In addition, we develop an analogous degree theory for possibly unbounded pseudomonotone operators $S : X \to 2^{X^*}$. The uniqueness and the invariance, under suitable pseudomonotone homotopies, of these degree mappings are also included herein. As applications of our main results, we give some associated mapping theorems as well as degree theoretic proofs of known results by De Figueiredo, Kenmochi and Le.
(Received September 05, 2011)

1077-46-499 **Ami Viselter*** (viselter@ualberta.ca), Department of Math. and Stat. Sciences, University of Alberta, Edmonton, Alberta T6G 2G1, Canada. *Cuntz-Pimsner algebras for subproduct systems.*

The study of Cuntz-Pimsner algebras of C^*-correspondences has its origins in an influential paper of Pimsner. The construction of this algebra (which was shown to be a quotient of the Toeplitz algebra of the correspondence) is very flexible, and many aspects of it have been comprehensively studied, for instance: exactness and nuclearity, ideal structure, K-theory and Morita equivalence.

The notion of a subproduct system, generalizing that of (the product system associated with) a C^*-correspondence, has been systematically studied recently by several authors. In particular, some work has been done on its associated tensor and Toeplitz algebras and their representations.

In this talk we will present an attempt to extend the concept of Cuntz-Pimsner algebras to the setting of subproduct systems. When restricted to the case of Arveson's d-dimensional "symmetric" subproduct system, our construction yields, as expected, the C^*-algebra of continuous functions on the boundary of B_d (and a suitable infinite-dimensional version of this assertion also holds). We demonstrate via examples why some features of the Cuntz-Pimsner algebras of C^*-correspondences fail to generalize "easily" to our setting, and discuss what we have instead. (Received September 05, 2011)

1077-46-628 **Jonathan Henry Brown*** (jbrown@maths.otago.ac.nz). *Decomposing the C^*-algebras of groupoid extensions.*

Groupoids are generalizations of groups that are useful in modeling (among other things) the time evolution of a dynamical system. Furthermore, many interesting examples of C^*-algebras can be constructed from groupoids and thus the study of groupoid C^*-algebras illuminates the study of a large class of C^*-algebras. In joint work with Astrid an Huef, we decompose the full and reduced C^*-algebras of an extension of a groupoid by the circle into a direct sum of twisted groupoid C^*-algebras. (Received September 08, 2011)

1077-46-677 **Kelly Bickel*** (kbickel@math.wustl.edu). *Fundamental Agler Decompositions.*

It is well-known that every holomorphic function $\phi : \mathbb{D}^2 \to \mathbb{D}$ possesses an Agler decomposition; i.e. that there exist positive semi-definite kernels functions K_1 and K_2 such that

$$1 - \phi(\lambda)\overline{\phi(\mu)} = (1 - \lambda_1\bar{\mu_1})K_1(\lambda, \mu) + (1 - \lambda_1\bar{\mu_1})K_2(\lambda, \mu) \qquad \forall \lambda, \mu \in \mathbb{D}^2. \tag{1}$$

In general, such decompositions are difficult to write down explicitly. In this talk, we present a constructive, elementary proof of (1) using fundamental shift-invariant subspaces of the Hardy space on the bidisk. We then use these constructed decompositions to analyze properties about general Agler decompositions. (Received September 09, 2011)

1077-46-701 **Don Hadwin*** (don@unh.edu), MATH DEPT UNH, Durham, NH 03824, and **Qihui Li**, **Weihua Li** and **Junhao Shen**. *A survey of topological free entropy dimension.* Preliminary report.

We discuss the development of Dan Voiculescu's notion of topological free entropy dimension, which is an analog for C*-algebras of his notion of free entropy dimension for von Neumann akgebras having a tracial state. We include new results that give an upper bound 1 for the topological free entropy dimension for a large class of C*-algebras, which parallels results in the von Neumann algebra setting. (Received September 10, 2011)

1077-46-909 **Dmitry Kaliuzhnyi-Verbovetskyi*** (dmitryk@math.drexel.edu), Department of Mathematics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104. *Noncommutative analytic functions.*

In this talk, I will review some basic facts and new results of the noncommutative function theory, with the emphasis on domains of analyticity and on different types of convergence of noncommutative power series. (Received September 14, 2011)

1077-46-1090 **Jeremy J Becnel*** (becneljj@sfasu.edu). *Recovering a Function from the Gauss Radon Transform in White Noise Analysis.*

We describe the Gauss Radon transform in White Noise Analysis. We then develop several means of recovering a function from the function's Gauss Radon transform. (Received September 16, 2011)

1077-46-1227 **Igor Klep*** (igor.klep@fmf.uni-lj.si), Univerza v Ljubljani, Fakulteta za matematiko in fiziko, Jadranska 19, 1111 Ljubljana, Slovenia, and **J. William Helton**, **Scott McCullough** and **Markus Schweighofer**. *Convex Positivstellensatz, linear matrix inequalities and complete positivity.* Preliminary report.

Given polynomials p and q, it is natural to ask: does one dominate the other? That is,

$$\text{does} \quad q(x) \geq 0 \quad \text{imply} \quad p(x) \geq 0\ ? \tag{Q}$$

In this talk we focus on *free noncommutative* polynomials p, q and substitute matrices for the variables x_j. In case the positivity domain $\mathcal{D} = \{X \mid q(X) \succeq 0\}$ is *convex*, the domination question (Q) has an elegant answer. First of all, $\mathcal{D}$ then has a linear matrix inequality (LMI) representation, i.e., $\mathcal{D} = \{X \mid L(X) \succeq 0\}$ for a linear pencil L. Furthermore, the following "perfect" *Positivstellensatz* holds: p is *positive semidefinite* on the LMI domain $\mathcal{D}$ if and only if it has a weighted sum of squares representation with optimal degree bounds:

$$p(x) = s(x)^T s(x) + \sum_j f_j(x)^T L(x) f_j(x), \tag{A}$$

where $s(x), f_j(x)$ are vectors of polynomials of degree no greater than $\deg(p)/2$.

We shall also discuss the linear variant of (Q) and show how *LMI domination* is essentially equivalent to *complete positivity*. (Received September 18, 2011)

1077-46-1604 **Terje Hoim*** (`thoim@fau.edu`), Wilkes Honors College, 5353 Parkside Dr., Jupiter, FL 33458, and **David Robbins** (`david.robbins@trincoll.edu`), Department of Mathematics, 300 Summit St., Hartford, CT 06106. *Some hereditary properties of vector-valued functions.* Preliminary report.

Let X be a topological space and let $\{E_x : x \in X\}$ be a collection of Banach algebras indexed by X. Let $\mathcal{E} = \dot{\bigcup}_{x \in X} E_x$ be the disjoint union of the E_x, and let $\pi : \mathcal{E} \to X$ be the obvious projection. Suppose further that $\mathcal{F} : X \to \mathcal{E}$ is a space of selections such that $\mathcal{F}$ is full and $\mathcal{F}$ is a $C(X)$-module. Suppose each (or some) E_x has a certain property $\mathcal{P}$. The heredity problem then asks: Does $\mathcal{F}$ also have $\mathcal{P}$? Conversely, if $\mathcal{F}$ has a property $\mathcal{P}$, do the E_x's have it?

Examples of hereditary properties in bundles of Banach spaces include the approximation property and (in some bundles of commutative topological algebras) the spectral synthesis property.

In this paper we investigate the hereditary property of bounded approximate identities for section spaces of bundles of Banach algebras, and then use those results to examine a type of amenability for such section spaces, and how it relates to the amenability of the fibers E_x. (Received September 20, 2011)

1077-46-1629 **Cynthia Farthing** and **Nura Patani***, nura.patani@asu.edu, and **Paulette N. Willis**. *Topological k-graphs constructed from a topological dynamical systems and the associated C*-algebras.*

Generalizing the construction of a topological graph from a singly generated dynamical system (SGDS), one may construct a topological k-graph from a locally compact Hausdorff space and a family of local homeomorphisms which pairwise commute where the composition is defined. In joint work with Cindy Farthing and Paulette Willis, we consider the case where these maps are everywhere-defined and show that the C*-algebra of a topological k-graph constructed from such a system has a crossed product structure int he sense of Larsen. Time permitting, we describe work in process on developing a characterization of the topological k-graphs which arise from such a dynamical system. (Received September 20, 2011)

1077-46-1641 **J William Helton***, Bill Helton, Math Dept., UC San Diego, La Jolla, CA 92093. *Noncommutative Inequalities.*

The talk will cover aspects of inequalities for non-commutative functions on free *-algebras. At this point we have:

A. Free algebra versions of the classical real algebraic geometry description, or positivstellensatz, of when one polynomial p is positive on the domain where another, q, is positive. Recently a surprise is that if the domain defined by q is convex, then the positivstellensatz representation for p holds in a form which is as nice as it could possibly be and with no technical assumptions;

B. Classifications of convex rational functions, varieties and open sets. There are shockingly few;

C. A limited picture of free convex hulls and projections of free semi-algebraic sets;

D. Some theory of changes of variables to achieve non-commutative convexity;

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 20, 2011)

1077-46-1704 **Paul S. Muhly*** (`pmuhly@gmail.com`), Department of Mathematics, University of Iowa, Iowa City, IA 52246, and **Baruch Solel** (`mabaruch@techunix.technion.ac.il`), Department of Mathematics, Technion, Haifa, Israel. *Analytic Functions from Tensors.*

Let $\mathcal{T}_+(E)$ be the tensor algebra of a W^*-correspondence E over a W^*-algebra M. An important consequence of our dilation theorem (JFA **158**, p.389) is that each completely contractive representation of $\mathcal{T}_+(E)$ is determined by a pair (σ, z) where σ is a W^*-representation of M and z is a contraction in the space of operators that intertwine σ and $\sigma^E \circ \varphi$, where φ gives the left action of M on E. From this, it follows that $\mathcal{T}_+(E)$ can be represented as an algebra of bonafide analytic operator-valued functions on domains in operator spaces. In this talk we will describe the nature of these functions and discuss how they generalize the continuous multipliers of the Drury-Arveson space. (Received September 20, 2011)

1077-46-1717 **Alexander A. Katz** (katza@stjohns.edu), St. John's University, St. John's College of LAS, Dep. of Math&CS, 300 Howard Ave., DaSilva AC 314, Staten Island, NY 10301, and **Oleg Friedman*** (friedman001@yahoo.com), University of South Africa, Pretoria, RSA, ca: Touro College/Lander College for Men, Dep. of Math., 75-31 150th Str., Kew Gardens Hills, NY 11367. *On a version of dual space characterization of real Locally C*-algebras.*

A celebrated Jordan-Takeda-Grothendieck theorem provides a dual space characterization of complex C*-algebras among complex Banach *-algebras with continuous involutions as those in which every continuous linear functional is a difference of two positive linear functionals. In 1993 a version of a dual characterization of complex locally C*-algebras among complete complex Hermitean lmc*-algebras was published by Bhatt and Karia. Recently Katz announced a version of a dual characterization of complex locally C*-algebras among complex lmc*-algebras. In the present paper we generalize Katz's result to obtain the following version of a dual characterization of real locally C*-algebras: THEOREM. A complete real lmc*-algebra is real topologically *-isomorphic to a real locally C*-algebra iff every continuous linear functional on it is a finite linear combination of representable linear functionals. (Received September 20, 2011)

1077-46-1743 **Guimei An** and **Jung-Jin Lee***, Department of Mathematics and Statistics, 50 College Street, South Hadley, MA 01075, and **Zhong-Jin Ruan**. *p-operator spaces and approximation properties.*

Let G be a discrete group. Haagerup showed that G is weakly amenable if and only if $C^*_\lambda(G)$ has the completely bounded approximation property. Haagerup and Kraus later considered a slightly weaker property, say the approximation property, and showed that G has the approximation property if and only if $C^*_\lambda(G)$ has the operator approximation property. We extend these results using p-operator space, a generalization of operator spaces modeled on L_p spaces. This is a joint work with Guimei An and Zhong-Jin Ruan. (Received September 20, 2011)

1077-46-1750 **Xing-Gang He**, **Chun-Kit Lai** and **Ka-Sing Lau*** (kslau@math.cuhk.edu.hk), Department of Mathematics, The Chinese University of Hong Kong, Hong Kong, Hong Kong. *Exponential spectra in $L^2(\mu)$.* Preliminary report.

Initiated by Jorgensen and Pedersen's earlier work on the L^2-exponential basis of Cantor measures and the Fuglede problem, we consider the exponential type orthonormal basis, Riesz basis and frames in $L^2(\mu)$. We show that if $L^2(\mu)$ admits an exponential frame, then μ must be of pure type. We then give a detail study of the pure types and their convolutions. (Received September 20, 2011)

1077-46-1791 **Mihai Popa*** (popa@mast.queensu.ca), Department of Mathematics and Statistics, Queen's Unviersity, Jeffery Hall 209, University Avenue, Kingston, Ontario K7L 3N6, Canada. *Some Applications of Non-Commutative Functions in Free Analysis.*

Given two vector spaces, V and W over the complex numbers, a non-commutative function is, briefly, a mapping from a certain class of subsets of the matrix space over V to the matrix space over W satisfying some compatibility conditions: it has to respect direct sums and simultaneous similarities, or equivalently, simultaneous intertwinings. Noncommutative functions have very strong regularity properties and they admit a very nice differential calculus, closely related to some QD-bialgebras arising in free probabilities. Such objects were considered before by J. L. Taylor in his groundbreaking work on the noncommutative spectral theory, and more recently independently by D.-V. Voiculescu in free probability. Besides a brief introduction in the theory of non-commutative functions, the lecture will survey some applications of this theory in operator-valued non-commutative probability, such as non-commutative free Levy-Hincine formulas, Bercovici-Pata bijection, op-valued Cauchy and R-transforms, op-valued semicircle, arcsine and Bernoulli laws. Most of the results presented are joint work with V. Vinnikov and S. Belinschi. (Received September 21, 2011)

1077-46-1805 **Hafedh Herichi*** (herichi@math.ucr.edu), 900 University Ave, Riverside, CA 92521, and **Michel. L. Lapidus**. *Fractal Strings and the Invertibility of the Spectral Operator.*

The spectral operator was introduced for the first time by M. L. Lapidus and his collaborator M. van Frankenhuijsen in their theory of complex dimensions in fractal geometry. The corresponding inverse spectral problem was first considered by M. L. Lapidus and H. Maier in their work on a spectral reformulation of the Riemann hypothesis in connection with the question "Can One Hear The Shape of a Fractal String?". The spectral operator is defined on a suitable Hilbert space as the operator mapping the counting function of a generalized fractal string

η to the counting function of its associated spectral measure. It relates the spectrum of a fractal string with its geometry. During this talk, we will be discussing some fundamental properties of this operator and provide a condition ensuring its invertibility which is related to the Riemann hypothesis. (Received September 21, 2011)

1077-46-1815 **Giovanni Leoni** and **Daniel Spector*** (spectda@gmail.com), Hangzhou, 310013. *Characterization of Sobolev and BV spaces.*

In this talk I will discuss some recent results obtained in collaboration with G. Leoni on some new characterizations of Sobolev spaces $W^{1,p}(\Omega)$, $1 < p < \infty$, and the space of functions of Bounded Variation $BV(\Omega)$. These characterizations stem from some questions on the limiting behavior of non-local functionals, and because of this are interesting beyond the functional analysis involved. In particular, one application of these results is to connect the recent work of Gilboa and Osher (see Non-Local Operators with Applications to Image Processing) to the more classical model of Rudin, Osher, and Fatemi in image processing. (Received September 21, 2011)

1077-46-1843 **Otmar Scherzer*** (otmar.scherzer@univie.ac.at), Nordbergstr. 15, Vienna, Austria, and **Maarten de Hoop** and **Lingyun Qiu**. *Hoelder Stability and Iterative Rconstruction in Inverse Problems.*

We consider a class of inverse problems defined by a nonlinear map from parameter or model functions to the data. We assume that solutions exist. The space of model functions is a Banach space which is smooth and uniformly convex; however, the data space can be an arbitrary Banach space. We study sequences of parameter functions generated by a nonlinear Landweber iteration and conditions under which these strongly converge, locally, to the solutions within an appropriate distance. We express the conditions for convergence in terms of Hölder stability of the inverse maps, which ties naturally to the analysis of inverse problems. (Received September 21, 2011)

1077-46-1856 **James A Mingo*** (mingo@mast.queensu.ca), Department of Mathematics and Statistics, Queen's University, Kingston, Ontario K7L 3N6, Canada, and **Octavio Arizmendi**. *Second Order Even and R-diagonal Operators.* Preliminary report.

Voiculescu showed that circular operators, the free analogue of complex Gaussian random variables, and Haar unitaries are related by polar decomposition. This relationship was deepened by Nica and Speicher who showed that both are examples of R-diagonal operators. Nica and Speicher also showed that R-diagonal operators and even operators, self-adjoint operators with vanishing odd moments, are related combinatorically and via their free cumulants. We extend these results to the case of second order freeness. (Received September 21, 2011)

1077-46-1917 **Upasana Kashyap*** (ukashyap1@citadel.edu), 171 Moultrie Street, Dept. of Math and Computer Science, Charleston, SC 29409. *Picard group of dual operator algebras.* Preliminary report.

We discuss the Picard group of dual (weak*-closed) operator algebras. We prove that for a weak*-closed function algebra A, the weak Picard group Picw(A) is a semidirect product of the automorphism group of A, and subgroup of Picw(A) consisting of symmetric equivalence bimodules. In particular we show that the weak Picard group of space of bounded analytical functions is isomorphic to the group of conformal automorphisms of the disk. (Received September 21, 2011)

1077-46-2071 **Bacim Alali**, **Robert Lipton** and **Tadele Mengesha*** (mengesha@math.psu.edu), Penn State University, PA. *Multiscale analysis of the peridynamic equation of motion.*

We study the homogenization of the nonlocal equation of motion that models the dynamics of heterogeneous media based on the peridynamic formulation. The approach presented here provides the ability to model the macroscopic dynamics while at the same time resolving the dynamics at the length scales of the microstructure. Central to the methodology is a novel two-scale evolution equation. The rescaled solution of this equation is shown to provide a strong approximation to the actual deformation inside the peridynamic material. Moreover,the interplay between the microscopic and macroscopic dynamics is given by a coupled system of evolution equations. The equations show that the forces generated by the homogenized deformation inside the medium are related to the homogenized deformation through a history dependent constitutive relation. (Received September 21, 2011)

1077-46-2092 **Prahlad Vaidyanathan*** (pvaidyan@math.purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47906. *E-theory for Continuous Fields of C* algebras.* Preliminary report.

We define the E-theory for continuous fields of C* algebras over a locally compact, Hausdorff space and explain its basic properties. We compute the E-theory for various types of continuous fields of C* algebras, including a new result for the so-called sky-scraper algebras. We also provide a context for these results within the broader classification program for C* algebras. (Received September 21, 2011)

1077-46-2104 **Bonnie C. Jacob*** (bcjntm@rit.edu). *Selection of an optimal source to make the optical tomography problem less ill-posed.*

Optical tomography is an imaging method that has a great deal of allure in medical applications in particular because it does not cause harm to a patient. However, the ill-posed nature of the problem makes optical tomography difficult to use in practice. To combat this problem, we have worked on developing a method to choose a source that makes the problem as well posed as possible. The process depends on the choice of spaces, which we consider as well. In this talk, I will discuss the process of choosing an optimal source, as well as the analytical solution in a simple case. Finally, I will briefly describe an analogue of the problem on a network. (Received September 21, 2011)

1077-46-2193 **Christopher Jankowski*** (cjankows@math.upenn.edu), Department of Mathematics, 209 South 33rd Street, David Rittenhouse Lab., Philadelphia, PA 19104, and **Daniel Markiewicz** and **Robert Powers**. *Prime E_0-semigroups.*

A semigroup $\alpha = \{\alpha_t\}_{t\geq 0}$ of $*$-endomorphisms of $B(H)$ is called an E_0-semigroup if it is weakly continuous in t and $\alpha_t(I) = I$ for all $t \geq 0$. We say α is prime if, whenever α is cocycle equivalent to $\beta \otimes \gamma$ for some E_0-semigroups β and γ, it follows that β or γ is a semigroup of $*$-automorphisms. By considering E_0-semigroups constructed using Powers' theory of CP-flows, we exhibit an uncountable family of E_0-semigroups of type II_0. This is joint work with Daniel Markiewicz and Robert Powers. (Received September 22, 2011)

1077-46-2207 **Kevin Rion*** (krion@bridgew.edu), Mathematics and Computer Science Department, Bridgewater State University, Bridgewater, MA 02325. *The Aluthge Sequence of a Shift Operator.*

For any bounded linear operator T on a Hilbert space, the Aluthge transform is defined by $\Delta(T) = |T|^{\frac{1}{2}}\,U\,|T|^{\frac{1}{2}}$, where $T = U\,|T|$ is the polar decomposition of T. Moreover, the nth Aluthge transform is defined for $n \geq 1$ by $\Delta^n(T) = \Delta(\Delta^{n-1}(T))$, with $\Delta^0(T) = T$. If T is a bilateral forward shift, the Aluthge transform is also a bilateral forward shift with weights easily described as a function of the weights of T. We modify this description so that the successive operators $T, \Delta(T), \Delta^2(T), ...$ are seen as resulting from an elementary looking averaging process. We then use a strong form of Stirling's formula and Chebyschev's inequality to draw some conclusions about the convergence or divergence of the sequence $T, \Delta(T), \Delta^2(T), ...$ (Received September 21, 2011)

1077-46-2212 **Alexander A. Katz*** (katza@stjohns.edu), St. John's University, St. John's College of LAS, Dep. of Math&CS, 300 Howard Ave., DaSilva AC 314, Staten Island, NY 10301. *On locally JB*-algebras.*

We introduce locally JB*-algebras as complex locally convex topological Jordan *-algebras whose topology is defined by a separating saturated family of submultiplicative regular seminorms. We first prove that a complex locally convex Jordan *-algebra is a locally JB*-algebra iff it is topologically Jordan *-isomorphic to a projective limit of a projective family of JB*-algebras. Then we show that a selfadjoint part of each locally JB*-algebras is a locally JB-algebra of Katz and Friedman, and that a complexification of each locally JB-algebra can be endowed with a topology under which it becomes a locally JB*-algebra. As a corollary we get that: a). each maximal abelian Jordan *-subalgebra and the center of each locally JB*-algebra is again a locally JB*-algebra; b). a bounded part of each locally JB*-algebra is a dense JB*-subalgebra. (Received September 21, 2011)

1077-46-2260 **Genady Ya. Grabarnik*** (grabarng@stjohns.edu), Dept. of Math & CS, St Johns College, St Johns University, Queens, NY , and **Alexander A. Katz** (katza@stjohns.edu), St. John's University, St. John's College of, Staten Island, NY. *Convergence of the spherical averages for Markov semigroups on operator algebras.*

The goal of the note is to extend results of the Nevo, Bufetov et all. [1] and results of the authors [3] about convergence (in norm and in Egorov sense) of the spherical averages over action of general Markov (semi-) group of operators affiliated to operator algebra and integrated with p-th power (p greater than 1). Our interest in such general groups actions is motivated by Gromov's result [2] on word hyperbolic group exibiting Markov property with respect to any symmetric set of generators.

References

[1] Bufetov, A. and Khristoforov, M. and Klimenko, A., Cesaro convergence of spherical averages for measure-preserving actions of Markov semigroups and groups. *ArXiv e-prints*, **1101.5459B** (2011).

[2] M. Gromov, Hyperbolic groups, in *Essays in Group Theory*, *MSRI Publ.* **8** (1987), 75–263, Springer-Verlag, New York.

[3] G. Ya. Grabarnik, A. A. Katz, L. A. Shwartz On non-commutative ergodic type theorems for free finitely generated semigroups *Vladikavkaz Math Journal* (2007) **9** 38–47.

(Received September 21, 2011)

1077-46-2437 **Andrew K Greene*** (akoichig@gmail.com), Department of Mathematics, University of Iowa, Iowa City, IA 52242. *Extensions of Hilbert Modules over Operator Tensor Algebras.*

Given a C^*-correspondence E over a C^*-algebra A, one may form its tensor algebra $\mathcal{T}_+(E)$, a noncommutative generalization of the classical disc algebra. J. Carlson and D. Clark in *J. Funct. Anal.* **128** (1995), no. 2, 278–306., defined Ext groups for Hilbert modules over the disc algebra. We extend their methods to Hilbert modules over $\mathcal{T}_+(E)$. We examine the particular case when $E = A$ with left action given by an automorphism or more generally, if time permits, an endomorphism of A. (Received September 22, 2011)

1077-46-2539 **Craig Kleski*** (ckleski@virginia.edu). *Boundaries for operator systems.*

In 2006, Arveson resolved a long-standing problem by showing that for any element x of a separable self-adjoint unital subspace $S \subseteq B(H)$, $\|x\| = \sup \|\pi(x)\|$, where π runs over the boundary representations for S. Here we show that "sup" can be replaced by "max". This implies that the Choquet boundary for a separable operator system is a boundary in the classical sense; a similar result is obtained in terms of pure matrix states when S is not assumed to be separable. (Received September 22, 2011)

1077-46-2645 **Kevin Beanland** and **Daniel Freeman*** (freeman@math.utexas.edu), 4009 Victory dr, apt# E101, Austin, TX 78704, and **Rui Liu**. *Shrinking and Boundedly complete frames for Banach spaces.*

A Schauder frame for a Banach space X is a sequence $(x_i, f_i) \subset X \times X^*$ such that $\sum f_i(x)x_i = x$ for all $x \in X$. Frames can be thought of in some respect as redundant bases, and thus it is natural to consider what theorems for bases can be generalized to frames. We will discuss how James' and Zippin's theorems about shrinking and boundedly complete bases can be generalized to frames. (Received September 22, 2011)

47 ► Operator theory

1077-47-198 **Joseph A Ball*** (joball@math.vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061. *Realization and interpolation theory for the Herglotz-Agler class over the poly-right-halfplane.* Preliminary report.

The Schur-Agler class of functions is defined as the class of holomorphic functions S on the polydisk $\mathbb{D}^d$ for which $S(T_1, \dots, T_d)$ has norm at most 1 whenever $T_1, \dots, T_d$ is a commutative tuple of strict contraction operators on a Hilbert space $\mathcal{H}$. The Herglotz-Agler class is the class of holomorphic functions H on the d-variable poly-right-halfplane for which $H(X_1, \dots, X_n)$ has positive real part whenever $X_1, \dots, X_d$ is a commutative family of operators with each having strictly positive real part. While the Herglotz-Agler class is just a linear-fractional transform of the Schur-Agler class and the realization theory for the Schur-Agler class (i.e., realization of S as the transfer function of a multidimensional conservative input/state/output linear system) is well understood, the realization theory for the Herglotz-Agler class is considerably more subtle, especially in the several-variable case. We discuss several approaches to the realization theory for the Herglotz-Agler class with special attention to the rational case, and also indicate connections with a homogeneous subclass (the so-called Bessmertnyi class) of the Herglotz-Agler class. (Received August 11, 2011)

1077-47-200 **Joseph A Ball*** (joball@math.vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061. *Realization and interpolation theory for generalized Schur classes.* Preliminary report.

An object of much study over the past several decades is the so-called Schur class (holomorphic functions mapping the unit disk into the closed unit disk) and its generalizations. Such functions have several equivalent characterizations: contractive Hardy-space multipliers, positivity of an associated de Branges-Rovnyak kernel function, and realization as the transfer function of a conservative input/state/output linear system. There have now appeared increasingly more sophisticated generalized Schur classes; besides allowing matrices or operators for the values, one can allow more and more sophisticated domains: Schur-Agler classes in commuting or noncommuting variables, generalized Hardy algebras constructed from the Fock space arising from a W^*-correspondence, noncommutative functions on an operator-space unit ball. In this talk we focus on one particular type of generalized Schur class (holomorphic functions from the unit operator ball to operators of the form $T \mapsto s(T)$ with s a scalar Schur-class function and $s(T)$ defined by the standard Riesz-Dunford functional calculus) and show how the theory for this class can be developed from a number of different points of view. (Received August 11, 2011)

1077-47-264 **Carl C. Cowen*** (ccowen@math.iupui.edu). *Invariant Subspaces for Composition Operators.*

If ϕ is an analytic map of the disk into itself and H is a Hilbert space of analytic functions on the disk, the composition operator C_ϕ is the operator given by $C_\phi f = f \circ \phi$ for f in H.

Nordgren, Rosenthal, and Wintrobe (1984) observed that, if ϕ is a hyperbolic automorphism of the disk, then $C_\phi^* - I$ acting on the Hardy space is a 'universal operator' in the sense that every bounded operator on a Hilbert space is unitarily equivalent to a restriction of a multiple of this operator to an invariant subspace. This incomplete survey of results on invariant subspaces of composition operators will suggest that this is a rich area for future study.

The most striking result up to now has been the characterization by Montes, Ponce, and Shkarin (2010) of the lattice of invariant subspaces of a composition operator with symbol a linear fractional map of the disk into (but not onto) itself.

Much work, a promising beginning, concerns invariant subspaces of composition operators that are also invariant for the operator of multiplication by z. Work for Hermitian weighted composition operators has led to identifying extremal functions for subspaces in weighted Bergman spaces associated with the usual atomic inner functions. (Received August 17, 2011)

1077-47-380 **Sivaram K. Narayan*** (sivaram.narayan@cmich.edu), Department of Mathematics, Pearce Hall 218, Central Michigan University, Mount Pleasant, MI 48859. *Commutators of composition operators with adjoints of composition operators on weighted Bergman spaces.*

For linear-fractional self-maps φ and ψ of the unit disc $\mathbb{D}$, where at least one of φ and ψ is a non-automorphism, we show that the commutator $[C_\psi^*, C_\varphi]$ is non-trivially compact on the weighted Bergman space $A_\alpha^2(\mathbb{D})$ if and only if either φ and ψ are both parabolic or φ and ψ are both hyperbolic, with associated conclusions about their fixed points in each case. In the automorphism case, we show that the commutator $[C_\psi^*, C_\varphi]$ is compact if and only if both φ and ψ are rotations. This is a joint work with Barbara MacCluer and Rachel Weir. (Received August 27, 2011)

1077-47-393 **Irina Seceleanu*** (iseceleanu@bridgew.edu), Bridgewater State University, Department of Mathematics & Computer Science, Hart Hall 216, Bridgewater, MA 2325. *Cyclicity of vectors inducing an orbit with a non-zero limit point.*

Hypercyclicity is the study of linear operators that possess a dense orbit, where we denote the orbit of a vector x under T by $Orb(T, x) = \{x, Tx, T^2x, ...\}$. Chan and Seceleanu showed if a weighted shift has an orbit with a single non-zero limit point it will also possess a dense orbit, however the orbit with the non-zero limit point may not be dense. We investigate whether the linear span of such an orbit with a non-zero limit point must be dense in the whole space. (Received August 29, 2011)

1077-47-436 **Dan D. Pascali*** (dp39@nyu.edu), Courant Institute, New York University, 251 Mercer Street, New York, NY 10012-1185. *Equations involving pseudomonotone mappings with respect to two Banach spaces.*

Some existence results for solutions of variational inequalities with strong nonlinearities are proved using new classes of generalized mappings of monotone type. (Received September 01, 2011)

1077-47-467 **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. *Compactness of Hankel operators on convex domains.* Preliminary report.

We are interested in the following question: How does compactness of (products of) Hankel operators on Bergman spaces relate to the boundary geometry of domains in C^n? We will present some previous results on convex domains as well as some ongoing work on convex Reinhardt domains. (Received September 03, 2011)

1077-47-486 **Quanlei Fang***, quanlei.fang@bcc.cuny.edu, and **Jingbo Xia**. *Essential normality of polynomial-generated submodules.*

Recently, Douglas and Wang proved that for each polynomial q, the submodule $[q]$ of the Bergman module on the ball generated by q is essentially normal. Using improved techniques, we show that the analogue of this result holds in the case of the Hardy space $H^2(S)$ and in the first non-trivial case H_2^2 of free Hilbert module over $\mathbf{C}[z_1, z_2]$, and more. More specifically, we consider the family of reproducing-kernel Hilbert spaces $\mathcal{H}^{(t)}$, $-n \le t < \infty$, where n is the complex dimension of the ball. Here, $\mathcal{H}^{(t)}$ is defined by the reproducing kernel $(1 - \langle \zeta, z \rangle)^{-n-1-t}$, and one can think of the value t as the "weight" for the space $\mathcal{H}^{(t)}$. We show that if $q \in \mathbf{C}[z_1, \ldots, z_n]$, then for each real value $-3 < t < \infty$ the submodule $[q]^{(t)}$ of $\mathcal{H}^{(t)}$ is p-essentially normal for every $p > n$. Applications of this general result to the cases $t = -1$ and $t = -2$ yield the above-mentioned results for $H^2(S)$ and H_2^2 respectively. (Received September 04, 2011)

1077-47-495 **Constanze Liaw*** (conni@math.tamu.edu), Mailstop 3368, College Station, TX 77845-3668, and **Ronald G. Douglas**. *Rank one unitary perturbations via the theory of dilations.*

We study the spectral properties of rank one unitary perturbations in terms of the properties of a naturally associated model space which consist of certain analytic functions. We embed results by A. G. Poltoratski and M. S. Livsic into the framework of dilations and use it to prove new statements. (Received September 19, 2011)

1077-47-509 **Gelu F Popescu*** (gelu.popescu@utsa.edu). *Free Biholomorphic Functions and Operator Model Theory.*

Several results concerning the noncommutative multivariable operator theory on the unit ball of $B(\mathcal{H})^n$ are extended to noncommutative domains $\mathbf{B}_f(\mathcal{H}) \subseteq B(\mathcal{H})^n$, which are ranges of free biholomorphic functions f. We develop an operator model theory and dilation theory for $\mathbf{B}_f(\mathcal{H})$, where the associated universal model is an n-tuple $(M_{Z_1}, \ldots, M_{Z_n})$ of left multiplication operators acting on a Hilbert space of formal power series. Inverse mapping theorems, noncommutative Hardy spaces, and unitary invariants such as the characteristic function and curvature invariant (associated with $\mathbf{B}_f(\mathcal{H})$) are discussed. Most of these results can be extended to noncommutative varieties in $\mathbf{B}_f(\mathcal{H})$. (Received September 06, 2011)

1077-47-548 **Greg Knese*** (geknese@bama.ua.edu), University of Alabama, Dept. of Mathematics, Box 870350, Tuscaloosa, AL 35487-0350. *Stable symmetric polynomials, the Grace-Walsh-Szego theorem, and the Schur-Agler class.*

Two powerful theorems in the study of one variable stable polynomials (polynomials with all zeros outside the unit disk) are the Grace-Walsh-Szego coincidence theorem and the Christoffel-Darboux formula (from orthogonal polynomials on the unit circle). We will present an attempt to unify these results and show how they can help us better understand topics in operator related function theory, namely von Neumann inequalities and rational inner functions in the Schur-Agler class. (Received September 07, 2011)

1077-47-558 **Michael T Jury*** (mjury@ufl.edu), Department of Mathematics, University of Florida, PO Box 118105, Gainesville, FL 32611-8105. *"Noncommutative" Aleksandrov-Clark measures and function theory in the unit ball.* Preliminary report.

Let $\mathcal{S}$ denote the set of functions b, holomorphic in the unit ball of $\mathbb{C}^d$, such that the kernel $(1 - b(z)\overline{b(w)})(1 - \langle z, w\rangle)^{-1}$ is positive, and write $\mathcal{H}(b)$ for the corresponding reproducing kernel Hilbert space. In one variable these are known as the *de Branges-Rovnyak spaces*. Their theory is well-developed; the central objects are the backward shift operator on $\mathcal{H}(b)$ and the Aleksandrov-Clark (AC) measure μ.

The natural analog of the AC measure in the multivariable setting is a certain positive linear functional on a (noncommutative) operator system. The next difficulty is to understand what should be meant by "backward shift." We introduce a canonical solution to the Gleason problem in $\mathcal{H}(b)$ which preserves many features of the backward shift in the one-variable setting, and identify a subclass of $\mathcal{S}$ called *quasi-extreme* functions. (In one variable, these are the extreme points of the unit ball of H^∞.) As an application we obtain a version of Clark's theorem on rank-one perturbations of the backward shift, and some further function-theoretic results. (For example, $\mathcal{H}(b)$ is z_j-invariant for each $j = 1, \ldots d$ if and only if b is not quasi-extreme.) (Received September 07, 2011)

1077-47-572 **Rongwei Yang*** (ryang@albany.edu), 10 Harmony Court, Cohoes, NY 12047. *On a pair of commuting isometries.*

Let V_1, V_2 be a pair of commuting isometries on a separable Hilbert space H. The so-called fringe operator F for the pair is defined on $H \ominus V_1 H$ by $Fx = PV_2 x$, where P is the orthogonal projection from H onto the wandering space $H \ominus V_1 H$. We will see that much information about the pair is encoded in the fringe operator F. For instance, (V_1, V_2) is Fredholm if and only if F is Fredholm. Moreover, in this case $index(F) = index(V_1, V_2)$. (Received September 07, 2011)

1077-47-616 **Kenneth R. Davidson*** (krdavids@uwaterloo.ca), Pure Math. Dept., University of Waterloo, Waterloo, ON N2L3G1, Canada. *Dilation theory, commutant lifting and semicrossed products.*

We take a new look at dilation theory for nonself-adjoint operator algebras. Among the extremal (co)extensions of a representation, there is a special property of being fully extremal. This allows a refinement of some of the classical notions which are important when one moves away from standard examples. This leads to variations of the notions of commutant lifting and Ando's theorem. This is applied to the study of semicrossed products by automorphisms, and endomorphisms which lift to the C*-envelope. (joint work with Elias Katsoulis.) (Received September 08, 2011)

1077-47-642 **Carl Sundberg** and **Dechao Zheng*** (dechao.zheng@vanderbilt.edu). *The spectrum and essential spectrum of Toeplitz operators.*

On the Hardy space, by means of an elegant and ingenious argument, Widom showed that the spectrum of a bounded Toeplitz operator is always connected and Douglas showed that the essential spectrum of a bounded Toeplitz operator is also connected. On the Bergman space, in 1979, G. McDonald and the C. Sundberg showed that the essential spectrum of T_φ is connected for φ a harmonic function on the unit disk which is either real or piecewise continuous on the boundary. They asked whether the essential spectrum of a Toeplitz operator on the Bergman space with bounded harmonic symbol is connected. In this talk, we will show an example that the spectrum and the essential spectrum of a Toeplitz operator with bounded harmonic symbol is disconnected. (Received September 09, 2011)

1077-47-679 **Anna Skripka*** (skripka@math.ucf.edu). *Schatten norms of operator derivatives.*

For a large class of admissible scalar functions f, we obtain estimates for Schatten norms of operator (Gâteaux) derivatives $\frac{d^n}{dt^n} f(H_0 + tV)$, where H_0 is a self-adjoint or unitary operator and V its perturbation in some Schatten class. These estimates are used to establish that the remainder of the Taylor-type approximation $\mathrm{Tr}\left(f(H_0 + V) - \sum_{k=0}^{n-1} \frac{1}{k!} \frac{d^k}{dt^k}\big|_{t=0} f(H_0 + tV)\right)$ is a bounded functional on $f^{(n)}$ for V in the nth Schatten class. The talk is based on joint work with D. Potapov and F. Sukochev. (Received September 09, 2011)

1077-47-758 **David P Kimsey** and **Hugo J Woerdeman*** (hugo@math.drexel.edu), Department of Mathematics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104. *The truncated matrix valued multivariable K-moment problem.*

The matrix-valued truncated K-moment problem on $\mathbb{R}^d$ requires necessary and sufficient conditions for a multi-sequence of Hermitian matrices $\{S_\gamma\}_{\gamma\in\Gamma}$, where Γ is a finite subset of $\mathbb{N}_0^d$, to be the corresponding moments of a positive matrix-valued Borel measure σ and also the support of σ must lie in some given non-empty set $K \subseteq \mathbb{R}^d$, i.e.

$$S_\gamma = \int_{\mathbb{R}^d} \xi^\gamma d\sigma(\xi), \quad \gamma \in \Gamma, \tag{1}$$

and

$$\mathrm{supp}\ \sigma \subseteq K. \tag{2}$$

In this paper we obtain necessary and sufficient conditions for the existence of a finitely atomic measure which satisfies (1) and (2). In particular, our result can handle the case when the indexing set that corresponds to the powers of total degree at most $2n + 1$. We will also discuss a similar result in the complex setting. (Received September 14, 2011)

1077-47-779 **Paul S. Bourdon*** (bourdonp@wlu.edu), Department of Mathematics, Washington and Lee University, Lexington, VA 24450. *Invertible weighted composition operators.*

Let X be a set of analytic functions on the open unit disk $\mathbb{D}$, and let φ be an analytic function on $\mathbb{D}$ such that $\varphi(\mathbb{D}) \subseteq \mathbb{D}$ and $f \mapsto f \circ \varphi$ takes X into itself. We present conditions on X ensuring that if $f \mapsto f \circ \varphi$ is invertible on X, then φ is an automorphism of $\mathbb{D}$, and we derive a similar result for mappings of the form $f \mapsto \psi \cdot (f \circ \varphi)$, where ψ is some analytic function on $\mathbb{D}$. We obtain as corollaries of this purely function-theoretic work, new results concerning invertibility of composition operators and weighted composition operators on Banach spaces of analytic functions. For instance, our work permits us to completely characterize invertibility of composition operators and weighted composition operators on automorphism-invariant functional Banach spaces such as S^p, which consists functions on $\mathbb{D}$ having derivatives in the Hardy space $H^p(\mathbb{D})$. We also show that if a composition operator $f \mapsto f \circ \varphi$ or weighted composition operator $f \mapsto \psi \cdot (f \circ \varphi)$ on any weighted Hardy space $H^2(\beta)$ is invertible, then φ must be an automorphism of $\mathbb{D}$. (Received September 12, 2011)

1077-47-876 **Richard Rochberg*** (rr@math.wustl.edu), MO. *A Metric from a Reproducing Kernel Hilbert Space.* Preliminary report.

If H is a reproducing kernel Hilbert space of functions on a set X there are several ways that H can be used to define a metric on X. One example is the metric which sets the distance between two points to be the operator norm of the difference of the projections onto the spans of the respective kernel functions. This metric arises, for instance, in giving sharp estimates for the modulus of continuity of the Berezin transforms of linear operators on H. I will present some results about this metric.

(Received September 13, 2011)

1077-47-883 **Paul S Muhly** and **Baruch Solel*** (mabaruch@tx.technion.ac.il), Department of Mathematics, Technion, 32000 Haifa, Israel. *Non commutative Hardy operator algebras.*

In this talk we will describe the study of certain non-self-adjoint operator algebras, the (non commutative) Hardy algebras, and their representation theory. We view these algebras as algebras of (operator valued) functions on their spaces of representations. We will show that these spaces of representations can be parameterized as unit balls of certain bimodules and the functions can be viewed as Schur class operator functions on these balls. In fact, every element of the Hardy algebra gives rise to a family of functions, each defined on a different ball. we will discuss the properties of such families. (Received September 14, 2011)

1077-47-972 **Pamela B. Gorkin*** (pgorkin@bucknell.edu), Department of Mathematics, Bucknell University, Lewisburg, PA 17837. *To get (or not to get) uniform approximation by interpolating Blaschke products.*

This talk is motivated by a well-known question about approximating Blaschke products (uniformly) by interpolating Blaschke products. In this talk, we focus on two results. The first result is a positive one, giving information on where we can place zeroes to obtain a good (uniform) approximation of our function. The second result looks at various properties that must be maintained when we approximate a Blaschke product by an interpolating Blaschke product and is connected to the number of generators of a uniform algebra. The first result is joint work with David Farmer and the second with Eva Gallardo-Gutiérrez. (Received September 15, 2011)

1077-47-1097 **Derek Allen Thompson*** (theycallmedt@gmail.com), 4253 Willow Bend Dr., Apt. D, Beech Grove, IN 46107. *Restrictions to Invariant Subspaces of Composition Operators.* Preliminary report.

If ϕ is an analytic map of the disk into itself and H is a Hilbert space of analytic functions on the disk, the composition operator C_ϕ is the operator given by $C_\phi f = f \circ \phi$ for f in H.

Though we have learned much about composition operators and their affect on Hilbert spaces of analytic functions, little is yet known about the restrictions of these operators to invariant subspaces. For example, if a composition operator C_ϕ on the Hardy space $H^2(D)$ is such that its symbol $\phi : D \to D$ fixes the origin, then for $k \in \mathbb{N}$ the subspaces $z^k H^2 = \{z^k f | f \in H^2\}$ are invariant for C_ϕ. What are the norms of these restrictions? What are their spectra? Are they ever unitarily equivalent? We explore what is known about these restrictions and pose further questions. (Received September 16, 2011)

1077-47-1159 **Mehdi Nikpour*** (mnikpou@rockets.utoledo.edu), Department of Mathematics and Statistics, The University of Toledo, 2801 W. Bancroft St., Toledo, OH 43606-3390. *Algebraic and Operator-theoretic properties of Hardy-Hilbert space PTOs.*

From the matricial point of view, moving one step to the southeast, provides us a bounded operator-valued linear transformation on the C*-algebra of all bounded linear operators on the Hardy-Hilbert space to itself, which enables us first to answer partially a spectral problem raised by Paul R. Halmos, and second to embed Toeplitz operators in an extended setting. In this setting, a new indexed-class of Hardy-Hilbert operators, namely Parametric Toeplitz Operators (PTOs), is defined, and some of their Brown-Halmos type algebraic and operator-theoretic properties are studied. At the end, some Toeplitz and Hankel-type operator-equations are considered and solved. (Received September 17, 2011)

1077-47-1176 **Scott McCullough*** (sam@ufl.edu). *Free Inequalities.* Preliminary report.

The talk will cover aspects of inequalities for non-commutative functions on free *-algebras. At this point we have:

A. Free algebra versions of the classical real algebraic geometry description, or positivstellensatz, of when one polynomial p is positive on the domain where another, q, is positive. Recently a surprise is that if the domain defined by q is convex, then the positivstellensatz representation for p holds in a form which is as nice as it could possibly be and with no technical assumptions;

B. Classifications of convex rational functions, varieties and open sets. There are shockingly few;

C. A limited picture of free convex hulls and projections of free semi-algebraic sets;

D. Some theory of changes of variables to achieve non-commutative convexity;

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. It also has pleasing connections to operator systems and spaces and matrix convexity. The talk will focus on a topic from the list above and will be co-ordinated with the speaker's collaborators who are in attendence. (Received September 17, 2011)

1077-47-1313 **Flavia Colonna*** (fcolonna@gmu.edu), 4400 University Drive, Fairfax, VA 22030, and **Glenn R. Easley** and **David Singman**. *Norm of the multiplication operators from H^∞ to the Bloch Space of a bounded symmetric domain.*

Let f be a complex-valued holomorphic function on a bounded homogeneous domain D in $\mathbb{C}^N$ containing the origin. For $z \in D$ define

$$Q_f(z) = \sup_{u \in \mathbb{C}^N \setminus \{0\}} \frac{|(\nabla f)(z)u|}{H_z(u,\overline{u})^{1/2}},$$

where ∇f is the gradient of f and H_z is the Bergman metric on D at z. The *Bloch space* of D is the Banach space $\mathcal{B}$ of holomorphic functions f such that $Q_f = \sup_{z \in D} Q_f(z) < \infty$ with norm $\|f\|_{\mathcal{B}} = |f(0)| + Q_f$.

In this talk, we determine the operator norm of the bounded multiplication operator from the space of bounded holomorphic functions on a bounded symmetric domain D to $\mathcal{B}$ when the symbol fixes the origin. If no restriction is imposed on the symbol, we have a formula for the operator norm when D is the unit ball or has the unit disk as a factor. The proof of this result for the latter case makes use of a minimum principle for multiply superharmonic functions. We also show that there are no isometries among the multiplication operators when the domain does not have exceptional factors or the symbol fixes the origin. (Received September 19, 2011)

1077-47-1359 **Katherine Heller** and **Barbara D. MacCluer*** (bdm3f@virginia.edu), Kerchof Hall, PO Box 400137, University of Virginia, Charlottesville, VA 22904-4137, and **Rachel J. Weir**. *Compact differences of composition operators in several variables.*

For an analytic self-map φ of a domain Ω in $\mathbb{C}^N$, the composition operator C_φ is defined by $C_\varphi(f) = f \circ \varphi$, for f analytic in Ω. For a pair φ, ψ of linear-fractional self-maps of the unit ball B_N in $\mathbb{C}^N$, $N \geq 1$, we show that the difference $C_\varphi - C_\psi$ cannot be non-trivially compact on either the Hardy space $H^2(B_N)$ or any standard weighted Bergman space $A^2_\alpha(B_N)$. Our arguments emphasize geometric properties of the maps φ and ψ. (Received September 19, 2011)

1077-47-1434 **Gabriel T Prajitura*** (gprajitu@brockport.edu). *The many faces of linear chaos.* Preliminary report.

There are many definition of chaotic behavior. In the particular case of linear operators on Hilbert spaces these definitions are equivalent to simpler conditions. Moreover, in this context there are several relations between the different concepts of chaos which do not exist in the general case. (Received September 19, 2011)

1077-47-1497 **Ruhan Zhao*** (rzhao@brockport.edu), Department of Mathematics, College at Brockport, SUNY, Brockport, NY 14420. *Generalization of Schur's test and its application.*

We generalize the classical Schur's test to the boundedness of integral operators from L^p to L^q spaces equipped with different measures, for $1 \leq p \leq q < \infty$. As an application, we determine exactly when a class of integral operators are bounded between different weighted L^p spaces on the unit ball of $\mathbb{C}^n$. (Received September 20, 2011)

1077-47-1575 **Daniel Aron Alpay*** (dany@math.bgu.ac.il), **Palle Jorgensen**, **Izchak Lewkowicz** and **Itzik Marziano**. *Representation formulas for Hardy space functions through the Cuntz relations and new interpolation problems.*

We introduce connections between the Cuntz relations and the Hardy space H_2 of the open unit disk . We then use them to solve a new kind of multipoint interpolation problem in H_2, where for instance, only a linear combination of the values of a function at given points is preassigned, rather than the values at the points themselves. We also consider the case of de Branges-Rovnyak spaces. (Received September 20, 2011)

1077-47-1648 **Waleed K. Al-Rawashdeh*** (walrawashdeh@mtech.edu), Department of Mathematical Sciences, Montana Tech of The University of Montana, 1300 W. Park Street, Butte, MT 59701. *Compact Weighted Composition Operators on Bergman Spaces.*

Let φ be an analytic self-map of the unit ball $\mathbb{B}_n$ and let ψ be an analytic function on $\mathbb{B}_n$. For $\alpha > -1$ and $p > 0$ the weighted Bergman space $A^p_\alpha(\mathbb{B}_n)$ consists of all holomorphic functions in $L^p(\mathbb{B}_n, dv_\alpha)$, the weighted Lebesgue measure dv_α is defined as $dv_\alpha(z) = c_\alpha(1-|z|^2)^\alpha dv(z)$, where dv is the volume measure on $\mathbb{B}_n$ and $c_\alpha = \frac{\Gamma(n+\alpha+1)}{n!\Gamma(\alpha+1)}$ is a normalizing constant so that dv_α is a probability measure on $\mathbb{B}_n$.

Given $W_{\psi,\varphi} : A^p_\alpha(\mathbb{B}_n) \to A^q_\beta(\mathbb{B}_n)$ we characterize the boundedness and compactness of the weighted composition operator $W_{\psi,\varphi}$, where $0 < q < p < \infty$ and $-1 < \alpha, \beta < \infty$, in terms of Carleson measures. The results will be expressed in terms of the weighted φ-Berezin transform. (Received September 20, 2011)

1077-47-1746 **Maria Neophytou*** (maria.neophytou@belmont.edu). *On the Point Spectrum of the Adjoints of Some Composition Operators and Weighted Composition Operators.*

Let H^2 be the Hardy-Hilbert space. If φ is an analytic map of the unit disk into itself and ψ is analytic on the disk, the composition operator C_φ with symbol φ is defined by $C_\varphi f = f \circ \varphi$, and the weighted composition operator $W_{\psi,\varphi}$ by $W_{\psi,\varphi} f = \psi(f \circ \varphi)$, for f in H^2. We look at adjoints of composition operators with symbols φ that have a fixed point inside the disk and a fixed point on the boundary with finite angular derivative there. By imposing a few extra assumptions on φ, we show that the point spectrum of the adjoint contains a disk centered at the origin, and that the corresponding eigenspaces are infinite-dimensional. We also identify a subspace of H^2 which is invariant for the adjoint and on which the adjoint acts like a weighted shift. Finally, we generalize these results for weighted composition operators. (Received September 20, 2011)

1077-47-1968 **Vladimir Bolotnikov***, vladi@math.wm.edu, Williamsburg, VA 23185-8795, and **Joseph A Ball**. *Characteristic functions of row contractions: unitary equivalence and coincidence.*

The Sz.-Nagy-Foias characteristic function of a Hilbert space contraction T turns out to be is a complete unitary invariant of T in case T is completely nonunitary. Popescu introduced the notion of the characteristic function of a row contractions and showed that it is a complete unitary invariant of a row contraction in the completely noncoisometric case. The commutative version of this results appears in a more recent Bhattacharyya-Eschmeier-Sarkar paper. In the talk, we will present these results from a different point of view (using de Branges-Rovnyak type realizations based on the Agler decompositions for a characteristic function) and discuss what happens or what may happen beyond the completely noncoisometric case. This is the joint work with J.A. Ball. (Received September 21, 2011)

1077-47-1979 **Linda J. Patton*** (lpatton@calpoly.edu), Mathematics Department, Cal Poly, San Luis Obispo, CA 93407. *Numerical Ranges of Some Cubic Operators.* Preliminary report.

In 1999, Tso and Wu showed that the boundary of the numerical range of a quadratic operator T on a Hilbert space is an ellipse with foci at the eigenvalues of T. Consequently, an operator T satisfying $T^2 = I$ cannot have a circular disk as its numerical range. Recently it was shown that there exists an operator T satisfying $T^3 = I$ on an infinite dimensional Hilbert space with a circular disk as its numerical range. In this talk, a special case when T is a composition operator on $H^2(\mathbb{D})$ will be discussed. (Received September 21, 2011)

1077-47-2006 **Christopher S Nelson*** (csnelson@math.ucsd.edu). *Noncommutative Real Ideals and an Algorithm for Computing Them.*

The zero set of a noncommutative polynomial p is the set of all pairs (X, v), where X is a tuple of square matrices and v is a vector, such that $p(X)v = 0$. If $p(X)v = 0$ whenever $q(X)v = 0$ for some other noncommutative polynomial q, then the zero set of q is contained in the zero set of p. A polynomial q has the left nullstellensatz property if whenever the zero set of a polynomial p contains the zero set of q, the polynomial p is equal to fq for some polynomial f. I give a framework for proving that certain polynomials have this left nullstellensatz property. Using this adds several natural cases to those previously known. Further, I introduce a noncommutative analog to the concept of a real ideal. The left ideal generated by a noncommutative polynomial q with the left nullstellensatz property must be a real ideal. I provide an algorithm for computing the smallest noncommutative real left ideal containing a noncommutative polynomial q. (Received September 21, 2011)

1077-47-2190 **Trieu L. Le*** (trieu.le2@utoledo.edu). *Boundedness and compactness of composition operators on Segal-Bargmann spaces.* Preliminary report.

For E a Hilbert space, let $\mathcal{H}(E)$ denote the Segal-Bargmann space (also known as the Fock space) over E, which is a reproducing kernel Hilbert space with kernel $K(x, y) = \exp(\langle x, y\rangle)$ for x, y in E. If φ is a mapping on E, the composition operator C_φ is defined by $C_\varphi h = h \circ \varphi$ for $h \in \mathcal{H}(E)$ for which $h \circ \varphi$ also belongs to $\mathcal{H}(E)$. We will discuss necessary and sufficient conditions for the boundedness and compactness of C_φ. Our results generalize results obtained earlier by Carswell, MacCluer and Schuster for finite dimensional spaces E. (Received September 21, 2011)

1077-47-2228 **James M Carter*** (carter42@iupui.edu). *Commutants of Composition Operators on the Hardy Hilbert Space.* Preliminary report.

For ϕ a map of the unit disk into itself, the induced composition operator C_ϕ acts on the Hilbert space of analytic functions on the disk by $C_\phi f = f \circ \phi$. The composition operator is bounded and several properties can be deduced from the properties of the symbol of ϕ.

If $\phi_t = e^{-t}z + 1 - e^{-t}$ where $t > 0$, then $\phi_t(1) = 1$ and $\phi_t'(1) < 1$ and the induced composition operators are not compact, however the operators do form a semigroup.

Given a bounded operator, A, the set of operators that commute with A is called the commutant of A and each such operator, B, satisfies the equation $AB = BA$. In the case where ϕ induces a compact composition operator, a complete characterization of the commutant is well-known.

The definition of commutant can be extended to a set of operators and this talk will discuss which operators commute with every C_{ϕ_t} for $t > 0$ as well as some of the properties of the commuting operators. (Received September 21, 2011)

1077-47-2234 **Yun-Su Kim*** (yunsu120@gmail.com), 1517 Secor road UP APT 228, Toledo, OH 43607. *Algebraic Elements and Invariant Subspaces.*

We prove that if a completely non-unitary contraction T in $L(H)$ has a non-trivial algebraic element h, then T has a non-trivial invariant subspace. (Received September 21, 2011)

1077-47-2314 **Maria Tjani*** (mtjani@uark.edu), Department of Mathematical Sciences, SCEN 301, 1 University of Arkansas, Fayetteville, AR 72701. *Closed-Range Composition Operators on Dirichlet type spaces.* Preliminary report.

For an analytic self map of the unit disk $\mathbb{D}$ we give new necessary and sufficient conditions for the composition operator C_ϕ to be closed-range on Dirichlet type spaces. (Received September 22, 2011)

1077-47-2318 **Christopher Hammond*** (cnham@conncoll.edu), 270 Mohegan Avenue, New London, CT 06320. *Complex Symmetric Composition Operators.* Preliminary report.

An operator T on a Hilbert space $\mathcal{H}$ is called *complex symmetric* if there is an involutive, isometric, antilinear operator C on $\mathcal{H}$ such that $T = CT^*C$. This talk, based on ongoing work with Stephan Ramon Garcia, explores which composition operators on various weighted Hardy spaces can possess the property of complex symmetry. (Received September 22, 2011)

1077-47-2356 **Hyun Kwon*** (hyunkwon@snu.ac.kr), **Ronald Douglas** and **Sergei Treil**. *Similarity of Operators in the Bergman Space Setting.*

We characterize the 2- hypercontractions that are similar to the backward shift operator in the Bergman space A^2. This description resembles the one given for contraction operators that are similar to the backward shift in the Hardy space H^2, where the eigenvector bundle structure of the operators is used. (Received September 22, 2011)

1077-47-2691 **Victor Vinnikov*** (vinnikov@math.bgu.ac.il), Department of Mathematics, Ben Gurion University of the Negev, 84105 Beer Sheva, Israel. *Noncommutative functions: examples and key features.*

A *noncommutative (nc) space* $\mathcal{V}_{\rm nc}$ over a vector space $\mathcal{V}$ is the disjoint union of the spaces of $n \times n$ matrices over $\mathcal{V}$ for all n; if $\mathcal{V}$ is an operator space, $\mathcal{V}_{\rm nc}$ carries a natural topology, induced by the sequence of matrix norms. A subset of $\mathcal{V}_{\rm nc}$ is called a *nc set* if it is closed under direct sums. A function f from a nc set in $\mathcal{V}_{\rm nc}$ to $\mathcal{W}_{\rm nc}$, for vector spaces $\mathcal{V}$ and $\mathcal{W}$, is called a *nc function* if it maps $n \times n$ matrices to $n \times n$ matrices for all n and satisfies certain compatibility conditions as we vary the matrix size n — namely, if it respects direct sums and similarities, or equivalently, intertwinings.

I will discuss some examples of nc functions (polynomials, rational functions, and power series in noncommuting inderterminates, as well as various transforms arising in operator-valued free probability), and some key features of their theory, including the regularity properties (roughly, local boundedness implies continuity and analyticity) and the power series expansions. This is a joint work with Dmitry Kaliuzhnyi-Verbovetskyi. (Received September 22, 2011)

49 ► Calculus of variations and optimal control; optimization

1077-49-178 **Elena Constantin*** (constane@pitt.edu), University of Pittsburgh-Johnstown, Mathematics Department, 450 Schoohouse Road, Johnstown, PA 15904. *Higher-Order Necessary Conditions in Nonsmooth Set Constrained Optimization.*

The goal of this talk is to give some higher-order necessary conditions of extremum for a nonsmooth optimization problem with an arbitrary set constraint in terms of contingent vectors and of interior directions to the constrained set at the extremum point using the directional derivatives of higher-order in Ginchev sense. Illustrative examples are presented. (Received August 08, 2011)

1077-49-180 **Mostafa Ghandehari*** (ghandeha@uta.edu), Univ. of Texas at Arlington, Civil Engineering, Box 19308, Arlington, TX 76019. *Geometric Applications of the Maximum Principle.*

Pontyagin's maximum principle of control theory is introduced and used in a study of planar curves. Applications to plane sets of constant width as well as plane curves with bounded piecewise continuous curvature will be given. Three dimensional generalizations are discussed. (Received August 08, 2011)

1077-49-221 **Boris Mordukhovich** and **Nghia Tran*** (ttannghia@wayne.edu), 667 W Hancock, Apt 309, Detroit, MI 48201. *Subdifferentials of Supremum Lipschitzian Functions and Its Applications to Nonsmooth Semi-infinite and Infinite Programs.*

The paper concerns the study of subdifferentials of a function which is the supremum of an arbitrary family of uniformly Lipschitzian functions in Asplund spaces. As a consequence we get involved first-order optimality conditions for nonsmooth optimization problems of the so-called infinite programming that are generally defined on infinite-dimensional spaces of decision variables and contain infinitely many of inequality constraints with arbitrary index sets. These problems reduce to semi-infinite programs when the spaces of decision variables are finite-dimensional. We also extend the classical Mangasarian-Fromovitz constraint qualification and introduce some new types of closedness conditions to such semi-infinite and infinite programs. (Received August 14, 2011)

1077-49-223 **R. N. Mohapatra*** (ramm1627@gmail.com), Mathematics Department, University of Central Florida, 4000 Central Florida Blvd., Orlando, FL 32816, and **Ram U Verma** (verma99@msn.com), Mathematics Department, Texas A & M University, Kingsville, TX 32817. *The $\epsilon-$Optimality conditions for Multiobjective Fractional Programming Problems.*

Consider a multiobjective fractional programming problem (based on the generalized $(\rho,\eta)-$invexity of non-differentiable functions)
(P)

$$Minimize\,(\frac{f_1(x)}{g_1(x)},\cdots,\frac{f_p(x)}{g_p(x)})$$

subject to $x\in R^n$ such that $h_j(x)\leq 0$ for j=1,...,m,
where f_i, g_i, $i=1,...,p$ are real-valued functions, and $\epsilon=(\epsilon_1,...,\epsilon_p)$ with $\epsilon_i\geq 0$ for i=1,...,p. We explore parametric and semiparametric sufficient conditions for $\epsilon-$efficient solvability of (P) based on the generalized $(\rho,\eta)-$invexity. (Received August 14, 2011)

1077-49-224 **Frank Morgan*** (Frank.Morgan@williams.edu) and **Aldo Pratelli**. *Existence of isoperimetric regions in R^n with density.*

We prove the existence of isoperimetric regions in R^n with density under various hypotheses on the growth of the density. Along the way we prove results on the boundedness of isoperimetric regions. (Received August 15, 2011)

1077-49-278 **Alexander J. Zaslavski*** (ajzasl@tx.technion.ac.il), Department of Mathematics, The Technion - Israel Institute of Technology, 32000 Haifa, Israel. *Convergence of a proximal point method and of a projected subgradient method in the presence of computational errors in Hilbert spaces.*

We discuss the convergence of a proximal point method in a Hilbert space under the presence of computational errors. Most results known in the literature establish the convergence of proximal point methods when computational errors are summable. In our recent work the convergence of the method is established for nonsummable computational errors. We show that the proximal point method generates a good approximate solution if the sequence of computational errors is bounded from above by some constant. We also discuss the convergence of the projected subgradient method for constrained convex optimization in a Hilbert space. Our goal is to obtain an approximate solution of the problem in the presence of computational errors. (Received August 18, 2011)

1077-49-319 **Jon M. Conrad*** (jmc16@cornell.edu), Dyson School of Applied Economics and Managem, 431 Warren Hall, Cornell University, Ithaca, NY 14853, and **Martin D. Smith** (marsmith@duke.edu), A122 LSRC, Nicholas School of the Environment, Duke University, Durham, NC. *Non-Spatial and Spatial Models in Bioeconomics.*

Beginning in the 1960s, ecologists, mathematicians, and economists started developing a class of models which today are referred to as bioeconomic models. These early models started with a difference or differential equation describing the dynamics of a biological resource. To this equation one might add a second difference or differential equation describing the dynamics of "harvesting effort." Alternatively, one could formulate a dynamic optimization problem seeking to maximize discounted net benefit. These models provided important insights into the tragedy of the commons and policies that might promote optimal management. By the 1970s more complex models were developed incorporating multi-species interactions, age-structured populations, and models with stochastic growth. In the late 1990's, spatial bioeconomic models were developed in recognition of the importance of location when managing biological resources. The objectives of this survey are to (1) review some of the early models in bioeconomics, (2) present some of the key spatial models in bioeconomics that have been used to assess the value of marine (no-take) reserves, and (3) speculate on the direction of future research in spatial bioeconomics. (Received August 21, 2011)

1077-49-323 **Aden Omar Ahmed*** (aden.ahmed@tamuk.edu), 700 University BLVD, Kingsville, TX 78363-8202. *Quantum Games & Quaternionic Strategies.*

For the quantization of two player, two strategy games by Eisert, Wilkens, and Lewestein, S. Landsburg has constructed a quaternionic representation of the payoff function using which he classified potential Nash equilibria in these games. Landsburg's construction is based on a specific maximally entangled initial state. It turns out, however, that there is an entire class of maximally entangled states any member of which can be used for the "quaternionization" of these games. Here, we present a generalization of Landsburg's construction by using an arbitrary representative from the class of maximally entangled states and classify the potential Nash equilibria in the corresponding two player, two strategy games. (Received August 22, 2011)

1077-49-341 **Wandi Ding*** (wding@mtsu.edu), 1301 E. Main Street, MTSU Box 34, Murfreesboro, TN 37132, and **Volodymyr Hrynkiv** (hrynkivv@uhd.edu) and **Xiaoyu Mu** (xiaoyumoon@gmail.com). *Optimal Control Applied to Native-Invasive Species Competition via a PDE Model.*

We consider an optimal control problem of a system of parabolic partial differential equations modeling the competition between an invasive and a native species. The motivating example is cottonwood-salt cedar competition, where the effect of disturbance in the system (such as flooding) is taken to be a control variable. Flooding being detrimental at low and high levels, and advantageous at medium levels led us to consider the quadratic growth function of the control. The objective is to maximize the native species and minimize the invasive species while minimizing the cost of implementing the control. A new existence result for an optimal control with these quadratic growth functions is given. Numerical examples are given to illustrate the results. Our findings will provide suggestions to the natural resource managers for controlling the invasive species. (Received August 24, 2011)

1077-49-349 **Thomas Schulte-Herbrueggen*** (tosh@tum.de), Dept. Chem. OC-II, TU-Munich, Lichtenbergstrasse 4, 85747 Garching, Germany. *Symmetry Principles in Quantum Systems Theory with Applications in Simulation and Control.*

Elucidating quantum systems theory in terms of symmetry principles has triggered us in a number of recent advances: (i) it leads to a new controllability criterion, (ii) it guides the design of universal quantum hardware, (iii) it governs which quantum system can simulate another one given, and (iv) it specifies the limit between time-optimal control and relaxation-optimised control of open systems.

How principles turn into practice is illustrated by practical applications in solid-state devices and circuit-qed. – The algorithmic tools are presented in a unified programming framework. (Received August 25, 2011)

1077-49-365 **Jannett Highfill** (highfill@bradley.edu), Department of Economics, Bradley University, and **Michael McAsey*** (mcasey@bradley.edu), Department of Mathematics, Bradley University, Peoria, IL 61625. *Optimal R & D Spending and Competition Between Firms.* Preliminary report.

The goal is for a firm to determine the optimal expenditure of research and development (R&D) funding that increases the quality of their product so as to maximize the integral representing total discounted profit. The integrand in the optimal control problem is constructed from a distribution of reservation prices which results in a function that is quadratic in the state variable $x(t)$ (the quality level of the product) and linear in the control $E(t)$ (the R&D expenditure). The quality is regarded as a number between 0 and 1 so that $1-x(t)$ is the failure rate of the product. The state equation is $dx/dt = k(1-x)E^{1/2}$, so that quality gets more difficult to increase as the product has higher quality and the R&D funding has diminishing returns. In an initial model a competitor is another firm that is either "complacent" (doing no R&D) or "lockstep" (matching improvements to the product instantaneously). Extensions of the basic model include changes in the planning period, introducing trade costs, and considering intermediate competitive scenarios. In another extension, the behavior of the two firms are characterized in a dynamic game setting. (Received August 26, 2011)

1077-49-448 **Xiyin Zheng** (xyzheng@ynu.edu.cn), Department of mathematics, Yunnan University, Kunming, Yunnan 650091, Peoples Rep of China, and **Wei Ouyang*** (ej0264@wayne.edu), 1104 Faculty and Administration BLD, 656 W. Kirby, Detroit, MI 48202. *Metric subregularity for composite-convex generalized equations in Banach spaces.* Preliminary report.

This paper consider a convex-composite generalized constraint equation in Banach spaces. Using variational analysis technique, in terms of normal cones and coderivatives, we first establish sufficient conditions for such an equation to be metrically subregular. Under the Robinson qualification, we prove that these conditions are also necessary for the metric subregularity. In particular, some existing results on error bound and metric subregularity are extended to the composite-convexity case from the convexity case. (Received September 01, 2011)

1077-49-485 **Douglas E Ward*** (wardde@muohio.edu), Dept of Mathematics, Miami University, Oxford, OH 45056. *An Epigraph-Based Approach to Second-Order Sensitivity Analysis in Set-Valued Optimization.* Preliminary report.

Estimates are obtained for the second-order contingent and adjacent derivatives of the epigraph of the marginal multifunction in parametric set-valued optimization. These estimates generalize sensitivity results from scalar-valued optimization. Corollaries include new estimates for the first-order contingent and adjacent derivatives of the epigraph of the marginal multifunction. (Received September 04, 2011)

1077-49-634 **Mohsen Razzaghi*** (razzaghi@math.msstate.edu), Department of Mathematics and Statistics, Mississippi State University, Mississippi State, MS 39762. *Solution of optimal control problems via combined block-pulse functions and polynomial series.*

Orthogonal functions and polynomial series have been used when dealing with various problems of the 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. The approach is based on converting the underlying differential equation into an integral equation through integration, approximating various signals involved in the equation by truncated orthogonal functions and polynomial series, and using the operational matrix of integration to eliminate the integral operations. This matrix can be uniquely determined based on the particular orthogonal functions and polynomial series. In this work, we present a new direct computational method to solve optimal control problems. The approach is based of reducing the optimal control problems into a set of algebraic equations by first expanding the candidate function as a combined block-pulse functions and polynomial series with unknown coefficients. The operational matrix of integration is then utilized to evaluate the unknown coefficients and find the solution of optimal control problems. Some properties together with illustrative examples are given. (Received September 08, 2011)

1077-49-680 **Ruixing Long*** (rlong@princeton.edu). *Gradient flow in quantum control problems and the role of singular controls.*

Due to the lack of direct motion planning algorithms, the task of steering a quantum system from one state to another is often achieved by optimizing a suitable objective function in the control space. A commonly used optimization procedure in the quantum control community is the gradient flow. In order to explain the wide success of this procedure in numerical simulations, we propose to analyze the asymptotic behavior of the corresponding continuous dynamical system in the control space. Understanding the role of a specal class of controls called singular controls is of critical importance in this analysis. We will present some recent results in that direction. (Received September 09, 2011)

1077-49-936 **Janos Turi***, turi@utdallas.edu, and **Alain Bensoussan**. *Optimal Control of Variational Inequalities.*

We consider control problems for the variational inequality describing a single degree of freedom elasto-plastic oscillator. We are particularly interested in finding the "critical excitation", i.e., the lowest energy input excitation that drives the system between the prescribed initial and final states within a given time span. This is a control problem for a state evolution described by a variational inequality. We obtain Pontryagin's necessary condition of optimality. An essential difficulty lies with the non continuity of adjoint variables. We define an algorithm which leads to the optimal control. (Received September 14, 2011)

1077-49-1034 **Farhod Abdullayev*** (farkhad.abdullaev@ndsu.edu), Department of Mathematics, North Dakota State University, NDSU Dept. #2750, P.O. Box 6050, Fargo, ND 58108-6050. *A variational characterization of the effective yield set for ionic polycrystals.*

The effective yield set for ionic polycrystals is characterized by means of a family of variational principles associated to supremal functionals acting on matrix-valued divergence-free fields. Joint work with Marian Bocea (Loyola University Chicago) and Mihai Mihailescu (University of Craiova, Romania). (Received September 15, 2011)

1077-49-1302 **A L Dontchev*** (ald@ams.org), 416 Fourth Street, Ann Arbor, MI 48103. *Global Metric Regularity.*

We introduce a new definition of global metric regularity and associated definitions of Aubin continuity and linear openness that are equivalent to metric regularity on the same sets and with the same constant. When the sets are neighborhoods of a point in the graph of the mapping, these definitions reduce to the well studied properties at a point. We present Lyusternik-Graves type theorems in metric spaces for single-valued and set-valued perturbations, and show that they can be derived from, and some of them are even equivalent to, corresponding set-valued fixed point theorems. (Received September 19, 2011)

1077-49-1345 **Eunju Sohn***, Boyd Graduate Studies Research Center, Department of Mathematics, University of Georgia, Athens, GA 30602, and **Qing Zhang**, Boyd Graduate Studies Research Center, Department of Mathematics, University of Georgia, Athens, GA 30602. *Near Optimal Selling Rule for a Mean-Reverting Asset.*

This paper is concerned with trading a stock of which the price fluctuates randomly. We assume that the price of the stock is governed by a switching geometric Brownian motion and a mean-reversion model. We also consider two time scales that reflect short-term and long-term market changes. The process is modeled as a continuous-time Markov chain with a finite number of states. Our objective is to find an optimal selling/buying rule to maximize the overall return. We solve the system of the Hamilton-Jacobi-Bellman equations for the limiting problem, obtain asymptotic solutions, and compare them with numerical results. (Received September 19, 2011)

1077-49-1354 **Ellina Grigorieva*** (egrigorieva@twu.edu), PO BOX 425262, Denton, TX 76204, and **Evgenii Khailov** and **Andrei Korobeinikov**. *Optimal control of HIV treatment.*

We consider a 3 -dimensional nonlinear control model describing possible effect of medication intake (bounded control parameter) on HIV infected patients and his (her) possible recovery. The ODE model describes the dynamics of a viral infection with lytic and nonlytic immune response and has the following phase variables: populations of infected and uninfected cells, and population of immune response cells. The optimal control problem of minimizing the infected cells is stated and solved. Optimal trajectories of the system are obtained analytically under condition of the absence of own immune system. Numerical simulation demonstrate behavior of the model under different system's parameters. (Received September 19, 2011)

1077-49-1645 **Jung-Ha An*** (jan@csustan.edu), One University Circle, Turlock, CA 95382, and **Paul Bigeleisen** and **Steven Damelin**. *Identification of Nerves in Ultrasound Scans Using a Modified Mumford-Shah Functional and Prior Information.*

Ultrasound scans have many important clinical applications in medical imaging. One of clinical applications is to find nerves. One of the skills necessary to conduct ultrasound model, several numerical guided nerve blocks is the ability to recognize the nerves, vessels, muscles and bones in sagittal and axial cross sections. The goal of this talk is to present an efficient image segmentation algorithm which identifies nerves in ultrasound scans. A new region based variational model is proposed using a modified piecewise constant Mumford-Shah functional and prior information. The region of interests are extracted by using Γ-approximation to a piecewise constant Mumford-Shah functional. However, this method only is not able to accommodate all types of imaging difficulties including noise, artifacts, and loss of information. Therefore, the prior information is incorporated with the distance function. The distance function consists of the global rigid transformation and local non-rigid deformation. The proposed model is applied to healthy human neck ultrasound images. The preliminary numerical results show the effectiveness of the suggested algorithm and is compared to an existing piecewise constant Mumford-Shah model and expert results. (Received September 20, 2011)

1077-49-1734 **Ahmad R Almomani*** (almomaar@clarkson.edu) and **Katie R. Fowler**. *A Comparison of Derivative-Free Optimization Methods with Constraint Methods.*

Derivative free methods are highly demanded by researches for solving optimization problems for which derivatives are unavailable or intractable to compute. A variety of algorithms, each with inherent strengths, weaknesses,

and supporting theory have been developed and analyzed in the last two decades. For these methods, optimization is guided only by function values, which may be computationally expensive in some cases. In practice, constraints add a significant challenge. In this work we consider a variety of derivative-free methods; implicit filtering, a genetic algorithm, particle swarm optimization, and simulated annealing—paired with the standard penalty and barrier methods for handling constraints. We provide a comparison of methods to understand the best pairing of optimizer/constraint approach and include a new algorithm which combines implicit filtering with the filter method for constraints. We consider a suite of test problems that include jump discontinuities, low-high amplitude noise, and some higher dimensional problems. Performance and data profiles can help understand algorithm performance and guide users when choosing a solution approach.
(Received September 20, 2011)

1077-49-1818 **Markus Grasmair*** (`markus.grasmair@univie.ac.at`), Computational Science Center, University of Vienna, Nordbergstrasse 15, Vienna, 1090. *Recent Results and Open Problems in Sparse Regularisation.*

During the last years, Tikhonov regularisation with sparsity promoting regularisation functionals has become an important tool in the solution of inverse and ill-posed problems. From the theoretical point of view, the application of these methods is in some special cases well founded, as one can show that l^1 regularisation, and also sub-linear, non-convex regularisation, together with the assumption of sparsity of the true solution allows the derivation of linear convergence rates. These results, however, are at the moment restricted to discrete settings, and no extension to important continuous settings like total variation regularisation is at hand. In this talk, we will give an overview of the existing results on sparse regularisation, and discuss the problems that arise in the continuous case. (Received September 21, 2011)

1077-49-1868 **Marian Bocea*** (`mbocea@luc.edu`), Department of Mathematics and Statistics, Loyola University Chicago, 1032 W. Sheridan Road, Chicago, IL 60660. *On the Characterization of the Effective Yield Set in Polycrystal Plasticity.*

I will discuss a general strategy for predicting the macroscopic response of a polycrystalline material, with an emphasis on several model cases. The new approach allows us to characterize the effective yield set of the polycrystal by means of variational principles in L^∞ for supremal functionals acting on fields subject to constant rank differential constraints. (Received September 21, 2011)

1077-49-1878 **Andreas H Hamel*** (`hamel@yu.edu`), 2495 Amsterdam Avenue, Belfer Hall, New York, NY 10033. *A new derivative concept for set-valued functions.*

The power set of a linear space is not a linear space with respect to element-wise operations. In particular, the inverse of the addition is lacking. So, how should one define a difference quotient for a function mapping into such a power set? On well-defined subsets of the power set of a preordered linear space, a residuation operation can be used as a substitute for the difference, and corresponding (directional) derivatives and subdifferentials for convex set-valued functions can be defined. The max-formula, a fundamental existence result, and calculus rules for the new derivatives will be established. Our approach is fundamentally different from previous ones (see, for example, Aubin/Frankowska 1990) since the latter require to pick a point in the graph of the function, and they only work under restrictive assumptions. (Received September 21, 2011)

1077-49-1976 **Julia Eaton*** (`jreaton@uw.edu`), UWT, Interdisciplinary Arts and Sciences, Campus Box 358436, 1900 Commerce Street, Tacoma, WA 98402-3100, and **James V Burke**. *On the subdifferential regularity of functions of roots of polynomials.*

In 2001, Burke and Overton showed that the abscissa mapping on polynomials is subdifferentially regular on the monic polynomials of degree n. We extend this result to the class of max polynomial root functions which includes both the polynomial abscissa and the polynomial radius mappings. The approach to the computation of the subgradient simplifies that given by Burke and Overton and provides new insight into the variational properties of these functions. (Received September 21, 2011)

1077-49-2047 **Lynn R. Greenleaf*** (`lynngreenleaf@ou.edu`), Department of Mathematics, 601 Elm Avenue, Room 423, University of Oklahoma, Norman, OK 73019. *Mathematical Modeling and Analysis of Atmospheric Vortices.*

The focus of this talk concerns valid statistical inferences from tangential wind measurements on intense atmospheric vortices arising in dust devils, waterspouts, tornadoes, mesocyclones and tropical cyclones when the analysis depends on a parametric model of the information in the data. In order to achieve this, a set of a priori candidate tangential velocity models of atmospheric vortices that each possess a small number of parameters are selected based on scientific principles and are ranked as to their ability to capture information in the data. The candidate models include versions of the Wood-White tangential wind profile as well as the idealized Vatistas, Rankine, Burgers-Rott and Sullivan vortex models. A model is selected from this list of candidate models to seek the model that loses as little information from the data as possible using Akaike's Information Criterion (AIC). The goal of this mathematical analysis is to assess each model's ability to capture information about the true tangential winds contained in observations. The model selection method will address two approaches. The first approach will involve ranking the models. The second approach will involve optimization predictions. (Received September 21, 2011)

1077-49-2055 **Aaron Luttman*** (aluttman@clarkson.edu), 10 Clarkson Ave., Box 5815, Potsdam, NY 13699, and **Erik Bollt**, **Ranil Basnayake** and **Sean Kramer**. *Regularization of Optical Methods for Computing Flow Dynamics.* Preliminary report.

Optical flow is the term used for the computation of flow fields from image data describing the evolution of a system. The classical variational formulation results in separate Euler-Lagrange equations for each component of the flow, but, when the flow is the gradient of a potential function, we can construct the potential directly from a single Euler-Lagrange equation. This allows us to impose regularity on the full flow, rather than on the components of the flow separately. We will show how this formulation leads to a more natural means of regularizing optical flow computations as well as how this formulation connects optical flow to classical image deblurring. The results of this approach will be demonstrated on ocean flows for which the classical formulation would generally fail. (Received September 21, 2011)

1077-49-2081 **David R. Adams**, Dept of Mathematics, University of Kentucky, Lexington, KY 40506-0027, **Volodymyr Hrynkiv***, Dept of Computer and Mathematical Sciences, University of Houston-Downtown, Houston, TX 77002-1014, and **Suzanne Lenhart**, Department of Mathematics, University of Tennessee-Knoxville, Knoxville, TN 37996-1300. *Optimal control of a biharmonic obstacle problem.*

We consider a variational inequality of the obstacle type where the underlying partial differential operator is biharmonic. We consider an optimal control problem where the state of the system is given by the solution of the variational inequality and the obstacle is taken to be a control. For a given target profile we want to find an obstacle such that the corresponding solution to the variational inequality is close the target profile while the norm of the obstacle does not get too large in the appropriate space. We prove the existence of an optimal control and derive the optimality system by using approximation techniques. Namely, the variational inequality and the objective functional are approximated by a semilinear partial differential equation and the corresponding approximating functional respectively. (Received September 21, 2011)

1077-49-2113 **Rick Chartrand*** (rickc@lanl.gov). *Splitting algorithms for nonconvex, matrix optimization.*

In this talk we'll look at how large-scale, nonconvex optimization problems can be solved efficiently using a variable splitting approach. We'll apply these methods to the decomposition of a matrix D of high-dimensional data into a sum $D = L + S$, where L is of low rank and S is sparse. This gives us both a robust, low-dimensional model for our data, and a set of possibly large discrepancies from that model, which can contain interesting features. There are close analogies with the field of sparse signal reconstruction (known as *compressive sensing*), and as in that field, we find that a nonconvex optimization problem is able to give us a more useful decomposition.

To solve our nonconvex problems efficiently, we construct a new objective function, a sort of proximal analog of the ℓ^p quasi-norm, where $p < 1$. Our function is designed to make the minimization process computationally very efficient, with the algorithm also being parallelizable. Our featured example will be the decomposition of video. We'll see that L will be the stationary background, and S will contain only the moving objects, a result that is useful for surveillance applications, and that is interesting in that it arises from purely geometric modeling. (Received September 21, 2011)

1077-49-2168 **Baasansuren Jadamba*** (bxjsma@rit.edu), School of Mathematical Sciences, Rochester Institute of Technology, 85 Lomb Memorial Drive, Rochester, NY 14623, and **Akhtar A. Khan** and **Fabio Raciti**. *Some remarks on stochastic variational inequalities with applications to equilibrium problems.*

In this talk we will discuss some new results on random variational inequalities by using a regularization technique. The solution technique will be compared with an existing approach. Two small scale network equilibrium problems will be analyzed in detail in order to illustrate the difference between the two approaches. (Received September 21, 2011)

1077-49-2196 **Akhtar A. Khan*** (aaksma@rit.edu), School of Mathematical Sciences, 85 Lomb Memorial Drive, Rochester, NY 14623, and **Miguel Sama**. *Conical Regularization for Abstract Constrained Optimization Problems in Hilbert Spaces.*

In this talk we discuss an abstract constrained optimization problem which appears commonly in the optimal control and inverse problem of linear partial differential equations. The main emphasis of the present study is on the case when the ordering cone for the optimization problem has an empty interior. To circumvent this major difficulty, we propose a new conical regularization approach in which the main idea is to replace the ordering cone by a family of dilating cones. We showed that this approach leads to a family of optimization problems that admit regular multipliers. Detailed convergence analysis is given. One of the main advantages of the proposed approach is that it is amenable for numerical computations. The motivation for the conical regularization is to overcome the difficulties associated to the lack of Slater's type constrain qualification which is a common hurdle in numerous branches of applied mathematics including optimal control, inverse problems, vector optimization, set-valued optimization, sensitivity analysis, variational inequalities, among others. The approach remains valid in the setting of general Hilbert spaces and it does not require any sort of compactness or positivity condition on the operators involved. (Received September 21, 2011)

1077-49-2448 **David C. Szurley***, 405 N. Ebenezer Rd., Florence, SC 29501. *Optimal Control of Projectile Motion with Sensitivity-Based Optimization.*

Many real-world problems may be formulated as optimal control problems. In these, we change some aspect of a system in order to obtain a desired outcome. There are many solution techniques for optimal control problems. We will consider sensitivity-based optimization. This technique may be described as quantifying the effect that changing some aspect of the system has on the final outcome.

We will formulate an optimal control problem for equations governing projectile motion. Sensitivity-based optimization will then be used to solve this problem. Finally, advantages and disadvantages of sensitivity-based optimization will be discussed, and future efforts will be mentioned. (Received September 22, 2011)

1077-49-2466 **Yakov Alber*** (alberya@gmail.com). *Applications of Banach Space Geometry for Optimization Problems and Variational Inequalities.*

We plan to give the short survey of all the known generalized projection operators in Banach spaces based on the Young-Fenchel transformations of conjugate functions. We apply these operators to describe the explicit and implicit (proximal) projection methods and present the convergence, stability and estimates of the convergence rate results for approximating sequences of iterations. We study methods for operator equations, optimization problems and variational inequalities in Banach spaces with both Hausdorff- and Mosco-perturbations of the constraint sets. We are also going to state final decomposition results for arbitrary elements in Banach spaces and decompositions of Banach spaces themself. (Received September 22, 2011)

1077-49-2477 **Casey L Richardson*** (clr@cis.jhu.edu) and **Laurent Younes**. *A Computational Method for Measure Matching Using Metamorphosis.*

Metamorphosis is a mathematical framework for pattern matching in which one defines a distance on a space of images or shapes. In the case of images, this distance is found by computing the energetically optimal way in which one image can be morphed into the other, combining both smooth deformations and smooth changes in image intensity. In this talk, I will discuss an extension of this approach to the case of measure matching, which was proposed by Holm, Trouvé, and Younes (2009). The particular case of matching combinations of Dirac measures has applications in shape analysis using landmark points. Then I will describe on-going work (joint with Laurent Younes) on the analysis and computation of measure metamorphosis. We show that, when matching two measures, minimizers can become more singular than the measures themselves, which complicates the computation of solutions. I will discuss the nature of these singularities and present computational results for simple examples of measure matching. (Received September 22, 2011)

1077-49-2552 **Florian Maris*** (florinmaris@wpi.edu), Department of Mathematical Sciences, 100 Institute Rd., Worcester, MA 01609. *Stochastic homogenization for permeable membranes.*

The problem of effective boundary conditions for the flow of a viscous fluid across a type of permeable membrane is considered. The membrane is periodically perforated, with randomly shaped and sized holes, and on the solid part threshold leak conditions are considered: the normal velocity is zero unless the jump in the normal stress across the membrane reaches an yield. The effective conditions are of subgradient type with an effective yield limit, in the case of a densely distributed solid part, or of Navier type, in the case of dilute solid part; in the intermediate case the tangential slip cancels, whereas the normal velocity and stress are cotinuous. Unlike in the case of perforated walls (E. Sanchez-Palencia, C. Conca), no stress concentrations are present. (Received September 22, 2011)

1077-49-2776 **Nhi Nguyen*** (nnguyen@math.carleton.ca) and **Boris Mordukhovich** (aa1086@wayne.edu). *Coderivative Analysis of Quasi-Variational Inequalities in Asplund Spaces.*

We study quasi-variational inequalities in the framework of Asplund spaces, with parameters entering both single-valued and multivalued parts of the corresponding generalized equations in the sense of Robinson. The main tools of our variational analysis involve coderivatives of solution maps to quasi-variational inequalities, which allow us to obtain efficient conditions for robust Lipschitzian stability of quasi-variational inequalities and also to derive new necessary optimality conditions for mathematical program with quasi-variational constraints. (Received September 22, 2011)

1077-49-2824 **Hem Raj Joshi*** (joshi@xavier.edu), Department of Math and CS, Xavier University, Cincinnati, OH 45207. *Reducing HIV Epidemic by Education and Treating it Using Optimal Control.* Preliminary report.

Throughout the world, efforts are being made to decrease the spread of HIV by increasing awareness through education. One of these campaigns presented by Uganda's government was the ABC campaign, which promotes Abstinence, Be Faithful, and Condoms to decrease the spread of HIV. A SIR model will be used to evaluate the effectiveness of educational campaign on the HIV epidemic. The model is a system of ordinary differential equations in which data from Uganda about the epidemic and educational influences will be used to run model simulation.

The rest of our presentation will focus on Optimal Control of HIV using Highly Active Antiretroviral Therapy (HAART). We will modify an existing system of ordinary differential equations (ODEs) to incorporate variables representing typical HAART treatment with two different classes of drugs (reverse transcriptase and protease inhibitors). We will calculate optimal treatment plan and present numerical simulations. We will also discuss the uses and limitations of this type of biological model and other types of models. (Received September 22, 2011)

51 ► Geometry

1077-51-1 **Assaf Naor*** (naor@cims.nyu.edu), 251 Mercer St, New York, NY 10012-1185. *The Ribe Program.* Preliminary report.

A theorem of M. Ribe from 1976 asserts that finite dimensional linear properties of normed spaces are preserved under uniformly continuous homeomorphisms. Thus, normed spaces exhibit a strong rigidity property: their structure as metric spaces determines the linear properties of their finite dimensional subspaces. This clearly says a lot about the geometry of normed spaces, but one can also use it to understand the structure of metric spaces that have nothing to do with linear spaces, such as graphs, manifolds or groups. After all, there is a deep and rich theory of finite dimensional linear invariants of Banach spaces with far reaching structural consequences. In view of Ribe's theorem we know that these invariants are preserved under homeomorphisms that are "quantitatively continuous", so in principle one can reformulate them using only the notion of distance; without referring to the linear structure in any way. Once this is achieved, one can study these properties in the context of general metric spaces using insights that originally made sense only in the context of linear spaces, and use these insights to solve problems in areas that do not have a priori connections to normed spaces. Thus, Ribe's rigidity theorem inspired a research program, known today as the Ribe program, which was formulated by Bourgain in 1986, the goal being to find explicit metric reformulations of key concepts and theorems from the theory of normed spaces. Major efforts by many mathematicians over the past 25 years led to a range of remarkable achievements within the Ribe program, with applications to areas such as group theory, harmonic analysis, and computer science. This talk will be a self-contained and elementary introduction to the Ribe program. We will explain some of the milestones of this research program, describe some recent progress, and discuss some challenging problems that remain open. (Received September 22, 2011)

1077-51-15 **Erik Demaine***, MIT, Cambridge, MA 02139. *Geometric puzzles: Algorithms and complexity.*

I love geometry because the problems and solutions are fun and often tangible. Puzzles are one way to express these two features, and are also a great source of their own computational geometry problems: which puzzles can be solved and/or designed efficiently using computer algorithms?

Proving puzzles to be computationally difficult leads to a mathematical sort of puzzle, designing gadgets to build computers out of puzzles. I will describe a variety of algorithmic and computational complexity results on geometric puzzles, focusing on more playful and recent results. (Received April 13, 2011)

1077-51-65 **Adaeze Christiana Anyaegbunam*** (adaezeanyaegbunam@rocketmail.com), Department of Mathematics and Statistics, University of Port Harcourt, Port harcourt, Nigeria. *Complete geometry on a Riemannian $\mathcal{A}$-module. Sylvester's theorem.*

Abstract

As part of more results from my recent PhD thesis titled: **Geometric algebra via sheaf theory: A view towards symplectic geometry**, which serves as a corner stone for Abstract Geomertic Algebra and this paper, and building on prior joint works done by Mallios and Ntumba, we study Sylvester's Theorem via sheaf theory. Given a *Riemannian* $\mathcal{A}$*-module* $\mathcal{E}$ equipped with an $\mathcal{A}$-metric ϕ that is a *symmetric and orthogonally convenient pairing* over an ordered algebraized space $(X, \mathcal{A})$. Then ϕ is $\mathcal{A}$-isometric to $r[1]\perp s[-1]$. Thus, the number r is invariant and it does not, in general, describe the geometry of $\mathcal{E}$ completely. It does so, however, in one important case, which is when every element of $\mathcal{A}$ is a square of an element of $\mathcal{A}$. This holds, for instance, if $\mathcal{A} := \mathcal{P} \cup -\mathcal{P}$, the *ordered* PID $\mathbf{R}$*-algebraized space.* There is an analog of this result in the setting of vector spaces. (Received July 15, 2011)

1077-51-315 **Dmitry Korotkin*** (korotkin@mathstat.concordia.ca), 1455 de Maisonneuve West, Montreal, Quebec H3G1M8, Canada. *Prym-Tyurin classes and tau-functions.*

In this paper we study the space of holomorphic n-differentials over Riemann surfaces of genus g for n>1. We introduce a set of n vector bundles over this space, which we call Prym-Tyurin vector bundles. Corresponding determinant line bundles are called Prym-Tyurin line bundles. We define a set of n tau-functions on the space M and interpret them as holomorphic sections of tensor product of certain powers of Prym-Tyurin line bungles and tautological line bundle. This allowes to express the first Chern classes of Prym-Tyurin line bundles (or Prym-Tyurin classes) via the boundary classes and the first Chern class of the tautological line bundle. The talk is based on joint work with Peter Zograf. (Received August 21, 2011)

1077-51-371 **Anton Lukyanenko*** (Anton@Lukyanenko.net), 1409 W. Green Street, Mathematics Department, Urbana, IL 61801. *Bi-Lipschitz Extension from Boundaries of Certain Gromov Hypebolic Spaces.*

The compactified Heisenberg group H is the boundary at infinity of complex hyperbolic space $\mathbb{CH}$. A quasi-isometry of $\mathbb{CH}$ extends to a quasi-symmetry of H, and all quasi-symmetries of H arise in this way. Can one say the same of bi-Lipschitz maps of $\mathbb{CH}$?

We define *metric similarity spaces* as spaces X^+ possessing an analogue of the upper half-plane model of hyperbolic space. In particular, $X^+ = X \times \mathbb{R}^+$ for a quasi-homogeneous base metric space X homeomorphic to $\mathbb{R}^n$, and homotheties of X extend to isometries of X^+. Metric similarity spaces include non-compact rank one symmetric spaces such as complex and quaternionic hyperbolic space, as well as warped products of many nilpotent groups with $\mathbb{R}^+$. Metric similarity spaces X^+ are Gromov hyperbolic, and the base X can be identified with the boundary at infinity of X^+ with a horospherical metric. We refer to both as ∂X^+.

For metric similarity spaces X^+ of dimension $n+1 \neq 4$, we show that every quasi-symmetry of ∂X^+ is induced by a bi-Lipschitz map of ∂X^+. In particular, a quasi-symmetry of H is induced by a bi-Lipschitz map of $\mathbb{CH}$, except possibly for the complex hyperbolic plane. (Received August 26, 2011)

1077-51-408 **Weiqiang Wu*** (waikng@math.umd.edu). *On Embedded Spheres of Closed Affine Manifolds.* Preliminary report.

We investigate compact affine n-manifold (M, ∂) with boundary homeomorphic to S^{n-1} for $n \geq 3$. If a neighborhood of the boundary can be developed to an embedded sphere in $\mathbb{A}^n$ and the bounded part of its complement, then M is homeomorphic to a n-ball. (Received August 29, 2011)

1077-51-488 **Michael Beeson*** (beesonpublic@gmail.com). *Tiling a triangle with congruent triangles.*

We investigate the problem of cutting a triangle ABC into N congruent triangles (the "tiles"), which may or may not be similar to ABC. We wish to characterize the numbers N for which some triangle ABC can be tiled by N tiles, or more generally to characterize the triples (N, T) such that ABC can be N-tiled using tile T. In the first part of the paper we exhibit certain families of tilings which contain all known tilings. We conjecture that the exhibited tilings are the only possible tilings. If that is so, then for there to exist an N-tiling of any triangle ABC, N must be a square, or 2, 3, or 6 times a square, or a sum of two squares. We have proved the result except for a certain class of exceptional triangles and certain values of N. For example, we have proved that there are no N-tilings of any triangle when $N = 7, 11$, or 19; and we have completely solved the case when ABC is similar to T. We made use of linear algebra and field theory, and for one case, the algebraic number theory of cyclotomic fields. The simplest unsolved case is $N = 28$, with a tile whose sides are 2, 3, and 4, and triangle ABC has sides 12, 14, and 16. (Received September 04, 2011)

1077-51-544 **David Richter*** (david.richter@wmich.edu), Department of Mathematics, MS 5248, Western Michigan University, Kalamazoo, MI 49008-5248. *Theory and examples of ghost symmetry.*

A "ghost symmetry" of an object is a symmetry which appears in a shadow of that object. Since it is easy to construct objects with at least one ghost symmetry, it is more interesting when an object has many ghost symmetries. If an object has enough ghost symmetries, then it may have a curious "symmetry recovery property". The purpose of this talk is to present examples of this phenomenon in a variety of contexts, the most prominent coming from projections of classical regular polytopes. (Received September 07, 2011)

1077-51-933 **Vaibhav Gadre*** (vaibhav@math.harvard.edu), Dept. of Mathematics, Harvard University, SC One Oxford St., Cambridge, MA 02138. *Dynamics of non-classical interval exchanges.*

A natural generalization of interval exchange maps are linear involutions, first introduced by Danthony and Nogueira. Recurrent train tracks with a single switch provide a subclass of linear involutions. We call such linear involutions non-classical interval exchanges. They are related to measured foliations on orientable flat surfaces.

Non-classical interval exchanges can be studied as a dynamical system by considering Rauzy induction in this context. This defines a renormalization on the parameter space similar to Kerckhoff's simplicial systems. We show that the renormalization gives an expansion with a key dynamical property called uniform distortion. We use uniform distortion to prove normality of the expansion. Consequently, we prove an analog of Keane's conjecture: almost every non-classical interval exchange is uniquely ergodic. Uniform distortion has been independently established by Avila-Resende. (Received September 14, 2011)

1077-51-1007 **Jing Tao*** (jing@math.utah.edu). *Hyperbolic directions in Teichmuller space equipped with the Lipschitz metric.*

In an unpublished manuscript, Thurston introduced an asymmetric metric on Teichmuller space T(S) of a surface S, which we call the Lipschitz metric, by considering the best Lipschitz maps between two hyperbolic structures on S. Much like the Teichmuller metric, the Lipschitz metric is not Gromov hyperbolic. In the Teichmuller metric, the hyperbolic directions or geodesics to which the closest-point projection is strongly contracting are well understood. Namely, a Teichmuller geodesic has strongly contracting property if and only if it stays in the thick part of T(S). In the Lipschitz metric, this characterization is false: there are Lipschitz geodesics which stay in the thick part but do not have strongly contracting property. In this talk, we will provide a sufficient condition for a Lipschitz geodesic to have strongly contracting property. This is joint with Anna Lenzhen and Kasra Rafi. (Received September 15, 2011)

1077-51-1162 **John Arden Hiigli*** (john@jardingalerie.org), 164 west 83rd street 1-R, NYC, NY 10024. *Tetrahedron Discovers Itself : Frequency & Scale Change.* Preliminary report.

The sub-division of polyhedra manifests a natural space which is characterized by transformation and change of scale. The artistic strategy of using transparent oil paint makes it possible to explore and communicate this world of higher dimensions. (Received September 17, 2011)

1077-51-1211 **S I Nada*** (snada@qu.edu.qa), Faculty of Arts and Sciences, University of Qatar, Doha, 2713, Qatar, and **el-naschie**. *A note on a topological geometrical interpretation of Bell's inequality and Hardy's quantum entanglement.*

The note gives a very simple topological, geometrical interpretation of Bell's inequality B$\leq$2 and Hardy's quantum entanglement (g) = Φ5. It is reasoned that quantum entanglement is due to the zero measure random Cantor set underpinning the topology and geometry of orthodox quantum mechanics. (Received September 18, 2011)

1077-51-1212 **Justin Malestein*** (justmale@temple.edu), Department of Mathematics, Rm 638 Wachman Hall, 1805 N. Broad St, Philadelphia, PA 19122, and **Juan Souto**. *On genericity of pseudo-Anosovs in the Torelli group.*

We will show that, for any (symmetric) finite generating set of the Torelli group of a closed surface, the probability that a random word is not pseudo-Anosov decays exponentially in the length of the word; i.e. a random walk in the Torelli group is exponentially unlikely not to be pseudo-Anosov. As a consequence of our methods, we will prove the same statement for some other finitely generated subgroups of the mapping class group. (Received September 18, 2011)

1077-51-1346 **Kasra Rafi*** (rafi@math.ou.edu) and **Matt Clay**. *Essential tori and Dehn twists in Outer space.* Preliminary report.

For a surface S, a Dehn-twist on S is an element of mapping class group of S that has a representative with support in a neighborhood of a simple closed curve. Similarly, if M is the connected sum of n copies of $(S^1 \times S^2)$, a Dehn-Twists on M is an element of the mapping class group of M that has a representative with support in a neighborhood of an essential torus.

The fundamental group of M is the free group F_n and the mapping class groups of M is closely related to the group $\mathrm{Out}(F_n)$ of outer automorphisms of F_n. We study subgroups of $\mathrm{Out}(F_n)$ generated by Dehn-twists by examining the different types of topological intersections between the associated tori. We prove a generalization of a theorem of Thurston in this setting. (Received September 19, 2011)

1077-51-1456 **Todd A. Drumm*** (tdrumm@howard.edu), **Virginie Charette** and **William M. Goldman**. *Two-holed cross surfaces and their affine deformations.*

A two-holed cross surface results from removing two discs from the real projective plane. The space of hyperbolic structures on a two-holed cross surface is parameterized by the lengths on the boundary geodesics and the length of one of the simple closed orientation reversing geodesics. We shall discuss the space of hyperbolic structures of the two-holed cross surface and their affine deformations: which projectively is a compact 2-disk bounded by four curves. (Received September 19, 2011)

1077-51-1483 **Deborah Oliveros*** (dolivero@matem.unam.mx), Instituto de Matematicas, UNAM, Área de la Investigación Científica, Circuito Exterior C.U., 04510 Mexico, DF, Mexico, and **Gabriela Araujo** (garaujo@matem.unam.mx), **Hubard Isabel** (hubard@matem.unam.mx) and **Egon Schulte**. *Resent developments about Colorful Polytopes.* Preliminary report.

Given a r-graph G with edge chromatic number r, there exist a natural construction of an abstract r-Polytope called the Colorful Polytope, such that, the 1-skeleton of such polytope is the graph G. In particular when the graph is a Cayley graph of the symmetric group the polytope is a generalization of the Permuthahedron called the Graphicahedron. In this talk we will discuss resent developments of the study of this polytope, explore some combinatorial symmetry properties of it, analyze transitivity properties of their automorphism group and discuss some interesting cases. Furthermore we will observe an interesting relation of this polytopes with PL-manifolds. (Received September 19, 2011)

1077-51-1486 **Ping Ngai Chung*** (briancpn@mit.edu), 471 Memorial Drive, Cambridge, MA 02139, and **Niralee K. Shah**, **Luis A. Sordo Vieira** and **Miguel A. Fernandez**. *Tilings with nonconvex pentagons.* Preliminary report.

In 2001, Thomas C. Hales proved the Honeycomb Conjecture, which says that regular hexagons provide a least-perimeter unit-area way to tile the plane. Squares and equilateral triangles provide least-perimeter unit-area tilings by quadrilaterals and triangles. It is interesting to ask about a least-perimeter unit-area *pentagonal* tiling, since regular pentagons do not tile the plane. A recent paper by Frank Morgan and his students proves that among all *convex* unit-area pentagonal tilings of the plane and of appropriate flat tori, the Cairo and Prismatic pentagons minimize perimeter. They also conjecture that the convexity assumption is not necessary. We attempt to eliminate nonconvex pentagons by restricting the ratio of convex and nonconvex pentagons, and prove the result for some small flat tori. In the process we prove some bounds on the perimeter of certain classes of pentagons. (Received September 20, 2011)

1077-51-1503 **Hung Lu*** (hlu@hpu.edu), 1188 Fort Street Mall, Suite 430, Honolulu, HI 96813, and **Michel L. Lapidus** and **Machiel van Frankenhuijsen**. *Explicit tube formulas for p-adic fractal strings.*

We present an explicit volume formula for the tubular neighborhood of a p-adic fractal string $\mathcal{L}_p$, expressed in terms of the underlying complex dimensions. The general tube formula is illustrated by some simple examples, the nonarchimedean Cantor, Euler, and Fibonacci strings. (Received September 20, 2011)

1077-51-1580 **Miguel A. Fernandez*** (maf2831@truman.edu), **Ping Ngai Chung**, **Niralee K. Shah** and **Luis A. Sordo Vieira**. *Geometry of Surfaces with Density.*

Perelman's stunning proof of the million-dollar Poincaré conjecture needed to consider not only manifolds, but "manifolds with density" (like the density used in physics to compute the mass). We explore the basic geometry of such spaces by tackling one of the oldest problems in mathematics: the isoperimetric problem. That is, we seek curves that minimize weighted perimeter for a given weighted area. The classical (unit-density) isoperimetric theorem states that, for the plane, circles anywhere are isoperimetric. This usually changes when we introduce a non-unit density. The Log Convex Density Conjecture says that for radial, log-convex densities, circles about the origin are isoperimetric. We present our results so far regarding the borderline case of the plane with density e^r, and offer numerical evidence suggesting that circles about the origin are indeed isoperimetric. We conclude with possible ways to make our numerical study rigorous. (Received September 20, 2011)

1077-51-1591 **Oscar Vega*** (ovega@csufresno.edu), 5245 North Backer Avenue M/S PB 108, Fresno, CA 93740-8001, and **N. L. Johnson** (norman-johnson@uiowa.edu) and **Vikram Jha** (vjha267@googlemail.com). *Large autotopism groups on translation planes.* Preliminary report.

Let π be a translation plane of order n. We study conditions for a linear collineation group of π of order $n-1$ that acts faithfully on ℓ_∞ to be an autotopism group of π.

The conditions obtained depend on the parity of n and the existence of non-trivial kernel homologies, among other conditions. (Received September 20, 2011)

1077-51-1685 **Spencer Dowdall**, **Moon Duchin*** (Moon.Duchin@tufts.edu) and **Howard Masur**. *Hyperbolicity and measure in Teichmüller space.*

As is well known, Teichmüller space is not hyperbolic. On the other hand, the exceptions to hyperbolicity seem to be rare occurrences. We study a collection of different measures on Teichmüller space (with the Teichmüller metric) and show that, with respect to any of these measures, the average distance between points in the ball of radius r is 2r. In fact, on the way to this we show something stronger: if three points are sampled in the ball of radius r, then with high probability the midpoints of the geodesics connecting them pairwise come within a fixed distance of the center, independent of r. This is a way of making precise the idea that hyperbolicity is generic. (Received September 20, 2011)

1077-51-1889 **Eleanor Conley*** (rhaas@smith.edu), **Emily Meehan**, **Elizabeth Denne** and **Rebecca Terry**. *Folded ribbon knots in the plane.* Preliminary report.

Knots and links are modeled as flat ribbons folded and lying in the plane. The ribbonlength of a knot is the length of a knot divided by the width of the ribbon around it. In this talk we'll give examples of flat ribbon knots and their ribbonlength. We'll also discuss the problem of minimizing ribbonlength for a given knot type. (Received September 21, 2011)

1077-51-1891 **Arielle McCoy*** (rhaas@smith.edu), **Cal Hotchkiss**, **Alison Pryor**, **Kirin Khan** and **James Henle**. *The Life and Death of a Geodesic.* Preliminary report.

We investigate geodesics on boxes that begin at one corner and move at an angle of 45 degrees from the sides. Our results concern the destinations of such geodesics and their lengths. (Received September 21, 2011)

1077-51-2102 **John McCleary*** (mccleary@vassar.edu), Department of Mathematics, Vassar College, Poughkeepsie, NY 12604. *Toward a history of the square-peg problem.* Preliminary report.

While a young instructor in Göttingen, Otto Toeplitz reported on 'a particular exercise in Analysis situs,' to find four points on a continuous closed curve in the plane that form a square. Toeplitz claimed a proof for convex curves but never published such a proof. This problem, known as the square-peg problem, has been considered from many different viewpoints during the last century. In this talk we will consider approaches to the problem, how it was transmitted, significant breakthroughs, and the parallel developments in topology. The talk is a kind of biography of a problem. (Received September 21, 2011)

1077-51-2277 **Jeff M Phillips***, University of Utah, 50 S. Central Campus Dr., Salt Lake City, UT 84112. *Computational Geometry on Uncertain Data.*

Computational geometry has been built on the study of fixed input points. A common way to start a paper is "Let P be a set of points in R^d." In this talk I will discuss recent work dealing with uncertain points, i.e. when each input point is not given precisely, but rather its location is presented as a probability distribution. This formulation leads to many interesting questions (and answers!). For instance, consider the problem of finding the smallest enclosing ball of a point set. For fixed points this has a unique solution, but for uncertain points the answer is a distribution of balls. How can we compute and conveniently represent this distribution? I will generalize this discussion on appropriate representations for questions on uncertain points, and I will present (often simple) methods to compute them. I will also illustrate the success of these techniques on real-world data, and also suggest some exciting directions for further work. (Received September 22, 2011)

1077-51-2347 **Ian P Biringer***, 84 Nash St, #2, New Haven, WI 06511. *Invariant random subgroups of Lie groups.*

We'll describe a probabilistic variant of Gromov-Hausdorff convergence, inspired by Benjamini-Schramm convergence in graph theory, that we recently used to analyze the growth of betti numbers in higher rank locally symmetric spaces. Examples will be given in PSL(2,R).

Joint with Abert, Bergeron, Gelander, Nikolov, Raimbault, Samet. (Received September 22, 2011)

1077-51-2422 **Jeffrey F. Brock***, Mathematics Department, Brown University, Box 1917, Providence, RI 02912. *Assembling surfaces from random pants: mixing, matching and correcting in the proofs of the surface-subgroup and Ehrenpreis conjectures.*

Though Perelman's solution to Thurston's geometrization conjecture has settled countless conjectures about the nature of 3-manifolds, it also provides for new approaches to many remaining structural questions. The recent solution by Jeremy Kahn and Vlad Markovic of the "surface-subgroup conjecture" of Waldhausen, that each closed, irreducible 3-manifold M with infinite fundamental group contains an immersed, π_1-injective surface, gives an illustrative example: geometric structures on M turn this seemingly topological question into a geometric question involving random 'pairs of pants' in M bounded by geodesics, as well as the dynamics of the geodesic flow on the unit tangent bundle of M.

Remarkably, a variant of their argument also proves the celebrated "Ehrenpreis conjecture" that any two Riemann surfaces have finite covers that are nearly isometric. Their techniques employ strikingly novel methods in geometry and dynamics, as well as results from computer science. In this talk I will describe their work and its implications for other questions in the study of 3-manifolds, such as whether each closed, irreducible atoroidal 3-manifold with infinite fundamental group admits a finite cover that fibers over the circle. (Received September 22, 2011)

1077-51-2565 **Niralee Shah*** (niraleekshah@gmail.com), 108 Brickyard Court, north Adams, MA 01247-3626, and **Luis Sordo Vieira**, **Ping Ngai Chung** and **Miguel Fernandez**. *Minimal Pentagonal Tilings.*

In 2001, Thomas Hales proved that regular hexagons provide a least-perimeter unit area tiling of the plane, better for example than squares and equilateral triangles, which are minimizing for polygons with three or four sides respectively, and no worse than a mixture of any other shapes. We seek the least-perimeter unit-area tiling of the plane by pentagons.

Work by Frank Morgan and students resulted in a proof that two other pentagons, called Cairo and Prismatic, yield least-perimeter unit-area tilings by convex pentagons. The original version of the paper asked whether there exist tilings by mixtures of these two pentagons. We have found uncountably many such mixtures and classified the doubly periodic ones by their wallpaper symmetry groups. We also consider tilings by mixtures of convex and nonconvex pentagons and perimeter-minimizing tilings on various flat tori. (Received September 22, 2011)

1077-51-2722 **Sam Northshield*** (northssw@plattsburgh.edu). *Ford Circles and Spheres.* Preliminary report.

Given coprime non-negative integers a, b, the circle above and tangent to the x-axis at a/b with radius $1/2b^2$ is called a Ford circle. One can alternatively parameterize these circles:

$$\{[a,b] : (a+b+c)^2 = a^2+b^2+c^2, \gcd(a,b,c)=1\}$$

where $[a,b]$ denotes the circle above and tangent to the x-axis at $(a0+b1)/(a+b)$ with radius $1/2(a+b)$. This generalizes nicely: let P_1, P_2 and P_3 denote the vertices of an equilateral triangle of side length 1, and let $[a,b,c]$ denote the sphere above and tangent to the x,y-plane at $(aP_1+bP_2+cP_3)/(a+b+c)$ with radius $1/2(a+b+c)$. Then the family of spheres

$$\{[a,b,c] : (a+b+c+d)^2 = a^2+b^2+c^2+d^2, \gcd(a,b,c,d)=1\}$$

shares many of the properties of the family of Ford circles. (Received September 22, 2011)

1077-51-2732 **Eric Price*** (ecprice@mit.edu), 32 Vassar St #G-678, Cambridge, MA 02139. *Geometric Aspects of Compressive Sensing.*

I will give an overview of the use of geometry in compressive sensing. The goal of compressive sensing is to recover sparse signals $x \in \mathbb{R}^n$ from $m \ll n$ *linear* measurements Ax. Developed over the last decade, compressive sensing is a well-defined mathematical problem with applications in diverse areas such as streaming algorithms, image acquisition, and disease testing. I will start with an overview of the basic framework of compressive sensing, covering how high dimensional geometry is used to characterize when compressive sensing is possible. I will then cover some recent research on exploiting the (low-dimensional) geometric structure of images, leading to more accurate compressive sensing algorithms for images. (Received September 22, 2011)

1077-51-2771 **Thinh D Le*** (le@math.psu.edu). *Some Applications of Differential Geometry in Studying Grain Growth and Non-local Calculus.*

The growth of microstructures in three dimensions: Despite the ubiquity of microstructures (grains), we know surprisingly little about how they grow. A central question is how the volume of a cell in a network of grains changes? In the two-dimensional case, the answer was found in 1950's by J. von Neumann and W. Mullins . For over 50 years, no exact extension of the von Neumann-Mullins formula was properly established. Fortunately this has been done recently by MacPherson and Srolovitz and their work was published on Nature in 2007. My work provides an extension of this MacPherson-Srolovitz formula. Non-local continuum exterior calculus: Recently a lot of work has been done on non-local image processing and non-local continuum peridynamic models. By non-local, we mean that any point/particle can interact directly with any other point/particle in the studied domain (at least in principle). Non-local models have been shown to have some great advantages over classical (local) models since smoothness of functions, fields, are not required. My work provides a framework for non-local exterior calculus, including non-local vector calculus. (Received September 22, 2011)

1077-51-2840 **P. Thomas Fletcher**, **John Moeller**, **Jeff M Phillips** and **Suresh Venkatasubramanian*** (suresh@cs.utah.edu). *Horoball Hulls and Extents in Positive Definite Space.*

The space of positive definite matrices $P(n)$ is a Riemannian manifold with variable nonpositive curvature. It includes Euclidean space and hyperbolic space as submanifolds, and poses significant challenges for the design of algorithms for data analysis.

In this paper, we develop foundational geometric structures and algorithms for analyzing collections of such matrices. A key technical contribution of this work is the use of *horoballs*, a natural generalization of halfspaces for non-positively curved Riemannian manifolds. We propose generalizations of the notion of a convex hull and a centerpoint and approximations of these structures using horoballs and based on novel decompositions of $P(n)$. This leads to an algorithm for approximate hulls using a generalization of extents. (Received September 22, 2011)

52 ► Convex and discrete geometry

1077-52-284 **Satyan L Devadoss*** (satyan.devadoss@williams.edu). *Deformations of surfaces and convex polytopes.*

The moduli space of surfaces with marked points appears in open-closed string theory, particularly with respect to holomorphic curves with Lagrangian submanifolds. A combinatorial framework is presented to view the compactification of this space based on the pair-of-pants decomposition of the surface. We classify all such spaces that can be realized as convex polytopes, yielding a new polytope based on truncations of cubes, whose combinatorial and algebraic structures are related to generalizations of associahedra and multiplihedra. (Received August 18, 2011)

1077-52-614 **Asia Ivic Weiss*** (weiss@mathstat.yorku.ca), Toronto, Ontario , Canada, and **Isabel Hubard**, **Alen Orbanic** and **Daniel Pellicer**. *Symmetries of Equivelar Toroids.*

A toroid of rank rank n+1 is the quotient of a Euclidean tessellation of n-space over a rank n subgroup of the group its translations. We derive some general results on the group of automorphisms of equivelar toroids, that is the toroids obtained from the regular tessellations. We give a complete classification of equivelar toroids in ranks 3 and 4. (Received September 08, 2011)

1077-52-814 **Gabe Cunningham***, 567 Lake Hall, Northeastern University, 360 Huntington Ave, Boston, MA 02115. *Constructing self-Petrie and self-dual covers of regular polyhedra.*

The dual of a polyhedron is obtained by switching the vertices and faces, while the Petrie dual is obtained by switching the Petrie polygons and faces. Polyhedra that are self-dual or self-Petrie are interesting for their high level of symmetry. Given a regular polyhedron $\mathcal{P}$, I will show how to construct the minimal self-Petrie regular polyhedron that covers $\mathcal{P}$. Similar constructions yield the minimal self-dual regular cover and the minimal cover that is both self-Petrie and self-dual. (Received September 13, 2011)

1077-52-866 **Richard Ehrenborg*** (jrge@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506, **Menachem Lazar** (lazar@math.ias.edu), School of Mathematics, Institute for Advanced Study, Einstein Drive, Princeton, NJ 08540, and **Jeremy Mason** (mason47@llnl.gov), Condensed Matter and Materials Division, Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550. *The Law of Aboav–Weaire and its analogue in three dimensions.*

When investigating the structure of metals it is known that the atoms lie in a lattice structure. However, the lattice property only holds locally, that is, in a three dimensional cell called a grain. Bordering the grain is a boundary where the atoms lie chaotically, and beyond that is a new grain where the lattice has a different orientation. The structure of these grains amounts to a three dimensional simple subdivision of space.

Looking at the two dimensional analogue, one observes that grains with a small number of sides tend to be surrounded by grains with a large number of sides, and vice versa. The Law of Aboav–Weaire states that the average number of sides of the neighbors of an n-sided grain should be roughly $5 + 6/n$. By introducing the correct error term we prove this law of Material Science and discuss its extension to three dimensions. (Received September 14, 2011)

1077-52-878 **Stedman M. Wilson*** (stedmanw@math.ucla.edu) and **Igor Pak**. *Strengthening Fary's Theorem: Convex and Star-Shaped Realizations of Polyhedral Complexes.*

Fary's Theorem states that every planar graph can be drawn in the plane such that each edge is a straight line segment. We study the problem of strengthening Fary's Theorem in the plane, as well as extending it to higher dimensions. Given a pure d-dimensional topological polyhedral complex (embedded in $\mathbb{R}^d$), we ask when it can be realized geometrically (that is, rectilinearly embedded in $\mathbb{R}^d$). We discuss positive and negative results. On the negative side, we exhibit a $(d = 3)$ polytopal complex that must have irrational vertex coordinates in any geometric realization. The techniques of this construction provide a novel method for creating topological complexes that cannot be realized geometrically. On the positive side, we show that all $(d = 2)$ polyhedral complexes homeomorphic to a ball, as well as a certain class of $(d = 3)$ polyhedral balls, may be realized geometrically with convex cells. Furthermore, we show that all $(d = 2)$ polyhedral *configurations* (a generalization of a complex) homeomorphic to a ball, as well as a certain class of $(d = 3)$ configurations, may be realized geometrically with star-shaped cells. Finally, we mention the analogous yet more restrictive results for $d > 3$. (Received September 14, 2011)

1077-52-917 **T. Bisztriczky*** (tbisztri@ucalgary.ca), University Drive N. W., Calgary, Alberta T2nN 1N4, Canada. *Combinatorial constructions of polytopes.* Preliminary report.

We look at some problems associated with the combinatorial construction of large classes of non-simplicial convex polytopes, with focus on description and realization. (Received September 14, 2011)

1077-52-945 **Olivia Beckwith**, **Matthew Grimm** and **Jenya Soprunova*** (soprunova@math.kent.edu), Summit st., Mathematical Sciences Building, Kent, OH 44242, and **Bradley Weaver**. *Minkowski length of 2D and 3D lattice polytopes.* Preliminary report.

The Minkowski sum of two polytopes is the set of all pairwise sums of their points. The central object of my talk is the Minkowski length $L(P)$ of a lattice polytope P which is defined to be the largest number of primitive lattice segments whose Minkowski sum is in P.

The Minkowski length represents the largest possible number of factors in a factorization of polynomials with exponent vectors in P and comes up in lower bounds for the minimum distance of toric codes. I will explain some combinatorial results about $L(P)$ where P is a 2D or 3D lattice polytope in connection with 2D and 3D toric codes. (Received September 14, 2011)

1077-52-1301 **Francisco Santos**, **Tamon Stephen*** (tamon@sfu.ca) and **Hugh Thomas**. *The width of 4-prismatoids.*

Santos' recent construction of a counterexample to the Hirsch conjecture highlights a particular 5-dimensional "prismatoid" polytope. We use the Euler characteristic to prove that there is no analogous 4-dimensional prismatoid. (Received September 22, 2011)

1077-52-1643 **B. Carrigan***, Auburn University, 221 Parker Hall, Auburn, AL 36849. *Non-Triangulatable Polyhedra.*

It has been known since 1911, that there exists polyhedra which cannot be triangulated. We will revisit a selection of known polyhedra which are non-triangulatable, and introduce new techniques which lead to more polyhedra which are non-triangulatable. In particular, in 2006, Rambau showed that a non-convex twisted prism over a convex polygon cannot be triangulated. We will introduce the more general dissection of polyhedra of tiling by tetrahedra, and show that the general non-convex twisted prism cannot be tiled by tetrahedra, thus it cannot be triangulated. We will also use a similar technique to show a previously unknown polyhedra, a non-convex twisted dodecahedron, cannot be tiled by tetrahedra. (Received September 20, 2011)

1077-52-1690 **Jaewoo Lee*** (`jlee@bmcc.cuny.edu`), Department of Mathematics, Borough of Manhattan Community College, 199 Chambers Street, New York, NY 10007. *Geometry of Numbers and Sumsets.*

There are many interesting connections between geometry and number theory. We will mention some of the recent developments on these connections. We will also mention how sumsets of finitely many lattice points give an approximation to lattice points inside dilated polytopes. (Received September 20, 2011)

1077-52-1841 **Jim Lawrence*** (`lawrence@gmu.edu`), Department of Mathematical Sciences, George Mason University, 4400 University Drive, Fairfax, VA 22030-4444. *Matrices associated with polar dual pairs of polytopes.* Preliminary report.

Given a pair of polar dual polytopes P, having vertices u_i, and P^o, having vertices v_j, we consider the matrix $A = (a_{i,j})$, where $a_{i,j} = u_i \cdot v_j$. The matrix determines P and P^o up to linear equivalence. We describe some properties of the matrix, consider some polytope classes obtained by restricting the matrices considered, and pose some questions. (Received September 21, 2011)

1077-52-2363 **Gregory Minton*** (`gminton@math.mit.edu`) and **Henry Cohn** (`cohn@microsoft.com`). *Optimality of spherical codes subject to symmetries.* Preliminary report.

A spherical code is a finite subset of the sphere, and when studying spherical codes one is typically interested in finding codes maximizing the minimum distance between two distinct points. One of the most successful approaches to this problem is to generalize to spherical codes minimizing a potential function, and to apply linear programming bounds to this generalization. In some cases these bounds are sharp, which allows for proofs of optimality. In this work we consider spherical codes possessing certain symmetry groups, including the binary tetrahedral group and s-fold rotation. We will develop linear programming bounds in this setting and use them to prove some new optimality results for codes subject to imposed symmetries. (Received September 22, 2011)

1077-52-2512 **Mark Mixer*** (`mark.mixer@gmail.com`), **Isabel Hubard**, **Daniel Pellicer** and **Asia Ivic Weiss**. *Equivelar 4-twistoids.*

Let N be a torsion free, discrete group of isometries of Euclidean n-space. The orbit space $\mathbb{E}^n/N$ is called an n-dimensional space form. It is a consequence of Bieberbach's theorem that there are only finitely many affine equivalence classes of n-dimensional compact Euclidean space forms; in particular there are two classes when $n = 2$, and ten classes when $n = 3$.

Abstract polytopes considered as tessellations of these space forms have been extensively studied when $n = 2$, namely tessellations on the 2-torus and the Klein bottle. In this talk we shall consider 4-polytopes that arise as quotients of the Euclidean tessellation $\{4, 3, 4\}$ by the ten fixed point free crystallographic groups of the Euclidean space. (Received September 22, 2011)

1077-52-2607 **Javier Bracho*** (`jbracho@matem.unam.mx`), Mexico City, Mexico. *Projective Polytopes.* Preliminary report.

The notion of Projective Polytope will be addressed with special emphasis on regularity and chirality. (Received September 22, 2011)

53 ▶ Differential geometry

1077-53-61 **James M Henle*** (`jhenle@smith.edu`), Clark Science Center, Smith College, Northampton, MA 01063, and **Frederick V Henle** (`fredhenle@gmail.com`), 185 N. Main St., Suffield, CT 06078. *Where Geodesics Go to Die.*

Given the dimensions a,b,c of a rectangular box, we investigate geodesics that start at one corner and move at angle of 45 degrees from the edges. Our results and conjectures concern whether or not the geodesic ends at a corner (dies), and if it does, its destination and length. We draw connections to number theory, the Sierpinski gasket and the Rubik's cube. (Received July 14, 2011)

1077-53-149 **Donovan C McFeron*** (dmcferon@ramapo.edu), Ramapo College of NJ, Theoretical and Applied Science, 505 Ramapo Valley Road, Mahwah, NJ 07430. *The Kähler-Ricci flow, the Mabuchi metric, and the existence of Kähler-Einstein metrics.*

The Kähler-Ricci flow on a Fano manfiold can be thought of as a path in the space of Kähler metrics. We show that convergence of the flow corresponds to this path having finite length in terms of a natural metric on this infinite dimensional space. This is motivated by an earlier result of Clarke-Rubinstein, and it depends on some smoothing properties of the flow. (Received September 08, 2011)

1077-53-1109 **Luis A. Sordo Vieira*** (dw8603@wayne.edu), **Niralee K. Shah**, **Miguel Fernandez** and **Ping Ngai Chung**. *Isoperimetry in the Plane with Density e^r.*

It is well known that on $\mathbb{R}^2$ the least perimeter curve that encloses a given area is a circle. But what if we give the plane a density that weights both area and perimeter? The Log Convex Density Conjecture (LCDC) says that if the density is radial and its log is convex, circles about the origin minimize weighted perimeter for given area. We will do a quick survey of the geometry of surfaces with some different densities. We will conclude by considering the borderline case of the LCDC by investigating the plane with density e^r. Our partial results use symmetrization, generalized curvature, and the four vertex theorem to prove that a minimizer is convex and contains the origin in its interior. (Received September 16, 2011)

1077-53-1365 **Richard H. Escobales,Jr.*** (escobalr@canisius.edu), Department of Mathematics and Statistics, Canisius College, Buffalo, NY 14208. *Metric Fibrations from Simply Connected Rank - One Projective Spaces.* Preliminary report.

In this paper we classify all non-trivial Riemannian submersions with connected fibers from any of the simply connected, rank-one projective spaces . The result follows from results of Gromoll, Grove, Wilking, Becker, Casson, Gottlieb, Schultz, Ucci and Wolf, together with results of the author. (Received September 19, 2011)

1077-53-1491 **Kenichi Maruno*** (kmaruno@utpa.edu), **Kenji Kajiwara**, **Jun-ichi Inoguchi**, **Yasuhiro Ohta** and **Bao-Feng Feng**. *Discrete integrable systems arising from motions of discrete curves in the Euclidean and Minkowski planes.*

We will present several discrete integrable systems arising from motions of discrete curves in the Euclidean plane and the Minkowski plane. (Received September 20, 2011)

1077-53-1756 **Scott J Simmons*** (ssimmons@drury.edu), Springfield, MO. *Rectifying Viviani curves.* Preliminary report.

Initializing passive sonar tracks in three dimensions leads naturally to the problem of rectifying cone-sphere intersections where the vertex of the cone lies inside or on the surface of the sphere. If the exterior plane of the cone contains the center of the sphere, then the projection of the cone-sphere intersection onto the exterior plane of the cone is a circle. We call such cone-sphere intersections (generalized) Viviani curves since they are the same as certain cylinder-sphere intersections. Rectification of Viviani curves results in hyperelliptic integrals which we express in terms of elliptic integrals by carefully applying a few changes of variable. Then we use Jacobi functions and power series techniques to carry out the rectification, with arbitrary precision. (Received September 21, 2011)

1077-53-1785 **John C Loftin***, loftin@rutgers.edu, and **Michael Wolf**. *Cubic Differentials and Limits of RP^2 Structures.* Preliminary report.

In a generalization of Thurston's compactification of Teichmüller space, Anne Parreau has described a limit of a family of RP^2 structures on a closed surface in terms of the asymptotic eigenvalues of the holonomies around free loops on the surface. One may identify a convex RP^2 structure on a closed surface of genus at least 2 with a conformal structure and a holomorphic cubic differential. On a given Riemann surface Σ with cubic differential U, we investigate Parreau's asymptotic data for the convex RP^2 structure corresponding to $(\Sigma, \lambda U)$ for $\lambda \to \infty$.

For a generic cubic differential U on a Riemann surface Σ, we explicitly describe Parreau's asymptotic information for the RP^2 structure corresponding to $(\Sigma, \lambda U)$ in terms of the singular Euclidean metric $|U|^{\frac{2}{3}}$ on Σ. We also provide a conjectural formulation for any cubic differential U. The proof involves analytic techniques similar to Wolf's approach to Thurston's boundary of Teichmüller space. (Received September 20, 2011)

1077-53-2015 **Arthur E Fischer*** (aef@ucsc.edu), Department of Mathematics, University of California, Santa Cruz, CA 95064. *Recent Developments in Conformal Ricci Flow.*

We introduce a variation of the classical Ricci flow equation that modifies the unit volume constraint of that equation to a scalar curvature constraint. The resulting equations are named the *conformal Ricci flow equations* because of the role that conformal geometry plays in constraining the scalar curvature and because these equations

are the vector field sum of a conformal flow equation and a Ricci flow equation. These new equations are given by

$$\frac{\partial g}{\partial t} + 2\big(\mathrm{Ric}(g) + \tfrac{1}{n} g\big) = -pg$$
$$R(g) = -1$$

for a dynamically evolving metric g and a scalar non-dynamical field p. The conformal Ricci flow equations are analogous to the Navier-Stokes equations of fluid mechanics. Because of this analogy, the time-dependent scalar field p is called a *conformal pressure* and, as for the real physical pressure in fluid mechanics that serves to maintain the incompressibility of the fluid, the conformal pressure serves as a Lagrange multiplier to conformally deform the metric flow so as to maintain the scalar curvature constraint. A variety of properties of the conformal Ricci flow are discussed. (Received September 21, 2011)

1077-53-2155 **Susan B Crook*** (sbcrook@ncsu.edu). *Curve Matching via Discrete Invariants.* Preliminary report.

As a result of its use in medical imaging, aerial photography, and handwriting recognition, curve matching is a significant problem in the field of image analysis. Previous works propose integral invariants as a robust solution for the curve matching problem. However, these invariants rely on a parametric equation fit to the curve and in many real world applications, this fit requires a fair amount of computational work. We generate discrete invariants that require only an ordered set of points.

We apply our discrete invariants to the fields of image recognition and object assembly. In this talk, we present examples of curve matching used for handwriting recognition and puzzle completion. (Received September 21, 2011)

1077-53-2470 **Dan Christensen** (jdc@uwo.ca), Department of Mathematics, Middlesex College, the University of Western Ontario, London, Ontario N6A 5B7, Canada, and **Enxin Wu*** (ewu22@uwo.ca), Department of Mathematics, Middlesex College, the University of Western Ontario, London, Ontario N6A 5B7, Canada. *A Model Category Structure on Smooth Spaces.*

Manifolds are favorite objects in mathematics. However, the category of manifolds are not so pleasant, for example, not every subset or quotient set of a manifold is again a manifold, and there is no standard way to talk about infinite dimensional manifolds which appear all the time, for instance, the loop space or the diffeomorphism group of a manifold, etc. Over the years, people are looking for nicer categories which contains the category of manifolds as a full subcategory, and on which we can still do differential geometry. There are many such kinds of generalizations, and one of them is called diffeological spaces, which was introduced by J. Souriau and further developed by P. Iglesias-Zemmour. One of the most beautiful thing in that theory is the irrational torus, on which the smooth homotopy groups differ from the usual continuous homotopy groups. We develope a homotopy theory on the category of diffeological spaces which extends the usual homotopy theory of manifolds and respects the smooth homotopy of the irrational torus. Moreover, based on the work of J. Baez and A. Hoffnung, we give a sufficient condition for the existence of a model category structure on the category of concrete sheaves over a concrete site. (Received September 22, 2011)

1077-53-2485 **Fatima Mahmood*** (fm88@cornell.edu), 310 Malott Hall, Cornell University, Ithaca, NY 14853. *Differential forms on contact quotients.* Preliminary report.

Let M be a cooriented contact manifold and G a compact connected Lie group that acts smoothly on M preserving the cooriented contact structure. The contact quotient of M by G is in general a singular space, but it has a stratification into contact manifolds. In this talk, we will introduce a de Rham complex for the total quotient space whose corresponding cohomology ring is isomorphic to its (Čech, singular) cohomology ring with real coefficients. We will also give an alternate definition of differential forms on the contact quotient, which is used to show that the de Rham complex does not depend on how reduction is done in stages.

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1077-53-2596 **Stanislav Dubrovskiy*** (dubr@msri.org), 17 Gauss Way, Berkeley, CA 94720-5070, and **Mikhail Shubin** (m.shubin@neu.edu). *An example of a wild geometric structure.* Preliminary report.

Classifying matrices with complex coefficients under conjugation leads to the Jordan canonical form. The same problem for pairs of matrices is unsolvable or wild, in the sense of Gel'fand-Ponomarev. I will explain the Gel'fand-Ponomarev construction and show that a local equivalence problem in Differential Geometry - that of

classifying pairs of connections on a vector bundle is wild as well, as it contains the former. This is a joint work with Mikhail Shubin. (Received September 22, 2011)

1077-53-2863 **Josef F Dorfmeister** (dorfm@ma.tum.edu), Zentrum Mathematik, Technische Universitat Munchen, D-85747, Garching bei Munchen, Germany, and **Ivan C Sterling*** (isterling@smcm.edu), Deparment of Mathematics and Computer Science, 18952 E. Fisher Road, St. Mary's City, MD 20686-3001. *Solutions to the Sine-Gordon Equation of Low Differentiability.* Preliminary report.

There is essentially a one to one correspondence between pseudo-spherical immersions in $\mathbb{R}^3$, Lorentz harmonic maps to S^2 and solutions to the sine-Gordon equation $\omega_{xy} = \sin\omega$. All C^2 solutions to the sine-Gordon equation are given by a loop group factorization process whose input are assume to be C^1. What happens if the input is only C^0? It turns out that one still obtains a C^1 solution to the sine-Gordon equation. That is ω_{xy} and ω_{yx} exist, are equal, and also equal $\sin\omega$.

Hilbert proved that there are no C^2 pseudo-spherical immersions of $\mathbb{R}^2$ into $\mathbb{R}^3$ using basic properties of the sine-Gordon equation. On the other hand Kuiper proved there exist such C^1 immersions, however no examples are known. We will review the loop group constructions, sketch proofs of the claims, hopefully show some graphics and discuss open questions. (Received September 22, 2011)

1077-53-2888 **Jason Cantarella** and **Jason Parsley*** (parslerj@wfu.edu). *Cohomology reveals when helicity is a diffeomorphism invariant.*

Using knot invariants as our guide, we seek to understand vector field invariants. One vector field invariant is helicity, which calculates the average linking number of the field's flowlines. Computed analogously to Gauss' linking integral, it is widely useful in the physics of fluids. Helicity is invariant under certain diffeomorphisms of its domain – we seek to understand which ones.

By integrating over the configuration space of $2n$ points on a circle, Bott and Taubes computed finite-type invariants of knots. By analogy, we realize helicity as an integral over the configuration space of 2 points on a domain in Euclidean space. We extend this framework to differential $(k+1)$-forms on domains R^{2k+1} and express helicity as a cohomology class. This topological approach allows us to find a general formula for how much helicity changes when the form is pushed forward by a diffeomorphism of the domain. We classify the helicity-preserving diffeomorphisms on a given domain, finding new ones on the two-holed solid torus and proving that there are no new ones on the standard solid torus. (Received September 22, 2011)

1077-53-2899 **Ivko M Dimitric*** (ivko@psu.edu), Mathematics Dept., Penn State University Fayette, 1 University Drive, Uniontown, PA 15401-0519. *The Chen-type of some isoparametric hypersurfaces in the unit sphere.* Preliminary report.

According to B. Y. Chen, an isometric immersion $x : M^n \to E^N$ of a Riemannian $n-$manifold M^n into a Euclidean space is said to be of fine type (Chen-type k) if the position vector x can be decomposed into a sum of a constant vector x_0, contributing to the translation of a submanifold, and a finite number (k) of vector eigenfunctions of the Laplacian on M^n from k different eigenspaces. We examine Chen-type of isoparametric hypersurfaces in sphere with three principal curvatures and some with four, via the second standard immersion of the unit sphere. For example, it is known that all minimal isoparametric hypersurfaces with three principal curvatures in the unit sphere are mass-symmetric and of 3-type. (Received September 22, 2011)

1077-53-2900 **John V Pardon***, Department of Mathematics, 450 Serra Mall, Building 380, Stanford, CA 94305-2125. *Gromov's knot distortion.*

Gromov defined the distortion of an embedding of S^1 into R^3 and asked whether every knot could be embedded with distortion less than 100. There are (many) wild embeddings of S^1 into R^3 with finite distortion, and this is one reason why bounding the distortion of a given knot class is hard. I will discuss recent work which shows that there exist knots which require arbitrarily large distortion. For example, torus knots require large distortion (by work of the speaker), as do the (knotted, connected) ramification sets of ramified covers $M \to S^3$ where M is an arithmetic hyperbolic 3-manifold (work of Gromov and Guth). I will also mention some natural conjectures about the distortion, for example that the distortion of the $(2, p)$-torus knots is unbounded. (Received September 22, 2011)

54 ► General topology

1077-54-165 **Arthur D. Grainger*** (arthur.grainger@morgan.edu), Department of Mathematics, Carnegie Hall, Room CR-152, 1700 East Cold Spring Lane, Baltimore, MD 21251.
Homeomorphisms of Compact Sets in Certain Hausdorff Spaces.

In this paper, we construct a class of Hausdorff spaces (compact and non compact) with the property that non empty compact subsets of these spaces that have the same cardinality are homeomorphic. Also, it is shown that these spaces contain compact subsets that are infinite. (Received August 04, 2011)

1077-54-261 **Ellen K Gasparovic*** (elleng@live.unc.edu), Chapel Hill, NC 27599. *Extending the analysis of the Blum medial axis to multiple regions.*

The Blum medial axis is a skeleton-like topological structure that is used in medical imaging to represent organs in two and three dimensional images. The mathematical analysis that has been done for the medial axis of a single object or region leads to the natural question of how these methods may be extended to the study of multiple regions, such as a complex of organs in the human body. There are a number of motivating issues relating to multi-object analysis, both medical and mathematical, that contributed to this work. In order to address these issues and advance the study of the medial axis, we introduce the new notion of a Blum medial linking structure as a generalization to multiple regions. We provide a complete singularity-theoretic classification of the generic structure of medial linking for dimensions 2 through 7, with an emphasis on the 2 and 3 dimensional cases as these are relevant to medical image analysis. The classification and genericity results follow from a transversality theorem. Furthermore, we use the medial linking structure to perform shape analysis using measures of comparison that we define for a collection of regions. (Received August 16, 2011)

1077-54-440 **Hueytzen J. Wu*** (kfhjw00@tamuk.edu), Department of Mathematics, Texas A & M University - Kingsville, Kingsville, TX 78363, and **Wan-Hong Wu** (dd1273@yahoo.com), University of Texas at San Antonio, One UTSA Circle, San Antonio, TX 78249. *A P- and C*(D)-filters process of compactifications and any Hausdorff compactification.*

By means of a characterization of compact spaces in terms of open C*(D)-filters induced by a subset D of C*(Y), a P- and open C*(D)-filters process of compactifications of any topological space Y is obtained by embedding Y as a dense subspace of (Y*(S),T)(or (Y*(M),T)), where Y*(S) is the union of Y(E) and Y(S)(or Y*(M) is the union of Y(E) and Y(M)), Y(E)= Nx : Nx is a P-filter at x, x in Y, Nx is the union of x and O : O is an open set containing x, Y(S)= E : E is an open C*(D)-filter that does not converge in Y (or Y(M) = F : F is a basic open C*(D)-filter that does not converge in Y, T is the topology induced by the base B = U* : U is a nonempty open set in Y and U* = L : L is in Y(S)(or Y(T)) such that U is in L. Furthermore, an arbitrary Hausdorff compactification (Z, h) of a Tychonoff space X can be obtained from a subset D of C*(X) by the similar process. (Received September 01, 2011)

1077-54-617 **Yulan Qing*** (yulan.qing@tufts.edu), Bromfield-Pearson Hall, 503 Boston Ave., Medford, MA 02155. *Boundary of a CAT(0) 2-Complex.* Preliminary report.

We study the visual boundary of the universal cover of a torus complex proposed by Croke and Kleiner. Croke and Kleiner proved that there changing the geometric data of the space changes G-equivariant homeomorphism type of its boundary. We aim to study the homeomorphism of the boundary without the G-equivariant condition. We present the study of the points in the path component that is not in the safe-path component of the boundary. (Received September 08, 2011)

1077-54-1393 **Dana P. Rowland*** (RowlandD@merrimack.edu), Merrimack College, Department of Mathematics, N5, 315 Turnpike St., North Andover, MA 01845, and **Andrea Politano**.
Knots in the canonical book representation of complete graphs.

It remains an open question to determine the least possible number of knotted cycles one can obtain in an embedding of the complete graph K_n, when the number of vertices n is 8 or more. The canonical book representation of a complete graph is known to contain the least possible number of knotted 7-cycles, all of which are trefoils, and so this family of embeddings is a strong candidate for minimizing the total number of knotted cycles. We describe what other knot types must appear in the canonical book representation of a complete graph, and we count the total number of knotted cycles in the canonical book representation for complete graphs with up to 11 vertices. Our results provide an upper bound on the minimum number of knotted cycles that can be achieved in any embedding of a complete graph. (Received September 19, 2011)

1077-54-1433 **K. Grace Kennedy*** (kgracekennedy@math.ucsb.edu), University of California Santa Barbara, Department of Mathematics, 6607 South Hall, Santa Barbara, CA 93106-3080. *A new algorithm for the Multivariable Alexander Polynomial of a Link.*

In 1923, Alexander discovered the Alexander Polynomial of a knot, and then in 1970, Conway published a multivariable version of the Alexander polynomial. Last spring, Stephen Bigelow gave a diagrammatic method for calculating the Alexander polynomial of a knot by resolving crossings in a knot or link in a planar algebra. I will present my multivariable version of Stephen Bigelow's calculation, which is the Multivariable Alexander Polynomial defined by Conway. The advantage of this algorithm is that it generalizes to a multivariable tangle invariant up to Reidemeister III. (Received September 19, 2011)

1077-54-2270 **Candice R Price*** (candice.r.price@gmail.com), 93 Milton st N, #4, St. Paul, MN 55104. *Oriented skein relation and a biological application.* Preliminary report.

My work focuses on properties of the *skein relation* in knot theory and applying them to the interactions of DNA with two types of proteins: *topoisomerases* and *site-specific recombinase*. Using the skein relation, along with knot Floer homology, I have created a table of knot triples that can be used to model the triple: DNA substrate, products resulting from topoisomerase action and products resulting from recombinase action. (Received September 22, 2011)

1077-54-2315 **Nigar Tuncer Ozarslan*** (nigaroz@yahoo.com). *Numerability in sets, spaces and covers.* Preliminary report.

In this work, it is introduced the concept of numerability of sets, spaces and collections of sets. We give a proof for the equivalence of numerable spaces to known notion of perfect normality and the equivalence of Dold-numerable covers to normal covers. (Received September 22, 2011)

1077-54-2702 **Scott M. Varagona*** (varagsm@auburn.edu). *Amalgamating Factor Spaces of Generalized Inverse Limits.*

Inverse limits with upper semi-continuous bonding functions have become a popular topic in Continuum Theory. One of the many problems being studied is the following: if such an inverse limit space is a continuum, then how can we detect whether the inverse limit is decomposable, or indecomposable? In this talk, we show how to "amalgamate" an inverse limit's factor spaces in order to write the inverse limit in an alternate form. We then apply this technique to help prove that certain inverse limit spaces are decomposable. (Received September 22, 2011)

1077-54-2745 **Joshua Sack** (joshua.sack@gmail.com) and **Saleem Watson*** (saleem@csulb.edu). *Correspondences between ideals and z-filters for rings of continuous functions between C^* and C.*

Let X be a completely regular topological space and let $A(X)$ be any ring of continuous functions satisfying $C^*(X) \subseteq A(X) \subseteq C(X)$. We show that the correspondence $\mathcal{Z}_A$ (defined in Redlin, L. and Watson, S.; Maximal ideals in subalgebras of $C(X)$, *Proc. Amer. Math. Soc.* **100** (1987), 763–766) between ideals of $A(X)$ and z-filters on X extends the well-known correspondence for $C^*(X)$ to any $A(X)$. We also define a new correspondence $\mathfrak{Z}_A$ that extends the well-known correspondence for $C(X)$ to any $A(X)$. In addition, we show that $\mathfrak{Z}_A$ is a one-to-one correspondence between the maximal ideals of any $A(X)$ and the z-ultrafilters on X, and we give an explicit formula that relates the correspondences $\mathcal{Z}_A$ and $\mathfrak{Z}_A$. We use properties of $\mathcal{Z}_A$ and $\mathfrak{Z}_A$ to characterize $C^*(X)$ and $C(X)$ among intermediate rings on X. For rings $A(X)$ that are C-rings, we use the map $\mathfrak{Z}_A$ to give a topological characterization of the maximal ideals in any $A(X)$ that generalizes the Gelfand-Kolmogoroff characterization of maximal ideals in $C(X)$. (Received September 22, 2011)

1077-54-2761 **Ellie A Grano*** (ellie@math.ucsb.edu), 789 Laurel Walk, Apt. F, Goleta, CA 93117. *The Disambiguated Temperley-Lieb Algebra.* Preliminary report.

The Disambiguated Temperley-Lieb Algebra is a new associative algebra defined using pictures and local relations. I will present my basis for this algebra as a vector space. (Received September 22, 2011)

55 ► Algebraic topology

1077-55-56 **William C Kronholm*** (wkronholm@whittier.edu), Department of Mathematics, Whittier College, Whittier, CA 90608. *On the equivariant cohomology of Stiefel manifolds.* Preliminary report.

Let G be a group of order 2. A Rep(G)-complex structure is put on the special orthogonal group with a particular action of G. This cell structure is then used to put a cell structure on the Stiefel manifold of k-frames in a real representation of G. These structures are then used to investigate the $RO(G)$-graded cohomology of the special orthogonal groups, Stiefel manifolds, and Grassmann manifolds. (Received July 12, 2011)

1077-55-98 **Chad D Giusti*** (cgiusti@willamette.edu), Department of Mathematics, Willamette University, 900 State St., Salem, OR 97301. *Unstable Vassiliev theory.*

We begin by describing a directed system of model spaces, called plumbers' knots, which converge in weak homotopy type to the space of long knots in $\mathbb{R}^3$. On these spaces we construct an inverse system of cohomological spectral sequences whose limit contains the classical Vassiliev spectral sequence, from which arises the family of finite-type knot invariants. In doing so, we introduce a new collection of geometric and combinatorial tools for the study of finite-type invariants. Relying on the accessible geometry of the spaces of plumbers' curves we then extend the notion of Vassiliev derivative to all singularity types of plumbers' curves and perform some explicit computations in these unstable spectral sequences. (Received July 26, 2011)

1077-55-215 **Daniel A. Ramras*** (ramras@nmsu.edu). *The homotopy limit problem in stable representation theory.*

The homotopy limit problem in stable representation theory yields a generalization, to infinite discrete groups, of the classical Atiyah-Segal map from the representation ring of a compact Lie group to the K-theory of its classifying space. This homotopy limit problem exhibits behavior analogous to the Quillen-Lichtenbaum Conjectures in algebraic K-theory, and has concrete geometric applications. This talk will discuss recent progress in these directions, partly joint with Thomas Baird. (Received August 13, 2011)

1077-55-258 **Jason B. McCarty*** (jbm2t@virginia.edu). *The* mod 2 *homology of infinite loopspaces.*

In a forthcoming joint paper with N. Kuhn, we describe universal differentials in a Goodwillie tower spectral sequence converging to $H_*(\Omega^\infty X)$ for connected spectra X. Using only these differentials, we construct an algebraic spectral sequence, depending functorially on $H_*(X)$ as a right module over the Steenrod algebra. We show that the E^∞ term of the algebraic spectral sequence can be described in terms of the derived functors of "destabilization," as studied by W. Singer and others. Moreover, we prove that the tower spectral sequence is a subquotient of the algebraic spectral sequence, and that the spectral sequences are identical for interesting spectra. I will discuss these results in my talk. (Received August 16, 2011)

1077-55-313 **Noureen Khan*** (noureen.khan@unt.edu). *On Kawauchi's 4-moves Question.*

We address the question proposed by Kawauchi [1], "are link -homotopic links 4 - move equivalent"? We define and apply the invariants of 4 - moves and present a link as potential counter example to answer Kawauchi's question.

[1] R. Kirby, Problems in Low-dimensional Topology; Geometric Topology (Proceedings of the Georgia International Topology Conference, 1993) (Received September 12, 2011)

1077-55-416 **Greg Chadwick*** (schadwic@indiana.edu), Department of Mathematics, Indiana University, 831 East Third Street, Bloomington, IN 47405. *Structured Orientations of Thom Spectra.*

Given a map of ring spectra out of the complex cobordism spectrum MU, we can ask whether it may be represented by an En map. For a complex oriented ring spectrum E, ring maps from MU to E have been described by Quillen. When the target E is an E-infinity ring spectrum and in particular MU, En maps live in the unit spectrum cohomology of a cover of the classifying space BU. For E2 or E4 ring maps this cohomology is readily computable and demonstrates every self ring map of MU is E2. This shows the Brown-Peterson spectrum BP is E2. (Received August 30, 2011)

1077-55-675 **Vera Tonic*** (verat@nipissingu.ca). *Proof of Edwards-Walsh resolution theorem without Edwards-Walsh complexes.*

In 1981, Robert Edwards and John Walsh proved the cell-like resolution theorem, which states that every compact metrizable space X can be resolved by a cell-like map from a compact metrizable space Z, having the property that $\dim Z \leq \dim_{\mathbb{Z}} X$. This means that there is a surjective map $\pi : Z \to X$ whose point preimages are cell-like, i.e., have the shape of a point.

We will look at how a certain type of CW-complexes, called Edwards-Walsh complexes, were used in the proof of this theorem, as an algebraic topology tool. Then we will see how the proof could have been done without using Edwards-Walsh complexes.

We will compare the two approaches, and discuss how omitting Edwards-Walsh complexes, or using a simpler version of them, can simplify the proof of Edwards-Walsh resolution theorem, as well as other resolution theorems and their consequences. (Received September 09, 2011)

1077-55-875 **Michael A Shulman*** (mshulman@ucsd.edu). *Cell complexes and inductive definitions.*

In recent work of Voevodsky, Awodey, and others, it has emerged that Martin-Löf's constructive type theory, originally conceived as a computational foundation for mathematics, can naturally be interpreted in homotopy theory. In particular, many standard theorems in homotopy theory can be proven inside of type theory, and thereby fully verified for correctness quite easily by a computer. This promises a fruitful interplay between the two disciplines, and potentially a new foundation for mathematics which is at once "homotopical" and "computational".

What is still missing, however, is a way to construct, in type theory, familiar spaces such as spheres, tori, manifolds, classifying spaces, Postnikov towers, and so on, which in homotopy theory we usually describe using cell complexes. In joint work with Peter Lumsdaine, we have shown that the type-theoretic notion of *inductive definition* admits a generalization that naturally includes all such constructions. I will describe the resulting notion, assuming no background in type theory, and explain how it matches homotopy-theoretic cell complexes and Quillen's small object argument. (Received September 13, 2011)

1077-55-886 **Victor Turchin*** (turchin@math.ksu.edu) and **Gregory Arone** (zga2m@virginia.edu). *Splitting in the rational homology and homotopy of the spaces of higher dimensional long embeddings.*

In the talk I will present explicit graph-complexes computing the rational homology and homotopy of the spaces in question. These graph-complexes are always direct sums of finite complexes, where the sum is taken over two parameters. This allows us to define the generating function of the Euler characteristics of this double splitting, which will be also discussed in the talk.

(Joint work with G. Arone. This talk is a continuation of his talk.) (Received September 14, 2011)

1077-55-986 **Paul Louis Bendich*** (bendich@math.duke.edu) and **Jacob Harer**. *Φ-somap: Estimating Intrinsic Distance Using Persistent Homology.* Preliminary report.

Many dimension reduction techniques (including IsoMap) start by constructing a graph on the data in order to estimate the geodesic distance from the underlying manifold. We present a algorithm that uses persistent homology (in dimensions one and zero) to construct a weighted proximity graph based on a carefully chosen ϵ; our initial experiments show that the shortest path metric associated to this graph produces strikingly good estimates of the underlying geodesic distance. (Received September 15, 2011)

1077-55-1002 **Miroslav Kramar*** (miroslav@math.rutgers.edu), **J Van den Berg** and **R. Van der Vorst**. *Oscillatory solutions of fourth order conservative systems via the Conley index.*

We investigate periodic solutions of second order Lagrangian systems which oscillate around equilibrium points of center type. The main ingredients are the discretization of second order Lagrangian systems that satisfy the twist property and the theory of discrete braid invariants. The problem with applying this topological theory directly is that the braid types in our analysis are so-called *improper*. This implies that the braid invariants do not entirely depend on the topology: the relevant braid classes are *non-isolating* neighborhoods of the flow, so that their Conley index is not universal. (Received September 15, 2011)

1077-55-1143 **Luke P. Diaz*** (diaz@nmsu.edu). *Applications of Discrete Morse Theory to Certain Complexes of Bounded Degree Graphs.* Preliminary report.

Following work of J. Jonsson, X. Dong, and others, we apply discrete Morse theory techniques to certain complexes of graphs with bounds on the vertex degrees. We extend the method of element matching to develop techniques to treat iterated element matchings. In particular, we give an inductive description of the critical simplices as they evolve through the stages of an iterated element matching. For some families, the general inductive description of critical simplices can be reduced to an explicit closed form. In these cases, we conclude the graph complexes have the homotopy type of a wedge of equidimensional spheres. Standard techniques of algebraic topology apply to deduce information about homotopy type and homology of related graph complexes.

Also, we obtain information about representation, in homology, of the appropriate symmetric group. We have implemented the general procedures in SAGE and will present performance data and results in experiments. (Received September 16, 2011)

1077-55-1185 **Kristine Pelatt*** (kpelatt@uoregon.edu). *Geometric representative of a* $(3d-8)-$*dimensional cycle in knot spaces.*

Applying the calculus of functors to the study of knot spaces gives spectral sequences, due to Sinha, converging to the homology and cohomology. This framework does not immediately lead to representatives of cycles and cocycles. By resolving knots with k double points, Cattaneo, Cotta-Ramusino and Longoni produced explicit, non-trivial $k(d-3)$-dimensional cycles. We generalize these results to resolutions of singular knots with triple points, producing a non-trivial $3(d-8)$-dimensional cycle. This extends and corrects the results in a preprint of Longoni. The techniques we use are closely related to the combinatorics of the embedding calculus homology spectral sequence, suggesting that they may lead to recipes for geometric representatives for all of the cycles in that spectral sequence. (Received September 17, 2011)

1077-55-1274 **David Hector Ayala*** (davidayala.math@gmail.com), 19 Hanson Street, Somerville, MA 02143. *Weak n-categories are sheaves on $d \leq n$-manifolds.* Preliminary report.

This talk will present a geometric setting equivalent to the theory of weak n-categories in the sense of Rezk. Specifically, I will explain how a weak n-category is indexed by the space of configurations of points in the diagram of projections

$$\mathbb{R}^n \to \mathbb{R}^{n-1} \to \cdots \to \mathbb{R}^0;$$

and as so, from a weak n-category we will construct a sheaf on a site of iterated submersions of framed n-manifolds which are equipped with a configuration of points. Applied to E_n-algebras, this construction is chiral homology. A theorem will be stated that this construction implements an equivalence between weak n-categories and sheaves on this site. This work is joint with Nick Rozenblyum. (Received September 18, 2011)

1077-55-1321 **Kristopher Williams*** (kristopher-williams@uiowa.edu), Doane College, 1014 Boswell Ave, Crete, NE 68333. *The Milnor fiber associated to parallel connections of hyperplane arrangements.* Preliminary report.

In 2005, a paper by Choudary, Dimca and Papadima explored higher dimensional analogs of affine nodal line arrangements. In particular, the authors were able to compute the homology of the associated Milnor fiber and showed that the monodromy action on the homology of the fiber was trivial except possibly in the top dimension. We extend their work to the more general class of parallel connections of central line arrangements and give an algorithm for computing the homology of the associated Milnor fiber F. In contrast to the work of Choudary, Dimca and Papadima, we give an example of a central arrangement in $\mathbb{C}^5$ such that the monodromy action on $H_3(F)$ and $H_4(F)$ is non-trivial. (Received September 19, 2011)

1077-55-1363 **Tyler Lawson*** (tlawson@math.umn.edu) and **Niko Naumann** (niko.naumann@mathematik.uni-regensburg.de). *Truncated Brown-Peterson spectra.*

Truncated Brown-Peterson spectra $\mathrm{BP}\langle n\rangle$ and related Johnson-Wilson spectra $\mathrm{E}(n)$ play an important role in Ausoni and Rognes' program to study algebraic K-theory chromatically. This talk will focus on two problems: giving highly structured multiplication to these spectra, and deciding what the definition of them should be. (Received September 19, 2011)

1077-55-1371 **John A. Lind*** (jlind@math.jhu.edu). *Higher Geometry and Algebraic K-theory.*

A cohomology theory E is particularly useful when we can understand its cocycles $E^*(X)$ in terms of geometric objects associated to the space X. A basic example is the description of topological K-theory in terms of complex vector bundles. I will give an analogous interpretation of cocycles for $E = K(R)$, the algebraic K-theory of an associative ring spectrum R, in terms of bundles of R-modules over X.

The main technological development is the use of diagram spaces. Diagram spaces are a symmetric monoidal model for the category of spaces in which A_∞ spaces are strict monoids. This provides a theory of "principal G-bundles" when G is an A_∞ space. The delooping BG classifies principal G-bundles, and the description of $K(R)$-theory follows from the case of $G = GL_n(R)$. (Received September 19, 2011)

1077-55-1404 **Tomasz Kaczynski*** (t.kaczynski@usherbrooke.ca), Département de mathématiques, Université de Sherbrooke, 2500 boul. Université, Sherbrooke, Quebec J1K 2R1, Canada, and **Marian Mrozek**. *Cohomology Ring: Algorithmic approach.*

In the past two decades, the homology and cohomology theories gained a vivid attention outside of the mathematics community prompted by its modern applications in sciences and engineering, in particular, in dynamics, material science, digital imaging, and electromagnetism. Until recently, the main progress has been done in computation of homology groups of finitely representable objects. Whenever a mathematical model was making it possible as, for example, in the case of orientable manifolds, the duality has been used to avoid explicitly working with cohomology. The cup product endows the cohomology with the ring structure which permits distinguishing between nonhomotopical spaces which homology groups do not distinguish. However, this intrinsically more difficult theory had to wait longer for computer implementations. Some of application-oriented work on computing the cohomology ring of simplicial complexes is done by Gonzalez-Diaz and Real. We developed a cohomology ring algorithm in a dimension-independent framework of combinatorial cubical complexes. This approach is convenient in the cup-product computation and motivated, among others, by interpreting pixels or voxels as cubes. The S-complex theory and so called co-reductions are adopted to speed up the computations. (Received September 19, 2011)

1077-55-1412 **Aaron David Valdivia*** (avaldivi@math.fsu.edu), Aaron Valdivia, 1306 1/2 B MLK Jr Blvd, Tallahassee, FL 32303. *Generalizing Penner's Asymptotics For Minimal Dilatation Pseudo-Anosov Mapping Classes.*

We will consider the mapping class group of an oriented surface with finite genus and number of punctures. The dilatation is a numerical invariant of a pseudo-Anosov mapping class, one which preserves a pair of projective measured laminations. We generalize Penner's proof for the asymptotic behavior of the minimal dilatation on closed surfaces to include sequences in which the genus and number of punctures are related by certain linear equations. We also give evidence that these results may be generalized further. (Received September 19, 2011)

1077-55-1490 **Nick Rozenblyum*** (nrozen@math.northwestern.edu), Northwestern University, Department of Mathematics, 2033 Sheridan Road, Evanston, IL 60208. *Manifolds, Higher Categories and Topological Field Theories.*

I will describe an ongoing project with David Ayala to describe weak n-categories with adjoints as sheaves on the site of n-manifolds together with the additional data of transversality. Such a sheaf gives an n-dimensional topological field theory which generalizes topological chiral homology for (twisted) E_n algebras and should be related to the blob complex. (Received September 20, 2011)

1077-55-1625 **Michael Ching*** (mching@amherst.edu). *A classification of Taylor towers.* Preliminary report.

I'll describe joint work with Greg Arone to classify Goodwillie's Taylor towers of homotopy functors to and from the categories of based spaces and spectra. This classification is in terms of structure that exists on the Taylor coefficients of a functor, and from which the entire tower to be reconstructed. In general, the structure involved is that of a coalgebra over a certain cotriple on the category of symmetric sequences. For functors from based spaces to spectra I'll give two more concrete descriptions of this cotriple in terms of modules over the little disc operads, and divided power modules over the Lie operad. (Received September 20, 2011)

1077-55-1647 **Mark J Behrens*** (mbehrens@math.mit.edu), MIT Dept of Mathematics, Rm 2-273, 77 Massachusetts Ave, Cambridge, MA 02139. *Morava E-theory of the Goodwillie tower.*

We will describe the Morava E-theory of the layers of the Goodwillie tower of the identity evaluated on odd spheres in terms of a modular isogeny complex. The E-homological behavior of attaching maps between layers will also be discussed. This is joint work with Charles Rezk. (Received September 20, 2011)

1077-55-1654 **Pascal Lambrechts*** (pascal.lambrechts@uclouvain.be), IRMP, chemin du cyclotron, 2, B-1348 Louvain-la-Neuve, Belgium. *Rational homotopy theory and spaces of smooth embeddings.* Preliminary report.

Goodwillie-Weiss manifold calculus is a powerful tool to study spaces of smooth embeddings. We will show on concrete examples how it can be used to get information on the rational homotopy type of these embedding spaces. (Received September 20, 2011)

1077-55-1662 **Gregory Arone*** (zga2m@virginia.edu) and **Victor Turchin** (turchin@math.ksu.edu). *Operads and modules in embedding calculus.*

It is now well known that embedding calculus is closely related to the theory of modules over the little balls operad. In particular the Taylor tower in embedding calculus can be represented, in favorable cases, as the space of maps between right modules (or weak bimodules) over this operad. We will consider from this point of view certain homological spectral sequences that arise in embedding calculus. We will use a "change of operads isomorphism" to show that the E^2 term of this spectral sequence can be represented in terms of the space of maps between modules over the *commutative* operad. When working rationally, formality of the little balls operad allows us to conclude, in some cases, that the spectral sequence terminates at the E^2 term, thus giving us a model for the rational homology of certain embedding spaces in terms of maps of modules over the commutative operad. (Received September 20, 2011)

1077-55-1672 **John E Harper*** (john.edward.harper@gmail.com). *Localization and completion with respect to topological Quillen homology.*

Quillen's derived functor notion of homology provides interesting and useful invariants in a wide variety of homotopical contexts. For instance, in Haynes Miller's proof of the Sullivan conjecture on maps from classifying spaces, Quillen homology of commutative algebras (André-Quillen homology) is a critical ingredient. Working in the topological context of symmetric spectra, this talk will introduce several recent results on localization and completion with respect to topological Quillen homology of commutative ring spectra (topological André-Quillen homology), E_n ring spectra, and operad algebras in spectra. This includes homotopical analysis of a completion construction and strong convergence of its associated homotopy spectral sequence—analogous to results by Bousfield-Kan on the R-completion of spaces—and a description of a point-set model of the derived comonad (or cotriple) that coacts on the object underlying topological Quillen homology; in other words, topological Quillen homology is a coalgebra over this comonad. Several of the results are joint work with Michael Ching and Kathryn Hess. (Received September 20, 2011)

1077-55-1678 **Henry Adams*** (henrya@math.stanford.edu), Mathematics, Building 380, 450 Serra Mall, Stanford, CA 94305. *Evasion Paths in Mobile Sensor Networks.* Preliminary report.

We say that an evasion path exists in a mobile sensor network if a continuously moving evader can avoid being detected by the sensors. In "Coordinate-free Coverage in Sensor Networks with Controlled Boundaries via Homology," Vin de Silva and Robert Ghrist use the local connectivity data of a mobile sensor network to determine, in some cases, that no evasion path exists. We consider examples that show the existence of an evasion path depends not only on the network's connectivity data but also on its embedding. We search for invariants of the embedding that provide sharper criteria for the existence of an evasion path. (Received September 20, 2011)

1077-55-1709 **Justin Michael Curry*** (jucurry@math.upenn.edu). *Obstruction-Theoretic Sensing.* Preliminary report.

This talk outlines a vision for obstruction-theoretic sensing. Motivation for such a proposal stems from two primary observations: (1) that modern applications increasingly require a systematic way of handling data living over a base space and (2) that the classical machinery of sheaves and vector bundles provides a unified language as well as topological forcing results. This talk goes on to describe a new class of pursuit-and-evasion problems, which serves as a testing ground for these ideas. (Received September 20, 2011)

1077-55-1731 **Martin Frankland*** (franklan@illinois.edu), UIUC, Department of Mathematics, 1409 W. Green St, Urbana, IL 61801. *Non-realizable 2-stage* Π*-algebras.*

It is a classic fact that Eilenberg-MacLane spaces exist and are unique up to weak equivalence. However, one cannot always find a space with two non-zero homotopy groups and prescribed primary homotopy operations. Using work of Baues and Goerss, we will present examples of non-realizable 2-stage Π-algebras, focusing on the stable range. (Received September 20, 2011)

1077-55-1745 **Ricardo Andrade*** (randrade@math.stanford.edu). *Model structures for higher categories.*

I will present some results on the existence of model structures. These will be applied to constructing and comparing different model categories which realize higher categorical structures. (Received September 20, 2011)

1077-55-1775 **Jeremy Kenneth Miller*** (jkmiller@stanford.edu), Building 380, Stanford University, Room 381K, Stanford, CA 94305. *Homological stability properties of spaces of rational J-holomorphic curves in* $\mathbb{C}P^2$.

In a well known work, Graeme Segal proved that the space of holomorphic maps from a Riemann surface to a projective space is homology equivalent to the corresponding continuous mapping space through a range of dimensions increasing with degree. We investigate if a result similar to that of Segal holds when other (not necessarily integrable) almost complex structures are put on a projective space. Under supervision of my advisor Ralph Cohen at Stanford University, I obtained the following partial result; the inclusion of the space of based degree k J-holomorphic maps from $\mathbb{C}P^1$ to $\mathbb{C}P^2$ into the based twofold loop space is a homology surjection for dimensions $j \leq 3k-3$. The proof involves using a result of Gromov showing that the topology of degree one J-holomorphic mapping spaces are independent of choice of almost complex structure. Then we construct a gluing map in the sense of Taubes gluing of instantons and compare it to a gluing map which is part of the little 2-disks operad structure on the integrable holomorphic mapping space introduced by Fred Cohen. (Received September 20, 2011)

1077-55-1866 **Anna Marie Bohmann***, Deparment of Mathematics, Northwestern University, 2033 Sheridan Road, Evanston, IL 60208. *Global equivariant homotopy theory.*

Much recent work has shown that equivariant homotopy theory can give insight into the non-equivariant world. While concrete calculations focus on specific groups, many familiar objects in homotopy theory have (or we would like them to have) equivariant generalizations that feel "natural." One way of stating such naturality is by asking how these generalizations fit together across different groups of equivariance. Global equivariant homotopy theory is the study of spectra that vary naturally in the group of equivariance. Change of groups is an important tool in existing calculations, and one might hope that some calculations work globally and not just one group at a time; it is also interesting to determine the precise functoriality of calculations such as the Segal conjecture or the Atiyah–Segal completion theorem that are already known to work globally. I will discuss the basic ideas of what we mean by "global" spectra and explain how these notions capture the naturalness we see in familiar spectra such as complex cobordism and K-theory, but don't see for Eilenberg–MacLane spectra. (Received September 21, 2011)

1077-55-1920 **Daniel Dugger*** (ddugger@uoregon.edu). *Cohomology of equivariant Grassmannians and motivic characteristic classes for quadratic bundles.*

The talk will present a computation of the RO(G)-graded Eilenberg-MacLane cohomology of Z/2-equivariant real Grassmannians. I will explain how this connects to a theory of characteristic classes for quadratic bundles with values in motivic cohomology. (Received September 21, 2011)

1077-55-1936 **Matthew Donovan Griisser*** (mgriisser3@gatech.edu), 3880 Overlake Drive, Cumming, GA 30041, and **Allison Miller** and **Jacqueline Brimley**. *The Wecken Property for Random Maps on Surfaces with Boundary.*

If f is a self-map on a compact ANR, the *minimal number of fixed points* of f, denoted $MF(f)$, is the minimum number of fixed points for any g homotopic to f. The *Nielsen number*, denoted $N(f)$, is a homotopy and homotopy-type invariant defined such that $N(f) \leq MF(f)$ for all f. Wecken established in the 1920s that if f is a self-map on a manifold (with or without boundary) of dimension not 2 then $N(f) = MF(f)$. In general, if f is any function such that $N(f) = MF(f)$, we say that f is *Wecken*. In the 1980s Jiang established that there are non-Wecken maps on surfaces with boundary.

We consider the action of a given $f : X \to X$ in terms of its induced homorphism $f_\# = \phi : \pi_1(X) \to \pi_1(X)$. In the case of surfaces with boundary, which are of the same homotopy type as bouquets of circles, we have that $\pi_1(X)$ is the free group on n generators. Wagner provided a way to calculate $N(f)$ in terms of ϕ's action on these generators. Using Wagner's algorithm, we obtained a lower bound, expressed in the language of asymptotic density, on the proportion of maps on surfaces with boundary that are Wecken. (Received September 21, 2011)

1077-55-1982 **Christopher J. Schommer-Pries*** (schommerpries.chris.math@gmail.com). *On the uniqueness of the homotopy theory of higher categories.*

We propose axioms that a quasicategory should satisfy to be considered a reasonable homotopy theory of (∞, n)-categories. This axiomatization requires that a homotopy theory of (∞, n)-categories, when equipped with a small amount of extra structure, satisfies a simple, yet surprising, universal property. We further prove that the space of such quasicategories is homotopy equivalent to $B(\mathbb{Z}/2)^{\times n}$. This generalizes a theorem of Töen when $n = 1$, and it verifies two conjectures of Simpson. In particular, any two such quasicategories are equivalent. We also provide a large class of examples of models satisfying our axioms, including those of Joyal, Kan, Lurie, Simpson, and Rezk. This is joint work with Clark Barwick. (Received September 21, 2011)

1077-55-2042 **Peter Bubenik*** (p.bubenik@csuohio.edu). *Persistent homology and statistical inference.* Preliminary report.

Given (possibly high-dimensional) data that does not lend itself to linear analysis, one can calculate its persistent homology in an attempt to capture global qualitative structure. This persistent homology can be encoded in a persistence diagram. A sequence of such diagrams obtained from the starting data can be considered to come from persistence-diagram-valued random variables $X_1, \ldots, X_n$. I will discuss means, variances, laws of large numbers, and central limit theorems in this framework. (Received September 21, 2011)

1077-55-2097 **Brenda Johnson*** (johnsonb@union.edu), **Kristine Bauer**, **Rosona Eldred** and **Randy McCarthy**. *Models for Taylor towers of functors.*

We discuss various methods for defining Taylor towers of functors and how they are related to Goodwillie's calculus of homotopy functors. We use some of these constructions to show that two potential methods for defining an analogue of DeRham cohomology for E_∞-algebras are equivalent. (Received September 21, 2011)

1077-55-2103 **Niles Johnson*** (niles@uga.edu) and **Justin Noel**. *Obstruction theory for E_∞ maps.* Preliminary report.

We take an obstruction-theoretic approach to the question of algebraic structure on spectra. At its heart, this is an application of the Bousfield-Kan spectral sequence adapted for general operadic structure in a range of topological categories. This talk will focus on examples from rational homotopy theory which illustrate the obstructions to rigidifying homotopy algebra maps between differential graded algebras to strict algebra maps. In the topological context, these provide explicit examples of H_∞ maps which cannot be rigidified to E_∞ maps. (Received September 21, 2011)

1077-55-2246 **William G. Dwyer** and **Kári Ragnarsson***, Google, 20 W Kinzie Street, Chicago, IL 60654. *The Segal conjecture in homotopical group theory.* Preliminary report.

For a finite p-group P and a finite group G, the Segal conjecture implies a description, due to Lewis–May–McClure, of the spectrum of stable maps from BP to the p-completion of BG as a wedge sum of suspension spectra. In unpublished work, Lannes showed that when P has order p, one can replace BG with a space X that shares some homotopy characteristics with the classifying space of a finite group, and obtain a similar description. We will discuss this work and show how, using iterated homotopy fixed points, one can obtain a description of the spectrum of stable maps from BP to X for a general finite p-group P. The allowable spaces X in this setting include p-compact groups and p-local finite groups, and thus we obtain a version of the Segal conjecture for those spaces. (Received September 21, 2011)

1077-55-2256 **Loring W. Tu*** (loring.tu@tufts.edu), Department of Mathematics, 503 Boston Ave, Tufts University, Medford, MA 02155-7049. *Computing integrals using equivariant cohomology.*

Under suitable circumstances, the localization theorem in equivariant cohomology provides a powerful tool for converting an integral on a manifold with a group action to a finite sum. I will discuss the type of integrals that can be computed this way and give a few examples, for instance, the computation of characteristic numbers of a homogeneous space. (Received September 22, 2011)

1077-55-2258 **Daniel Pryor*** (dmp5p@virginia.edu). *Embedding Calculus and Topological Categories.*

Embedding Calculus, as described by Weiss, is a calculus of functors, suitable for studying contravariant functors from the poset of open subsets of a smooth manifold M, denoted $\mathcal{O}(M)$, to a category of topological spaces (of which the functor $\mathrm{emb}(-, N)$ for some fixed N is a prime example). Polynomial functors of degree k can be characterized by their restriction to the subposet of $\mathcal{O}(M)$ consisting of open sets which are a disjoint union of at most k components, each diffeomorphic to the open unit ball. In this talk, we consider the situation in which M is given as a codimension zero submanifold of a fixed Euclidean space. Then we can characterize polynomial functors by their behavior on the more restrictive subposet consisting of elements which are a disjoint union of actual (translations and scalings of) open balls. Furthermore, these subposets carry a natural topology which can be kept track of while forming polynomial approximations to functors. We show that the Taylor towers generated in this richer setting agree with the previous ones. (Received September 22, 2011)

1077-55-2262 **Sanjeevi Krishnan*** (sanjeevi.krishnan@gmail.com). *Directed sheaf homology and information.* Preliminary report.

We generalize the classical max-flow, min-cut theorem from the setting of additive real-valued quantities (e.g. fluid volume, bits of information, traffic counts) flowing over directed graphs (e.g. pipelines, multicast networks having a single source, roadways) to more general information flowing over more general directed spaces (e.g. spacetimes, state spaces). In the process, we recast constraints on the capacities of communication channels as sheaves, flows as elements of a singular sheaf homology for directed spaces, and cuts as certain open neighborhoods of directed spaces satisfying a relative homological condition. We then discuss applications of our generalized duality theorem to various problems in network theory. (Received September 21, 2011)

1077-55-2265 **Paul Bendich**, **Herbert Edelsbrunner** and **Dmitriy Morozov***, dmitriy@mrzv.org, and **Amit Patel**. *Homology and Robustness of Level and Interlevel Sets.*

Levelsets of real-valued functions play a prominent role in scientific visualization. For instance, clusters of galaxies appear as components in the slices of the mass density function. Noisy data produces spurious components which scientists must filter out.

In this talk, we consider the preimages of intervals of real-valued functions and their homology groups. We quantify the robustness of the homology classes under perturbations of f using well groups. We show how to read the ranks of these groups from the extended persistence diagram of f. (Received September 22, 2011)

1077-55-2269 **Samuel Baruch Isaacson*** (isaacson@math.utexas.edu), Department of Mathematics, 1 University Station C1200, University of Texas at Austin, Austin, TX 78712. *Dendroidal sets and symmetric monoidal infinity categories.* Preliminary report.

Moerdijk, Berger, and Cisinski have developed several homotopy theories of ∞-operads based upon the combinatorics of "dendroidal sets." Their work generalizes many of the homotopy theories of $(\infty, 1)$-categories and is combinatorially attractive. In my talk I'll discuss some progress on analogues of some 1-categorical notions in the dendroidal world. (Received September 22, 2011)

1077-55-2288 **Paul Bendich** and **Bei Wang*** (beiwang@sci.utah.edu), Scientific Computing and Imaging Institute, 72 So. Central Campus Drive, Salt Lake City, UT 84112, and **Sayan Mukherjee**. *Stratification Learning through Local Homology Transfer.*

A stratified space is a collection of manifolds of different dimensions which fit together uniformly inside some larger space. The objective of this talk is to show that data sampled from such a space can be clustered by strata. We first define a multi-scale notion of stratified spaces, providing a stratification at different scales which are indexed by a radius parameter. We then use methods derived from kernel and cokernel persistent homology to cluster the data points into different strata. We prove a correctness guarantee for this clustering method under certain topological conditions. We then provide a probabilistic guarantee for the clustering for the point sample setting: we provide bounds on the minimum number of sample points required to state with high probability which points belong to the same strata. Then, we give an algorithm for the clustering. Finally, we will discuss some potential extensions and on-going work. (Received September 22, 2011)

1077-55-2294 **Mokhtar Aouina*** (mokhtar.aouina@jsums.edu), Jackson State University, Department of Mathematics, 1400 John R. Lynch Street, Jackson, MS 39217. *Embedding, sectioning and compression of thickenings.*

Fix K a connected finite CW complex. C. T. C Wall [Wa] constructed the suspension map $E : T_n(K) \to T_{n+1}(K)$, given by crossing with the unit interval, to study the set of path components of the moduli space of n-thickenings. This is a basic problem in geometric topology. He then tries to examine the deviation from which the map E is surjective. An $(n+1)$-thickening compresses if its associated equivalence class is in the image of E. In our work [A], we will outline, within our range, the conditions, the concepts and the techniques needed to compress an $(n+1)$-thickening.

1. [A] M. Aouina: The Moduli Space of thickenings. Transactions of the AMS. Accepted June 2011. 2. [Wa] Wall, C. T. C.: Classification problems in differential topology-IV. Thickenings. Topology 5, 73-94 (1966).
(Received September 22, 2011)

1077-55-2305 **Matthew J. K. Gelvin***, Universitetsparken 5, DK-2100 København Ø, Denmark, and **Kári Ragnarsson**. *A homotopical version of p-local finite groups.* Preliminary report.

A p-local finite group is an algebraic model for the p-completed classifying space of a finite group. Miller conjectured that such spaces could be understood as a homotopical phenomenon, in terms of maps between a given space and the classifying space of a finite p-group. In this talk we will describe these concepts in more detail and give an outline of a proof of Miller's conjecture. (Received September 22, 2011)

1077-55-2329 **Robin M. J. Koytcheff*** (robink@math.brown.edu), Box 1917, 151 Thayer St., Providence, RI 02912. *A homotopy-theoretic view of Bott–Taubes integrals and knot spaces.*

Bott and Taubes considered a bundle over the space of knots whose fiber is a compactified configuration space, and they constructed knot invariants by performing integration along the fiber of this bundle. Their method was subsequently used to construct real cohomology classes in spaces of knots in $\mathbb{R}^n$, $n > 3$. Replacing integration of differential forms by a Pontrjagin-Thom construction, we have constructed cohomology classes with arbitrary coefficients. Motivated by work of Budney and F. Cohen on the homology of the space of long knots in $\mathbb{R}^3$, we have proven a product formula for these classes with respect to connect-sum. We have also made some progress towards further understanding these classes using the cosimplicial model for knot spaces coming from the Goodwillie-Weiss embedding calculus. (Received September 22, 2011)

1077-55-2353 **Pawel Dlotko*** (pawel.dlotko@uj.edu.pl), Łojasiewicza 6, 30-348 Kraków, Poland, and **Ruben Specogna**. *Cohomology in electromagnetic modelling.* Preliminary report.

Electromagnetic modeling provides an interesting context to present a link between physical phenomena and homology and cohomology theories. When magneto-quasi-static discrete formulations based on magnetic scalar potential are employed in problems which involve conductive regions with holes, cuts are needed to make the boundary value problem well defined. While an intimate connection with homology theory has been quickly recognized, heuristic definitions of cuts are surprisingly still dominant in the literature. My talk will consist mainly of three parts: In the first one a survey of the heuristic methods present in the literature will be provided. For each of them a suitable example will be given which points out that the considered methods are not valid. In the second one a formal proof will be given showing, that the cuts for edge- element methods are first cohomology group generators. In the third part an efficient algorithmic techniques to compute cohomology group generators on various meshes (including nonstandard ones) will be presented. Finally, the numerical simulation for large-scale industrial meshes will be presented. If the time permits I will also present some semi-algorithms for a fast computations of cohomology generators. (Received September 22, 2011)

1077-55-2362 **Pawel Dlotko*** (pawel.dlotko@uj.edu.pl), Łojasiewicza 6, 30-348 Kraków, Poland. *Applications of computational homology and cohomology theory.* Preliminary report.

Depending on the time available, I will present a few selected applications of computational (co)homology theory, I am currently working on: 1) Computational topology and Maxwell's equation" An efficient numerical method to solve Maxwell's equation called DGA needs a kind of topological information which are the representatives of the first cohomology group generators. Idea of the method and fast algorithms to compute cohomology group and ring will be presented. 2) Analyzing nodal domains of trigonometric polynomials" Topology-preserving method based on interval arithmetic returns a non-regular cubical grid the homology of which need to be computed in some applications. In this part of talk I will present an algorithmic way of computing homology for a wide class of CW-complexes called regular CW-complexes and present how the homology can be used in material science. 3) Recently more attention is focused at distributed computations. In this part of my talk I will cover the topic of topology in sensor networks used to solve the coverage problem. (Received September 22, 2011)

1077-55-2376 **David T Oury***, doury@slu.edu, St. Louis, MO 63103. *The Anodyne Theorem in Model Category Theory.*

The goal of this talk is to define a class of theorems which we call Anodyne Theorems (AT) and to explain their use with respect to model categories. These theorems are used in the literature by Mark Hovey and by Dominic Verity but not under this name. We describe their use in developing model structures on presheaf categories, in general and then for a specific presheaf catgory. In the first part of the talk, we describe the role of Anodyne Theorems and their relationship to the concept of homotopy in demonstrating model structures. Examples of its use can be found in the work of Hovey and Verity with respect to monoidal model categories. In the second part of the talk, we describe the specific methods used to demonstrate an Anodyne Theorem on the category of Θ_2-sets. First though we describe the AT for the model structure on simplicial sets whose fibrant objects are quasi-categories. We then describe the Θ_2-sets and lift the AT for simplicial sets to the context of Θ_2-sets. This requires the use of Day Convolution to define a pushout product of n variables (akin to the pushout product of 2 variables.) The corner tensor is an essential piece of the AT in this context and we provide a sketch of its construction. (Received September 22, 2011)

1077-55-2465 **Nathaniel Rounds*** (nrounds@indiana.edu). *What is the algebraic structure of topological manifolds?* Preliminary report.

Can we associate an algebraic structure to a manifold such that this structure up to equivalence determines the manifold up to homeomorphism? If we replace the word "homeomorphism" with the word "homotopy equivalence", the answer is yes. We will describe various algebraic structures on a manifold's chains and cochains, all of which are known to be homotopy invariant. We will suggest, however, that the missing idea is that of algebraic locality. The various algebraic structures that we associate to a manifold are all local in an appropriate sense, but the inverse to the Poincaré duality map need not be local. We will show, using Ranicki's algebraic surgery, that considering the inverse to the Poincaré duality map leads to a topological invariant of manifolds. We will end with a (still partially conjectural) synthesis of all these ideas which gives an affirmative answer to the opening question. (Received September 22, 2011)

1077-55-2594 **Matt Sequin*** (sequin.2@osu.edu), Math Tower Rm. 505, 231 W. 18th Ave, Columbus, OH 43210. *An Algebraic Proof of the Equivalence of Two Quantum 3-Manifold Invariants: The Hennings Invariant and the Kuperberg Invariant.*

We will compare two different quantum 3-manifold invariants, both of which are given using a finite dimensional Hopf Algebra H. One is the Hennings invariant, given by an algorithm involving the link surgery presentation of a 3-manifold and the Drinfeld double $D(H)$; the other is the Kuperberg invariant, which is computed using a Heegaard diagram of the 3-manifold and the same H. We have shown that when H has the property of being involutory, these two invariants are actually equivalent. The proof is totally algebraic and does not rely on general results involving categorical invariants. (Received September 22, 2011)

1077-55-2600 **Rosona M Eldred*** (reldred2@illinois.edu), Dept of Math, UIUC, 1409 W. Green St., Urbana, IL 61801. *New Developments in Approximation Towers of Functors.* Preliminary report.

The n-excisive approximation to a functor is a homotopy colimit of finite limit constructions, T_n^k. We discuss a new decomposition of the T_n^k which yields interesting structure on our "partial approximation towers", which are inverse limit systems of T_n^k where n varies. (Received September 22, 2011)

1077-55-2623 **Bertrand J Guillou*** (bertg@illinois.edu), **J Peter May** and **Nathaniel Stapleton**. *G-spectra and equivariant commutativity.* Preliminary report.

I will discuss a model for the equivariant stable homotopy category in which the objects are spectral functors on a suitable domain category. One of the central ingredients is equivariant infinite loop space theory, whose input is appropriately commutative equivariant data. I will discuss this structure and consequences thereof from several viewpoints. (Received September 22, 2011)

1077-55-2644 **Angelica M. Osorno*** (aosorno@math.uchicago.edu) and **Niles Johnson**. *Stable homotopy 1-types and symmetric Picard groups.* Preliminary report.

It is a classical result that groupoids model homotopy 1-types, in the sense that there is an equivalence between the homotopy categories, via the classifying space and fundamental groupoid functors. We extend this result to stable homotopy 1-types and symmetric Picard groupoids, that is, symmetric monoidal groupoids in which every object has a weak inverse. Using an algebraic description of symmetric Picard groupoids, we identify the Postnikov data associated to a stable 1-type; the abelian goups π_0 and π_1, and the unique k-invariant. We relate this data to the exact sequences of Picard groupoids developed by Vitale. (Received September 22, 2011)

1077-55-2649 **John D. Foley*** (jfoley@ucsd.edu). *Homotopy Kac-Moody groups and infinite pseudoreflection groups.* Preliminary report.

Finite complex pseudoreflection groups appear as the Weyl groups of p-compact groups and faithfull p-adic representations of these Weyl groups are central to the recent classification of p-compact groups. Kac-Moody groups, which are a generalization of Lie groups, have Weyl groups with natural integral representations, but these Weyl groups are infinite crystallographic Coxeter groups in all non-Lie cases. Progress in the representation theoretic approach to the p-local homotopy theory of Kac-Moody groups suggests a path toward a notion of homotopy Kac-Moody groups with infinite pseudoreflection Weyl groups. However, in contrast to infinite Coxeter groups, the theory of infinite pseudoreflection groups is not well-developed. This talk will focus on which infinite complex pseudoreflection groups are suitable candidates for the Weyl groups of homotopy Kac-Moody groups and include relevant examples. (Received September 22, 2011)

1077-55-2774 **Eddie Santiago Beck*** (eddie.beck@gmail.com), Department of Mathematics, University of Georgia, Athens, GA 30602. *On Calculations of p-Typical Formal Group Laws.*

Formal group law theory provides computational tools with which to explore algebraic topology and homotopy theory. This paper studies the formal sum and the cyclic power operation for p-typical formal group laws, specifically to reduce prohibitive computation times through algorithm and time complexity analysis. We provide a combinatorial algorithm that directly computes terms of arbitrary degree using Mahler partitions. We also provide an online algorithm for computing the cyclic power operation, meaning that the precision of the calculations can be increased without restarting the computations. We measured the time complexity by counting the number of monomial multiplications required. These algorithms are at worst sub-exponential on the degree of the precision. Our algorithm substantially reduced previous computation times and show that the McClure formula on MU_{17} is non-zero. (Received September 22, 2011)

1077-55-2916 **Ilya Grigoriev***, Dept. of Mathemathics, Building 380, Stanford, CA 94305. *Some relations in the cohomology of classifying spaces of manifold bundles.*

The cohomology of the classifying space of surface bundles (or, equivalently, the moduli space of Riemann surfaces) is an active topic of research, especially in the so-called "unstable" range of dimensions. The same kind of study is possible for the classifying space of a higher-dimensional manifold. In this talk, I will describe how certain techniques (due to Randall-Williams) to find relations between tautological classes in the unstable range of the cohomology of the classifying space of surface bundles can be applied in the higher-dimensional case. (Received September 23, 2011)

1077-55-2958 **Johnathon Kyle Armstrong*** (karmstrong@fsu.edu), 406 Glenview Drive, Tallahassee, FL 32303. *Reflection diagrams and mixed-sign Coxeter Systems.* Preliminary report.

We discuss reflection diagrams and how they relate to mixed-sign Coxeter systems. (Received September 24, 2011)

57 ► Manifolds and cell complexes

1077-57-93 **Erica Flapan**, **Blake Mellor*** (bmellor@lmu.edu) and **Ramin Naimi**. *Topological Symmetry Groups of Complete Graphs.*

The *topological symmetry group* of an embedded graph Γ in S^3 is the subgroup of the automorphism group of Γ (as an abstract graph) which is induced by homeomorphisms of the pair (S^3, Γ). The topological symmetry group was introduced by Jon Simon in 1986 to study the symmetries of flexible molecular graphs. We address the question of classifying, for a particular graph, the possible topological symmetry groups of its embeddings. We answer this question completely for complete graphs, and discuss ongoing work on complete bipartite graphs. (Received July 25, 2011)

1077-57-134 **Morwen Thistlethwaite** and **Anastasiia Tsvietkova*** (tsvietkova@math.utk.edu), tsvietkova@math.utk.edu. *An alternative approach to hyperbolic structures on link complements.*

Thurston demonstrated that every link in S^3 is a torus link, a satellite link or a hyperbolic link and these three categories are mutually exclusive. It also follows from work of Menasco that an alternating link represented by a prime diagram is either hyperbolic or a $(2, n)$–torus link.

A new method for computing the hyperbolic structure of the complement of a hyperbolic link, based on ideal polygons bounding the regions of a diagram of the link rather than decomposition of the complement into ideal tetrahedra, was suggested by M. Thistlethwaite. Although the method is applicable to all hyperbolic links, it works particularly well for alternating (non-torus) links. The presentation will introduce the basics of the method. Some applications will be discussed, including a surprising rigidity property of certain tangles, a new numerical invariant for tangles, and formulas for the volume of 2–bridged links. (Received August 05, 2011)

1077-57-185 **Charles Frohman*** (charles-frohman@uiowa.edu), **Michael Fitzpatrick** (Michael-C-Fitzpatrick@uiowa.edu) and **Joanna Kania-Bartoszynska** (jkaniab@nsf.gov). *Projective Representations of the Mapping Class Group coming from the Extended TQFT underlying the Kauffman Bracket.*

For each odd counting number p greater than or equal to 3 and to each k relatively prime to p, and a choice of even labels for the boundary components of the surface S there is a projective representation of the mapping class group of the surface S. By organizing these representations according to the dimension of the underlying state space we get families of projective representations of the mapping class group of S that are parametrized by the roots of unity exp(Pi*I*k/p) on the unity circle. We will prove that in some cases these families of representations extend continuously to representations for each point on the unit circle. (Received August 08, 2011)

1077-57-240 **Heather M. Russell*** (heathemr@usc.edu), **Julianna S. Tymoczko** and **Matthew Housley**. *Interactions between knot theory and representations of the symmetric group.*

Springer varieties are a special collection of flag varieties whose homology carries an action of the symmetric group with the top-dimensional homology an irreducible representation. For a fixed integer n, there is a Springer variety for each partition of n. In the case of two-element partitions, Springer varieties have important connections to Khovanov's theory of categorified tangle invariants. In past work, we use this to explicitly construct the Springer representation for two-element partitions of n. This construction operates skein-theoretically on crossingless matchings.

This simple, knot-theoretic approach can be used once again to construct the Springer representation in the case of three-element partitions of n. In this setting embedded, trivalent, directed graphs called $sl(3)$ webs replace crossingless matchings, and the skein relation is more interesting. We will show how certain combinatorial data about symmetric group representations are naturally and intuitively encoded in this knot-theoretic framework. (Received August 16, 2011)

1077-57-263 **Danielle O'Donnol** and **Elena Pavelescu*** (pavelescu@oxy.edu), Occidental College, 1600 Campus Road, Los Angeles, CA 90041. *On Legendrian Graphs.*

We investigate Legendrian graphs in $(\mathbb{R}^3, \xi_{std})$. We extend the classical invariants, Thurston-Bennequin number and rotation number to Legendrian graphs. We prove that a graph can be Legendrian realized with all its cycles Legendrian unknots with $tb = -1$ and $rot = 0$ if and only if it does not contain K_4 as a minor. There are many examples of knots and links which are characterized up to Legendrian isotopy by the pair (tb, rot). We ask what graphs are characterized up to Legendrian isotopy by the pair (tb, rot) and give several examples. (Received August 16, 2011)

1077-57-309 **Aldo-Hilario Cruz-Cota*** (cruzal@gvsu.edu), Grand Valley State University, Department of Mathematics, 1 Campus Dr., A-2-178 MAK, Allendale, MI 49401, and **Teresita Ramirez-Rosas** (ramirezt@gvsu.edu), Grand Valley State University, Department of Mathematics, 1 Campus Dr., A-2-178 MAK, Allendale, MI 49401. *The Simple S^2-branched Cover Area of a Surface.* Preliminary report.

Given a surface M, the *complexity* of a branched cover $M \to S^2$ of degree d and with branching set of cardinality $n \geq 3$ is defined as d times the hyperbolic area of the complement of its branching set in S^2. The *simple S^2-branched cover area* of a surface M is the infimum of all complexities of simple branched covers $M \to S^2$. This is an invariant of the surface M that tells us how efficiently M covers the 2-sphere. We prove that if M is a connected closed orientable surface of genus $g \geq 1$, then its simple S^2-branched cover area equals $8\pi g$. (Received August 19, 2011)

1077-57-310 **Danny Calegari** and **Joel Louwsma*** (jlouwsma@ou.edu), Department of Mathematics, The University of Oklahoma, Norman, OK 73019. *Immersed surfaces in the modular orbifold.*

A hyperbolic conjugacy class in the modular group $\mathrm{PSL}(2,\mathbb{Z})$ corresponds to a closed geodesic in the modular orbifold. Some of these geodesics virtually bound immersed surfaces, and some do not; the distinction is related to the polyhedral structure in the unit ball of the stable commutator length norm. We prove the following stability theorem: for every hyperbolic element of the modular group, the product of this element with a sufficiently large power of a parabolic element is represented by a geodesic that virtually bounds an immersed surface. (Received August 19, 2011)

1077-57-311 **Joseph Maher*** (joseph.maher@csi.cuny.edu). *Exponential decay in the mapping class group.*

We show that a random walk on the mapping class group of a surface gives rise to a non-pseudo-Anosov element with a probability that decays exponentially in the length of the walk. More generally, for any B, we show exponential decay for the probability that a random walk gives rise to an element with translation length at most B on the complex of curves. Furthermore, this holds for all finitely generated non-elementary subgroups of the mapping class group. (Received August 19, 2011)

1077-57-357 **Moira Chas***, moira@math.sunysb.edu, and **Steven Lalley**, **Keren Li** and **Bangrui Chen**. *Statistics about curves on surfaces.*

Consider the set of free homotopy classes of oriented closed curves on a surface. This is the set of equivalence classes of maps from the circle into the surface, where two such maps are equivalent if the corresponding directed curves can be continuously deformed one into the other. There is a canonical bijection from this set to the set of conjugacy classes of the fundamental group of the surface.

Fix now a hyperbolic metric and a set of generators of the fundamental group of the surface. Each free homotopy class determines three numbers: the geometric length (the length of the geodesic in the class), the word length (the smallest number of generators needed for a description of the class), and the self-intersection (the minimum number of times, counted with multiplicity, a curve in the class intersects itself.)

We will discuss statistics about and relations between these three numbers associated to a free homotopy class.

Parts of this work are joint with Bangrui Chen, Steve Lalley, Keren Li and Anthony Phillips. (Received August 25, 2011)

1077-57-370 **Michael Bradley Henry*** (mbhenry@siena.edu), Department of Mathematics, Siena College, Loudonville, NY 12211, and **Daniel R Rutherford**, Department of Mathematics, University of Arkansas, Fayetteville, AR 72701. *A combinatorial differential graded algebra for Legendrian knots from generating families.*

A generating family for a Legendrian knot L in the standard contact structure on $\mathbb{R}^3$ is a function whose critical values encode the xz-projection of L. The current results contribute to a long-running program to prove deep connections exist between Legendrian invariants derived from generating families and those derived from the Chekanov-Eliashberg DGA. An algebraic analogue of generating families was defined by Petr Pushkar and has proven to be a useful and computable alternative. These objects are known as Morse complex sequences, abbreviated MCS. The definition of an MCS is geometrically motivated by the fiber-wise Morse-Smale chain complexes coming from a suitably generic generating family and metric for L. Our current work associates a differential graded algebra, abbreviated DGA, to an MCS. The DGA is geometrically motivated by Morse-theoretic techniques applied to generating families. The linear homology of the DGA is a Legendrian invariant and if the MCS is a special type, then the DGA is stable tame isomorphic to the Chekanov-Eliashberg DGA of L. (Received August 26, 2011)

1077-57-391 **Moshe Cohen*** (cohenm10@macs.biu.ac.il), Department of Mathematics, Bar-Ilan University, 52900 Ramat Gan, Israel, and **Michael Friedman**. *Analogy between knots and primes: number fields ramified over two primes.* Preliminary report.

Kadokami and Mizusawa further the analogy between knots embedded in three manifolds and prime ideals in number fields by considering number fields ramified over one prime. We extend this analogy by considering both the cyclotomic and the anti-cyclotomic extensions for fields ramified over two primes by considering two-component Z/2 boundary links. (Received August 29, 2011)

1077-57-397 **Aaron D Magid*** (amagid@gmail.com), 1301 Campus Dr., University of Maryland, College Park, MD 20742, and **Richard D Canary**. *Dynamics of the outer automorphism group on the $PSL(2,\mathbb{C})$ character variety of a 3-manifold.*

Let M be a compact hyperbolizable 3-manifold. We construct open sets in the $PSL(2,\mathbb{C})$ character variety on which the action of $Out(\pi_1(M))$ is properly discontinuous. These open sets depend on the characteristic submanifold of M. This is joint work with Richard Canary and extends previous work by Canary-Storm. (Received August 29, 2011)

1077-57-471 **Ryo Ohashi*** (ryoohashi@kings.edu), King's College, Department of Mathematics, Wilkes-Barre, PA 18711. *The finite group actions on prism manifolds.* Preliminary report.

A prism manifold is an elliptic manifold whose universal covering space is the three sphere. It is well known fact that these manifolds are Seifert fibered spaces. Further, there is a one-to-one correspondence between its fundamental group and topological structure.

In the first part of my talk, we will learn how to construct a prism manifold topologically. Secondly, we will see all isometry groups acting on each prism manifold, which is always an infinite group.

Thus, it is natural to ask "what are their finite subgroups?" There is a handy method to compute all finite subgroups of an infinite group. By using the method, we will classify all of such finite subgroups. Further, it will be addressed finite actions that a preserve fiber.

Note that the content of the talk is definitely accessible for graduate students who are interested in 3-manifold. (Received September 03, 2011)

1077-57-508 **Heather A Dye***, McKendree University, 701 College Rd, Lebanon, IL 62254, and **Louis Kauffman** and **Aaron Kaestner**. *Virtual knots and Khovanov Homology.*

We construct a Khovanov homology with integer coefficients for virtual knots. We discuss the issue that prevent a straightforward extension of Khovanov homology to virtual knots. We then introduce a modification of the multiplication map that allows Khovanov homology to be extended to virtual knots and links. (Received September 06, 2011)

1077-57-571 **Jesse Johnson*** (jjohnson@math.okstate.edu), 2131 Sunset, Stillwater, OK 74074. *Handlebody filling and the Heegaard tree.* Preliminary report.

The Heegaard tree of a 3-manifold is the graph in which vertices are isotopy classes of Heegaard surfaces and edges connect each surface to the new surface that results from adding an unknotted handle to the original surface. A number of recent results have shown that if one glues a handlebody into a boundary component of a manifold using a sufficiently complicated map then every low genus Heegaard surface for the new manifold is isotopic to a Heegaard surface in the original manifold. In other words, no vertices will be added to the new

Heegaard tree below a certain genus. I will discuss the problem of determining when the new and old Heegaard trees are isomomrphic below a given genus, i.e. guaranteeing that two existing vertices in the tree will not become equal after such a gluing. (Received September 07, 2011)

1077-57-588 **Craig D. Hodgson** (craigdh@unimelb.edu.au), Department of Mathematics and Statistics, University of Melbourne, Parkville, VIC 3010, Australia, **J. Hyam Rubinstein** (rubin@ms.unimelb.edu.au), Department of Mathematics and Statistics, University of Melbourne, Parkville, VIC 3010, Australia, and **Henry Segerman*** (segerman@unimelb.edu.au), Department of Mathematics and Statistics, University of Melbourne, Parkville, VIC 3010, Australia. *Triangulations of hyperbolic 3-manifolds admitting strict angle structures.*

It is conjectured that every hyperbolic 3-manifold with torus boundary components has a decomposition into positive volume ideal hyperbolic tetrahedra (a "geometric" triangulation of the manifold). Under a mild homology assumption on the manifold we construct topological ideal triangulations which admit a strict angle structure, which is a necessary condition for the triangulation to be geometric. In particular, every knot or link complement in the 3-sphere has such a triangulation. (Received September 07, 2011)

1077-57-589 **Tao Li*** (taoli@bc.edu), Department of Mathematics, Boston College, Chestnut Hill, MA 02467. *Rank and genus of 3-manifolds.*

We construct a counterexample to the Rank versus Genus Conjecture, i.e. a closed orientable hyperbolic 3-manifold with rank of its fundamental group smaller than its Heegaard genus. Moreover, we show that the discrepancy between rank and Heegaard genus can be arbitrarily large for hyperbolic 3-manifolds. We also construct toroidal such examples containing hyperbolic JSJ pieces. (Received September 07, 2011)

1077-57-591 **Liam Watson*** (lwatson@math.ucla.edu), UCLA Mathematics, 520 Portola Plaza, Los Angleles, CA 90095. *L-spaces vs. left-orderability.*

An L-space is a rational homology sphere with simplest possible Heegaard Floer homology; a group is left-orderable if it admits a strict total order of its elements that is invariant under multiplication on the left. It has been conjectured that being an L-space is equivalent to having a non-left-orderable fundamental group. This talk will discus some of the evidence for this conjecture, including joint projects with S. Boyer and C. Gordon, and A. Clay. (Received September 07, 2011)

1077-57-621 **Ilesanmi Adeboye***, Math and Computer Science Department, 265 Church St, 6th Floor Exley, Wesleyan University, Middletown, CT 06459. *Volumes of Complex Hyperbolic Orbifolds.*

We establish an explicit lower bound for the volume of a complex hyperbolic orbifold, depending only on dimension. (Received September 08, 2011)

1077-57-622 **John A. Baldwin**, **David Shea Vela-Vick*** (shea@math.columbia.edu) and **Vera Vertesi**. *On the equivalence of Legendrian and transverse knot invariants in Heegaard Floer homology.*

The Heegaard Floer package provides a robust tool for studying contact 3-manifolds and their subspaces. Within the sphere of Heegaard Floer homology, several invariants of Legendrian and transverse knots have been defined. The first such invariant, constructed by Ozsváth, Szabó and Thurston, was defined combinatorially using grid diagrams. The second invariant was obtained by geometric means using open book decompositions by Lisca, Ozsváth, Stipsicz and Szabó. We show that these two previously defined invariant agree. Along the way, we define a third, equivalent Legendrian/transverse invariant which arises naturally when studying transverse knots which are braided with respect to an open book decomposition. (Received September 08, 2011)

1077-57-699 **Louis H Kauffman*** (kauffman@uic.edu), Louis H. Kauffman, Math UIC, 851 Morgan Street, Chicago, IL 60607-7045. *Virtual Knot Theory - State Sum Invariants.* Preliminary report.

This talk will discuss state sum invariants in virtual knot theory, including the bracket and arrow polynomials and their parity generalizations. We will also discuss extensions of quantum invariants defined via solutions to the Yang-Baxter equation to rotational virtual knot theory (where the first virtual move is forbidden). All quantum invariants for classical knots generalize to rotational virtual knot theory, and this raises questions about virtual braids and about link homology for rotational virtuals. (Received September 10, 2011)

1077-57-749 **Douglas J LaFountain*** (dlafount@qgm.au.dk), **John B Etnyre** and **Bülent Tosun**.
Embeddings of contact solid tori and Legendrian cable knots.

We classify embeddings of solid tori representing positive torus knots in the standard contact 3-sphere, and in so doing uncover a new object in contact topology, namely partially thickenable solid tori. We then use this to completely classify Legendrian and transverse cables of positive torus knots, and in particular establish the existence of non-destabilizable Legendrians with Thurston-Bennequin number arbitrarily far from maximal, and which require arbitrarily many stabilizations before becoming isotopic to other classes with the same classical invariants. (Received September 12, 2011)

1077-57-757 **Eric Staron*** (estaron@math.utexas.edu), Department of Mathematics, The University of Texas at Austin, 1 University Station - C1200, Austin, TX 78712. *The Unknotting Number of 3-Stranded Pretzel Knots.*

We provide a partial classification of all 3-strand pretzels $P(p, q, r)$ with unknotting number one. Following Kobayashi's classification for all parameters odd, we treat the remaining case when $r = 2m$. Via Rasmussen's s-invariant, we identify the cases when $p + q = 0, \pm 2$ as the only cases of significant interest. We then attack the problem using methods such as Donaldon's diagonalisation theorem (and Greene's strengthening thereof), the Lickorish's unknotting bounds from the Alexander module, and the correction terms introduced by Ozsváth and Szabó. (Received September 12, 2011)

1077-57-760 **Ben McCarty*** (benm@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70767, and **Scott Baldridge**. *On the rotation class of knotted Legendrian tori in $\mathbb{R}^5$.* Preliminary report.

We present Lagrangian hypercube diagrams as a convenient tool to study knotted Legendrian tori in $\mathbb{R}^5$ with the standard contact structure. In particular, we describe an easy way to compute a Legendrian invariant, the rotation class, from a Lagrangian hypercube diagram. (Received September 12, 2011)

1077-57-860 **Christopher A Micklewright*** (cmicklewri@brynmawr.edu), Bryn Mawr College, Mathematics Department, 101 North Merion Avenue, Bryn Mawr, PA 19010. *Circle Valued Generating Families and Legendrian Link Invariants.*

Legendrian knot theory is the study of knots and links which satisfy a geometric condition imposed by a contact structure. In recent years, generating families and Morse theory have been used to develop new homological invariants for knots and links in $\mathbb{R}^3$ and $S^1 \times \mathbb{R}^2$. These invariants parallel Legendrian contact homology, and can be used to show that certain knots and links are topologically equivalent but not Legendrian equivalent. This talk will explore the extension of the generating family approach to circle valued functions, allowing the study of Legendrian knots and links in $T^2 \times \mathbb{R}$. Using techniques of Morse-Novikov theory, it is possible to define homological invariants which demonstrate that the components of certain links cannot be interchanged by Legendrian isotopy, although such an interchange is possible under topological isotopy. (Received September 13, 2011)

1077-57-865 **Samantha Pezzimenti*** (spezzime@ramapo.edu), Ramapo College of New Jersey.
Minimal Degree Parameterization for the Trefoil and Figure Eight Knots.

In this talk, we determine the minimal degree sequence for two compact rational knots, namely the Trefoil and Figure Eight knots. We find explicit projections with the minimal degree sequence of each knot. This is done by modifying a non-compact rational minimal-degree parameterization of the Trefoil and Figure Eight knots to make it compact. (Received September 13, 2011)

1077-57-970 **Suhyoung Choi*** (shchoixk@gmail.com), Department of Mathematical Sciences, Yuseong-Gu Guseong, Daejeon, Daejeon 305-701, South Korea. *Open problems in real projective structures on low-dimensional orbifolds.*

We can think of orbifolds as finite-group quotients of manifolds here. The orbifolds form more computable examples. Geometric structures on orbifolds are simply invariant G-structures. A real projective structure on an orbifold is a locally euclidean geodesic structure on it; that is, it is a local modelling by open subsets of a real projective space, on each of which a finite group of projective automorphisms acts. I would like to talk about the open problems on 2- and 3-dimensional orbifolds and the real projective and affine structures on these. Along the way, I will give a survey of some relevant results obtained since 1950s. (Received September 15, 2011)

1077-57-985 **Rafal Komendarczyk** and **Jeffrey Pullen*** (jpullen@tulane.edu), Mathematics Department, Tulane University, 6823 St. Charles Ave, New Orleans, LA 70118. *Finite Coverage Processes and Homology of Random Sets.* Preliminary report.

We address the issue of obtaining the probability of complete coverage for a given domain by a finite coverage process with compact convex grains. In the process, we define homology of a random compact set S and consider a random simplicial complex corresponding to the nerve of a random covering. This allows us to determine the distributions of random Betti numbers as well as the Euler characteristic of S. Armed with these notions, we address the probability of complete coverage of domains which have a homotopy type of a simplicial complex which has potential applications in the area of sensor networks. (Received September 15, 2011)

1077-57-994 **Tim D Cochran**, **Bridget D Franklin**, **Matthew Hedden** and **Peter D Horn*** (pdhorn@math.columbia.edu), 2990 Broadway, MC 4403, New York, NY 10027. *Knot concordance and homology cobordism.*

If two knots are concordant via an annulus, their exteriors are homology cobordant relative boundary. One can perform "n-framed Dehn surgery" on this annulus and see that the n-framed Dehn surgeries on the two knots are homology cobordant rel meridians. We consider the converse for n=0: if 0-framed Dehn surgeries on two knots are homology cobordant, are the knots concordant? This question has an affirmative answer if one of the knots is the unknot. In the category of smooth cobordism/concordance, we show that the answer is generally "no." We also show the answer is "no" in a generalization of the topological category. (Received September 15, 2011)

1077-57-1075 **Daniel S. Freed*** (dafr@math.utexas.edu), Department of Mathematics, University of Texas, 1 University Station C1200, Austin, TX 78712-0257. *The cobordism hypothesis: quantum field theory + homotopy invariance = higher algebra.*

Quantum field theory, which physicists initiated in the 1920s to construct a quantum theory of the electromagnetic field, has long attracted interest in mathematics. Over the past 30 years the geometric side of quantum field theory has come to the fore. In 1988 Witten introduced *topological* quantum field theory (TQFT) as a home for topological invariants of Donaldson and Jones. TQFT quickly became an inspiration for invariants in low-dimensional topology as well as a subject for mathematical study.

In the 1990s Baez-Dolan formulated a "cobordism hypothesis" characterizing TQFTs which are fully extended: n-dimensional theories which include invariants for manifolds of all dimensions $\leq n$. This was put into a rigorous context and proved first for $n = 2$ by Hopkins and Lurie, then for all dimensions n by Lurie. Deep ideas in Morse theory and higher categories are central to the proof; no physics is necessary. Rather, just as standard homology uses algebra to study topological spaces, TQFT uses algebra to study smooth manifolds. These ideas are now finding applications in other parts of topology and algebra, for example in representation theory.

In the lecture I will explain some of the basic ideas and examples, and give some hints about the proof. (Received September 16, 2011)

1077-57-1089 **Christoper William Davis***, Rice University mathematics department, 6100 Main St, Houston, TX 77005, MS-136, Houston, TX 77005. *Non-triviality of knots arising from iterated infection without the use of the Tristram-Levine signature.*

We give an explicit construction of linearly independent families of knots arbitrarily deep in the (n)-solvable filtration of the knot concordance group using first order signatures. A difference between previous constructions of infinite rank subgroups in the concordance group and ours is that the deepest infecting knots in the construction we present are allowed to have vanishing Tristram-Levine signatures. (Received September 16, 2011)

1077-57-1245 **Bridget D Franklin***, 6100 S Main St, Rice University – MS 136, Houston, TX 77005. *Obstructing concordance of related satellite operations.*

Various obstructions to knot concordance have been found using Casson-Gordon invariants, higher-order Alexander polynomials, as well as von-Neumann ρ-invariants. Examples have been produced using (iterated) satellite operations, described by $K = R(\eta, J)$, and considering these as parametrized by invariants of the base knot J and doubling operator R. Here, we introduce a method to obstruct concordance based upon the class of η in $\pi_1(S^3 \setminus R)$. Although the usual invariants fail, distinct concordance classes are found even while fixing the knots J and R, as well as the class represented by η in the Alexander module. (Received September 18, 2011)

1077-57-1253 **Effie Kalfagianni*** (kalfagia@math.msu.edu), Department of Mathematics, Michigan State University, E. Lansing, MI 48824. *Cosmetic crossing changes on knots.*

The talk will be on results on and around the question of when a crossing change on an oriented knot changes the isotopy class of the knot. (Received September 18, 2011)

1077-57-1331 **Matt T. Clay**, **Christopher J. Leininger** and **Johanna Mangahas*** (mangahas@math.brown.edu). *The geometry of right-angled Artin subgroups of mapping class groups.*

I'll describe joint work with Matt Clay and Chris Leininger. We give sufficient conditions for a finite set of mapping classes to generate a right-angled Artin group quasi-isometrically embedded in the mapping class group. Moreover, under these conditions, the orbit map to Teichmueller space is a quasi-isometric embedding for both of the standard metrics. As a consequence, we produce infinitely many genus h surfaces (h at least 2) in the moduli space of genus g surfaces (g at least 3) for which the universal covers are quasi-isometrically embedded in the Teichmueller space. (Received September 19, 2011)

1077-57-1333 **Moshe Cohen** and **Adam M Lowrance***, Department of Mathematics, 14 MacLean Hall, Iowa City, IA 52242-1419. *A categorification of the Tutte polynomial.* Preliminary report.

The Tutte polynomial is a graph and matroid polynomial with close ties to the Jones polynomial. We construct a categorification of the Tutte polynomial that is similar in spirit to odd Khovanov homology. We discuss morphisms in this categorification and show how the Tutte polynomial categorification gives an invariant of alternating links. (Received September 19, 2011)

1077-57-1343 **R. Taylor McNeill*** (rtm2@rice.edu), Mathematics Department, MS 136, Rice University, 6100 Main St, Houston, TX 77005. *A new filtration of the Magnus kernel of the Torelli group.*

For a surface Σ, the Torelli group is the group of orientation preserving homeomorphisms of Σ that induce the identity on homology. The Magnus representation represents the action on F/F'' where $F = \pi_1(\Sigma)$. For many years it was unknown whether the Magnus representation of the Torelli group is faithful. In recent years there have been many developments on this front including the result of Church and Farb that the kernel of the Magnus representation, denoted K, is infinitely generated. I show that, not only is K highly non-trivial but that it also has a rich structure as a group. Specifically, I define an infinite filtration of K by subgroups, called the higher-order generalized Johnson subgroups. I show that for each n, there are elements in the n^{th} term but not the next term of the filtration. To do this, I define a higher-order generalized Johnson type homomorphism on each new subgroup and show it has a non-trivial image. (Received September 19, 2011)

1077-57-1401 **Nicholas D Nguyen*** (ndn004@math.ucsd.edu). *The adjoint action on homotopy-associative H-spaces.*

Kono and Kozima introduce the adjoint action and commutator map for compact Lie groups and use the maps to characterize the commutativity of the homology ring. Iwase would extend their results to finite loop spaces.

In this paper, we extend Iwase's results to finite homotopy-associative H-spaces by finding useful formulas for the induced homomorphisms. (Received September 19, 2011)

1077-57-1413 **Shelly Harvey** and **Danielle O'Donnol*** (dodonnol@smith.edu). *Graph Floer homology.*

A natural extension of knot theory is the study of spatial graphs. A *spatial graph* is an embedding of a graph into $\mathbb{R}^3$ or S^3. We defined graph Floer homology, a generalization of knot Floer homology. Graph Floer homology is a bigraded homology theory for balanced spatial graphs. We extended the notion of grid diagrams to balanced spatial graphs, and defined a set of grid moves. We proved that the bigraded homology theory we associate with a grid diagram is independent of the grid moves. Thus graph Floer homology is an invariant.

Unlike many homology theories, our theory is not the categorification of an existing polynomial invariant. Thus taking the generalized Euler characteristic gives another new invariant, an Alexander polynomial for balanced spatial graphs. (Received September 19, 2011)

1077-57-1421 **John Berge** and **Brandy Guntel***, bguntel@math.utexas.edu, and **Sungmo Kang**. *Classifying primitive/Seifert knots.* Preliminary report.

Among knots that lie on the genus 2 Heegaard surface for the 3-sphere, two classes of knots, the primitive/primitive and primitive/Seifert knots, are of particular interest because they admit lens space surgeries and Seifert fibered surgeries, respectively. The primitive/primitive knots were introduced by Berge; the primitive/Seifert knots, a natural generalization of the primitive/primitive knots, were introduced by Dean. In Berge's work, he classified the primitive/primitive knots. In this talk, I will discuss work, joint with John Berge and Sungmo Kang, that classifies the primitive/Seifert knots. (Received September 19, 2011)

1077-57-1536 **Jason Cantarella** and **Elizabeth Denne*** (edenne@smtih.edu), Dept. Mathematics and Statistics, Smith College, Northampton, MA 01062, and **John McCleary**. *Squarepegs and Inscribed Polygons.* Preliminary report.

Given any Jordan curve in the plane, are there four points on the curve which are the vertices of a square? This is the "squarepeg" problem first posed by Toeplitz in 1911. This talk will give a brief overview of the history of the problem, as well as an update on our progress on the problem. I'll also discuss more general results about polygons inscribed in simple closed curves in dimensions 3 and higher. (Received September 20, 2011)

1077-57-1555 **Neil R Hoffman***, Department of Mathematics, Boston College, Chestnut Hill, MA 02467-3806. *Small knot complements, cyclic commensurability and hidden symmetries.*

Two manifolds are commensurable if they share a common finite index cover. The study of commensurable knot complements has been of recent interest. There are two known ways in which hyperbolic knot complements can be commensurable: being cyclically commensurable and admitting hidden symmetries. I will show for small knot complements cyclic commensurablity and hidden symmetries cannot occur in conjunction. (Received September 20, 2011)

1077-57-1627 **Benjamin Cooper** (bjc4n@virginia.edu) and **Slava Krushkal*** (krushkal@virginia.edu). *Categorification of the Jones-Wenzl projectors and applications.*

Categorification of the Jones-Wenzl projectors will be introduced, leading to a novel categorification of the colored Jones polynomial and of spin networks. An application to the problems of evaluating a categorification at a root of unity and of handle-slide invariance will be discussed. (Received September 20, 2011)

1077-57-1793 **Matthew Hedden*** (mhedden@math.msu.edu), Wells Hall, East Lansing, 48824, and **Sucharit Sarkar** (sucharit@math.columbia.edu), New York. *Knot Floer homology and Murasugi sum.* Preliminary report.

I'll discuss what is known about the behavior of Knot Floer homology under the Murasugi sum operation (Received September 21, 2011)

1077-57-1798 **Christopher J Leininger*** (clein@math.uiuc.edu), 1409 W. Green St., Urbana, IL 61801, and **Dan Margalit** (margalit@math.gatech.edu). *Short geodesics in moduli space.*

This talk concerns the moduli space $\mathcal{M}_g$ of Riemann surfaces of genus g equipped with the Teichmüller metric. Given any sufficiently large constant C, there are closed geodesics in $\mathcal{M}_g$ of length at most C/g. In this talk I will discuss a coarse description for the location of these geodesics in $\mathcal{M}_g$, as well a polynomial upper bound, in terms of g, for the number of such geodesics. (Received September 21, 2011)

1077-57-1801 **Adam Simon Levine*** (levinea@brandeis.edu), Department of Mathematics, MS 050, Brandeis University, Waltham, MA 02138, and **Sam Lewallen** (lewallen@math.princeton.edu), Department of Mathematics, Princeton University, Princeton, NJ 08544. *Strong L-Spaces and Left Orderability.*

An L-space is a rational homology sphere Y whose Heegaard Floer homology is as small as possible: $\widehat{HF}(Y) \cong \mathbb{Z}^{|H_1(Y;\mathbb{Z})|}$. Boyer, Gordon, and Watson have conjectured that Y is an L-space if and only if the fundamental group of Y is non-left-orderable, a conjecture that is known to hold for all non-hyperbolic geometric manifolds. We show that if an L-space Y admits a Heegaard diagram whose Heegaard Floer complex has exactly $|H_1(Y;\mathbb{Z})|$ generators and thus has vanishing differential, then $\pi_1(Y)$ is non-left-orderable. We call such manifolds strong L-spaces. Examples include double branched covers of alternating links; on the other hand, the Poincaré homology sphere is an L-space but not a strong L-space. (Received September 21, 2011)

1077-57-1882 **Denis Auroux**, **J. Elisenda Grigsby*** (grigsbyj@bc.edu) and **Stephan M. Wehrli**. *A relationship between categorified braid invariants from representation theory and Floer theory.* Preliminary report.

Given a braid, one can associate to it a sequence of "categorified" braid invariants (one for each integer in a finite range) in two apparently different ways: "algebraically," via the higher representation theory of $U_q(sl_2)$ (using work of Khovanov-Seidel, Chen-Khovanov, and Brundan-Stroppel), and "geometrically," using the bordered Floer invariants of its double-branched cover (defined by Lipshitz-Ozsvath-Thurston and reinterpreted by Auroux). Both collections of invariants are strong enough to detect the trivial braid.

I will discuss what we know so far about the connection between these invariants, focusing on the relationship between the representation theory and the Floer theory. In addition, I will describe how both invariants can be understood in terms of sutured versions of Khovanov and Heegaard-Floer homology. (Received September 21, 2011)

1077-57-2018 **John R. Burke*** (jburke@ric.edu), Mathematics and Computer Science Department, Rhode Island College, 600 Mount Pleasant Avenue, Providence, RI 02906. *Why you should infect your knots with links.* Preliminary report.

In the talk, we will define the concordance group of knots and discuss the n-solvable Filtration of this group defined by Cochran, Orr, and Teichner. We will then discuss some of the previous results about the structure of the concordance group, in particular, the structure of the abelian quotient groups, G_n, of n-solvable knots modulo n.5-solvable knots. We will then define string link concordance groups and end by discussing how using genetic infection with string links and not knots alone one can construct knots of infinite order in G_n which are linearly independent from nearly all previously studied knots in G_n. (Received September 21, 2011)

1077-57-2089 **Prudence Heck*** (ph6@rice.edu), Rice University, Department of Mathematics, 6100 S. Main St., Houston, TX 77005, and **Tim Cochran**. *Topologically slice knots with small fundamental group.* Preliminary report.

A well know result of Freedman states that knots in S^3 with trivial Alexander polynomial are topologically slice. His proof depends on the disk embedding theorem, which is only known to hold for 4-manifolds with "good" fundamental group. In this talk we will discuss necessary conditions for the exterior of a topologically flat disk in B^4 to have good fundamental group. In particular, we give a complete characterization of all genus one knots that are homotopy ribbon wherein the group of the exterior of the slice disk is metabelian. (Received September 21, 2011)

1077-57-2110 **Oliver Dasbach*** (kasten@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803, and **Cody Armond**. *Properties of the head and tail of the colored Jones polynomial.*

For certain classes of knots the colored Jones polynomial has a stabilizing head and tail as the color increases. In the simplest cases the head and tail functions are evaluations of the 2-variable Ramanujan theta function. We will discuss properties of the head and tail of the colored Jones polynomial. (Received September 21, 2011)

1077-57-2116 **Stacy L. Hoehn*** (stacy.hoehn@vanderbilt.edu), Department of Mathematics, 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240, and **C. Bruce Hughes**. *Mapping Cylinder Neighborhoods in Manifold Stratified Pairs.* Preliminary report.

Many interesting spaces are not manifolds themselves but instead are stratified spaces, which are spaces that can be decomposed into manifold pieces called strata. The exact requirements for how these strata fit together vary depending on the type of stratified spaces being discussed. For example, in the stratified spaces studied by Mather, Thom, and Whitney, the relationship between strata is given by certain geometric conditions, while in Quinn's stratified spaces, the strata are related by homotopy conditions.

While strata in geometrically stratified spaces all have neighborhoods which are mapping cylinders of fiber bundles, strata in Quinn's stratified spaces may fail to have mapping cylinder neighborhoods, and even when they do, the maps may fail to be bundle maps. Given a manifold stratified pair (X, B) in the sense of Quinn, we show that, under certain compactness and dimension conditions, the pair $B \times \mathbb{R}$ always has a neighborhood in $X \times \mathbb{R}$ which is the mapping cylinder of a manifold approximate fibration, even if B does not have such a neighborhood in X. We also reinterpret the obstruction to B having a mapping cylinder neighborhood in X in terms of splitting certain manifold approximate fibrations over $B \times \mathbb{R}$. (Received September 21, 2011)

1077-57-2121 **Patricia Cahn*** (patricia.cahn@dartmouth.edu), 6188 Kemeny Hall, Hanover, NH 03755. *Algebras Counting Minimal Intersection and Self-Intersection Numbers of Loops on a Surface.*

Goldman and Turaev defined a Lie Bialgebra structure on the vector space generated by the nontrivial free homotopy classes of loops on a surface. The Turaev cobracket gives a lower bound on the minimum number of self-intersection points of a loop in a given free homotopy class. Chas showed that this bound is not always sharp. We construct an operation μ which factors through the cobracket, and we show that in contrast to the cobracket, this operation always counts the minimal number of self-intersection points of a loop in a given class. If time permits, we will discuss the corresponding problem for intersections of loops. (Received September 21, 2011)

1077-57-2123 **R. Sean Bowman*** (sbowman@math.utexas.edu). *Knots in handlebodies with handlebody surgeries.*

Let K be a knot in a handlebody H of genus g. It is a natural question to ask when K has a nontrivial Dehn surgery yielding a handlebody. We say that K is 1–bridge in H if K is isotopic to $\alpha \cup \beta$, where $\alpha \subseteq \partial H$ is an arc, β is properly embedded in H, and there is an arc $\beta' \subseteq \partial H$ such that $\beta \cup \beta'$ bounds a disk. When $g = 1$, so that H is a solid torus, Gabai noted that in order to have a nontrivial surgery yielding a solid torus, K must be 1–bridge. Wu conjectured that this should be true when $g > 1$ as well. In this talk we give examples of knots in genus 2 handlebodies which have nontrivial handlebody surgeries but which are not 1–bridge. (Received September 21, 2011)

1077-57-2148 **Taylor E Martin*** (taylor.martin@rice.edu). *Classification of 0-solvable links.*

The n-solvable filtration, defined by Cochran, Orr, and Teichner in the late 90's, gives structure to the smooth knot and link concordance groups. Much is known about the n-solvable filtration of the knot concordance group for small n. For example, a knot is 0-solvable if and only if it has Arf invariant zero. Moreover, a knot is 0.5-solvable precisely when it's Seifert matrix looks like that of a slice knot, called algebraically slice. However, very little is known for links. In this talk, we will completely classify 0-solvable links. (Received September 21, 2011)

1077-57-2235 **Allison H Moore*** (moorea8@math.utexas.edu), The University of Texas at Austin, 1 University Station C1200, Austin, TX 78712. *Genus 2 mutation of knots.* Preliminary report.

Let F be a closed genus 2 surface in S^3, disjoint from a knot $K \subset S^3$, and equipped with the hyperelliptic involution τ. A genus 2 mutant of K is obtained by cutting M along F and regluing the two copies of F via τ. We will realize diagrammatic Conway mutation of knots as a specialization of genus 2 mutation in S^3, and explore some examples and properties of both, in particular how the Khovanov homology and knot Floer homology invariants behave with respect to genus 2 mutation. (Received September 21, 2011)

1077-57-2374 **Benjamin Himpel*** (himpel@imf.au.dk), Centre for Quantum Geometry of Moduli Spaces, Department of Mathematical Sciences, Aarhus U, Ny Munkegade 118, bldg. 1530, Aarhus, 8260, and **Jørgen Ellegaard Andersen**. *The asymptotic expansion of the Witten-Reshetikhin-Turaev invariants.*

Witten's influential invariants for links in 3-manifolds given in terms of a non-rigorous Feynman path integral have been rigorously defined first by Reshetikhin and Turaev. Their combinatorial definition based on the axioms of topological quantum field theory is expected to have an asymptotic expansion in view of the perturbation theory of Witten's path integral with leading order term (the semiclassical approximation) given by formally applying the method of stationary phase. Furthermore, the terms in this asymptotic expansion are expected to be well-known classical invariants like the Chern-Simons invariant, spectral flow, the Rho invariant and Reidemeister torsion. For mapping tori, the Witten Reshetikhin-Turaev invariants can also be defined as the characters of representations of central extensions of the mapping class group, constructed using the machinery of geometric Kähler quantization applied to the moduli space of flat connections on a surface. I will present new results on the expansion for finite order mapping tori, whose leading order terms we identified with classical topological invariants. (Received September 22, 2011)

1077-57-2413 **John A Baldwin*** (baldwinj@math.princeton.edu), Department of Mathematics, Fine Hall, Washington Road, Princeton, NJ 08544-1000. *Grid diagrams and the spectral sequence from Khovanov to Heegaard Floer homology.*

For a link L in the 3-sphere, Ozsvath and Szabo define a spectral sequence whose E_2 term is the reduced Khovanov homology of L and which converges to the Heegaard Floer homology the double cover of 3-sphere branched along L. There are two known ways of computing the higher terms in this spectral sequence - one uses bordered Floer homology and the other uses a link surgeries formula discovered by Manolescu and Ozsvath. I'll discuss a conceptually much simpler way of computing these higher terms using grid-like diagrams and will talk about potential applications. (Received September 22, 2011)

1077-57-2615 **Christopher K Atkinson*** (ckatkin@temple.edu), Wachman Hall, 1805 N. Broad St., Temple University, Philadelphia, PA 19122, and **David Futer** (dfuter@temple.edu), Wachman Hall, 1805 N. Broad St., Temple University, Philadelphia, PA 19122. *Small volume link orbifolds.* Preliminary report.

We will discuss recent investigations of small volume hyperbolic 3–orbifolds with singular locus a link. In the special case where the singular locus is a knot in the 3–sphere, we identify the smallest volume example. We will also describe more general results on lower volume bounds for hyperbolic 3–orbifolds with singular locus a link and identify the smallest volume example in certain cases. (Received September 22, 2011)

1077-57-2806 **Jeffrey Boerner*** (boernej@westminster.edu). *The sl(3) skein module.*
Skein modules of surfaces that are related to Khovanov homology have been explored in some detail by Asaeda, Frohman, and Kaiser. These skein modules are established by the relationship between the Frobenius algebra associated to Khovanov homology and TQFTs. Khovanov describes another link homology, sl(3) link homology, in terms of surfaces but there is not an underlying Frobenius algebra. Despite the absence of a Frobenius algebra, we are able to define the sl(3) skein module and explore the sl(3) skein module of certain 3-manifolds. (Received September 22, 2011)

1077-57-2910 **Jaejeong Lee** and **Kei Nakamura*** (nakamura@math.temple.edu), Department of Mathematics, Wachman Hall, 1805 N. Broad Street, Temple University, Philadelphia, PA 19106. *On convex and non-convex Fuchsian polyhedral realizations of hyperbolic surfaces with a single conical singularity.*
For a hyperbolic surface S with genus $g \geq 2$ and with some conical singularities of positive curvatures, its Fuchsian polyhedral realization is an incompressible isometric embedding of S in a Fuchsian cylinder $\mathbb{H}^3/\Gamma$ for some Fuchsian group Γ with genus g such that the image is a piecewise totally geodesic polyhedral surface. It is known by a theorem of Fillastre that, for any such S, there exists a unique convex Fuchsian polyhedral realization. We will describe the geometry of convex and non-convex Fuchsian polyhedral realizations when S has a single conical singularity, and show that the convex case indeed corresponds to the Delaunay triangulation of S. (Received September 23, 2011)

1077-57-2952 **Alexander M Zupan*** (alexander-zupan@uiowa.edu), 14 MacLean Hall, University of Iowa, Iowa City, IA 52242. *Paths in the pants complex and bridge splittings of knots.*
Recently, Jesse Johnson used paths in the pants complex of a Heegaard surface to define new invariants of a 3-manifold. Analogously, we demonstrate that a bridge splitting of a knot in a 3-manifold gives rise to paths in the pants complex of the bridge surface. These paths serve several purposes: they can be utilized to construct new knot invariants and carry information about the geometry of hyperbolic knots. (Received September 23, 2011)

58 ► Global analysis, analysis on manifolds

1077-58-89 **Eileen R Martin*** (emartin@mail.utexas.edu), **Ryan Hotovy** (ryan.hotovy@gmail.com) and **Daniel Freeman** (freeman@math.utexas.edu). *Global coordinate systems on manifolds lacking continuously moving bases.* Preliminary report.
In differential topology, it can be very useful to have a basis for the tangent space of a smooth manifold which varies continuously over the manifold. However, most manifolds do not have a continuously moving bases for their tangent space. In the absence of a moving basis, we propose to study continuously moving finite unit-norm tight frames (FUNTFs). These serve as a useful generalization of bases, and yet they exist on a larger class of manifolds. We investigate properties of manifolds that lead to the existence of FUNTFs and present results related to the minimum number of vectors needed to create FUNTFs on certain classes of manifolds including vector bundles on the circle and the tangent space of n-spheres. Further, we present a new numerical application of FUNTFs. (Received July 25, 2011)

1077-58-1102 **Swanhild Bernstein**, **Svend Ebert** and **Isaac Z. Pesenson*** (pesenson@temple.edu). *Splines for Radon transform on compact Lie groups with application to $SO(3)$.*
The Radon transform $\mathcal{R}f$ of functions f on $SO(3)$ has recently been applied extensively in texture analysis, i.e. the analysis of preferred crystallographic orientation. In practice one has to determine the orientation probability density function $f \in L_2(SO(3))$ from $\mathcal{R}f \in L_2(S^2 \times S^2)$ which is known only on a discrete set of points. Since one has only partial information about $\mathcal{R}f$ the inversion of the Radon transform becomes an ill-posed inverse problem.

Motivated by this problem we consider the Radon transform $\mathcal{R}f$ of functions f on general compact Lie groups and develop an approximate inversion algorithm. Our inversion is based on the interpolation of $\mathcal{R}f$ using its values on a discrete set of points. The interpolant is constructed as a minimizer of a certain Sobolev norm.

Our new algorithm fits very well to the application of Radon transform on $SO(3)$ to texture analysis.

This research was supported in part by the National Geospatial-Intelligence Agency University Research Initiative (NURI), grant HM1582-08-1-0019. (Received September 19, 2011)

1077-58-1138 **Michael Wolf*** (mwolf@rice.edu) and **David Dumas**. *Polynomial Pick forms for affine spheres and real projective polygons.* Preliminary report.

(Joint work with David Dumas.) Convex real projective structures on surfaces, corresponding to discrete surface group representations into SL(3, R), have associated to them affine spheres which project to the convex hull of their universal covers. Such an affine sphere is determined by its Pick (cubic) differential and an associated Blaschke metric. As a sequence of convex projective structures leaves all compacta in its deformation space, a subclass of the limits is described by polynomial cubic differentials on affine spheres which are conformally the complex plane. We show that those particular affine spheres project to polygons; along the way, a strong estimate on asymptotics is found. We will carefully describe the background material. (Received September 16, 2011)

1077-58-1528 **Tomoyuki Kakehi*** (kakehi@math.okayama-u.ac.jp), Department of Mathematics, Okayama University, Okayama, 700-8530, Japan. *Schroedinger equation on certain compact symmetric spaces.*

The support of the fundamental solution to the Schroedinger equation corresponding to a free particle on a compact symmetric space with even multiplicities becomes a lower dimensional subset at a rational time, whereas its support and singular support coincide with the whole symmetric space at an irrational time. In this talk I will provide some new insights and partial results into additional problems related to the above result. (Received September 20, 2011)

1077-58-1928 **Matthew B. Stenzel*** (stenzel.3@osu.edu), Ohio State University at Newark, 1179 University Drive, Newark, OH 43055. *A proof of a Theorem of Boutet de Monvel.* Preliminary report.

We use the transgression formula and the Laplace transform to obtain the Hadamard-Zelditch parametrix for the Poisson operator on a compact, real analytic Riemannian manifold, X, starting from the heat kernel. We use this to prove the Theorem of Boutet de Monvel which says that the operator $e^{-t\sqrt{\Delta}}$ followed by analytic continuation to a Grauert tube M_t of radius t, is a continuous bijection of the Sobolov spaces, $e^{-t\sqrt{\Delta}}\colon H^s(X) \to \mathcal{O}^{s+\frac{n-1}{4}}(\partial M_t)$. As an application we discuss an L^2-isometry theorem reminiscent of the Segal-Bargmann transform on a compact Lie group. (Received September 21, 2011)

1077-58-2005 **Seunghun Hong*** (hong@math.psu.edu), Department of Mathematics, Pennsylvania State University, University Park, PA 16802. *A Lie-Algebraic Approach to the Local Index Theorem on a Flag Variety.*

Let G be a compact Lie group and let T be a maximal torus in G (more generally we could consider any connected closed subgroup). Using a K-theory point of view, Bott related the Atiyah-Singer index theorem for elliptic operators on G/T to the Weyl character formula. In this talk we shall explain how to prove the *local* index theorem on G/T using Lie algebra methods. Our method follows in outline the proof of the local index theorem due to Berline and Vergne. But our use of Kostant's cubic Dirac operator in place of the Riemannian Dirac operator leads to substantial simplifications. An important role is also played by the quantum Weil algebra of Alekseev and Meinrenken. (Received September 21, 2011)

1077-58-2141 **Brett J. Pansano***, 4155 N. Valley Lake Dr. #6, Fayetteville, AR 72703, and **John A. Ryan** (jryan@uark.edu), Department of Mathematics, 301 SCEN - 1 University of Arkansas, Fayetteville, AR 72701. *Analytical Properties of the Conformal Dirac Operator on the Unit Sphere.* Preliminary report.

In this paper we develop tools to study the index of the conformal Dirac operator on the sphere. Using the heat equation approach to index theory we shall introduce the heat operator acting on sections of a Clifford bundle over the sphere. Basic properties of this operator are examined, in particular we examine the links to Clifford analysis on the sphere and Sobolev spaces. (Received September 21, 2011)

1077-58-2822 **Alexander Teplyaev*** (teplyaev@uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269-3009. *Derivatives on Fractals.* Preliminary report.

A Laplacian on fractals can be defined either as the generator of a diffusion process (Kusuoka, Barlow, Bass, Perkins, Lindstrom, Kumagai, Hambly et al) or as a re-normalized limit of graph Laplacians (Kigami, Strichartz et al). However, it is less clear how to define first order derivatives (different approaches were introduced earlier by Kusuoka, Kigami, Strichartz and the presenter). In the talk, based on joint work with Michael Hinz, Marius Ionecu, Luke Rogers and Dan Kelleher, I will describe recent progress toward better understanding of the derivatives and related notions of differential and Riemannian geometries on fractals. (Received September 22, 2011)

1077-58-2850 **Rebecca E Field*** (fieldre@math.jmu.edu), MSC 1911, James Madison University, Harrisonburg, VA 22807. *$MU(BG_2)$, $CH(BG_2)$, and descent.*

We use the descent spectral sequence to compute the complex oriented cohomology of the classifying space for the exceptional group G_2. This gives it as a quotient of the image of $BSpin_7$ in BSO_7. If time permits, I will explain how this enables one to compute the Chow groups of BG_2, even though the descent spectral sequence fails for higher Chow groups (as there are no Nisnevich sections for the fibrations we use). (Received September 22, 2011)

1077-58-2931 **Marlio Paredes*** (maparedes@suagm.edu), School of Science and Technology, Universidad del Turabo, P.O Box 3030, Gurabo, PR 00777-3030. *Cosymplectic Metrics on Flag Manifolds and Partial Differential Equations.*

Using moving frames we obtain a formula to calculate the codifferential of the Kähler form on a maximal flag manifold. We use this formula to prove that a metric on a classical maximal flag manifold is cosymplectic if satisfies a partial differential equation. (Received September 23, 2011)

60 ► Probability theory and stochastic processes

1077-60-168 **Linda J.S. Allen** and **Sukhitha W Vidurupola*** (sukhitha.vidurupola@ttu.edu). *Basic Stochastic Models for Viral Infection Within a Host.* Preliminary report.

Two new stochastic models are formulated for intra-host viral and cellular dynamics. The deterministic skeleton of the stochastic models is a system of four ordinary differential equations (ODEs) for healthy, latently infected and actively infected target cells and free viral particles. The two stochastic models are Itô stochastic differential equations (SDEs) that differ in how viruses are released from an infected cell, either through budding from the cell membrane or through cell lysis in a burst of viral particles. Application of multivariate Itô's formula to the forward Kolmogorov differential equation for the joint distribution of the stochastic models leads to an infinite system of differential equations for the moments of the distribution. Under the assumption of normality, the system of differential equations for the moments forms a closed system that can be solved numerically. Numerical examples illustrate the dynamics of the ODE and SDE models. (Received August 05, 2011)

1077-60-247 **Cristina Tone*** (cristina.tone@louisville.edu), 328 Natural Sciences Building, University of Louisville, Louisville, KY 40292. *A Functional Central Limit Theorem for Empirical Processes.*

We introduce a functional central limit theorem for empirical processes endowed with real values from a strictly stationary random field satisfying an interlaced mixing condition. We proceed by using a common technique from Billingsley (1999), by first obtaining the limit theorem for the uniformly distributed case. We then generalize the result to the case where the absolutely continuous marginal distribution function is no longer uniform. In this case we show that the empirical process endowed with values from the ρ'-mixing stationary random field, due to the strong mixing condition, doesn't converge in distribution to a Brownian bridge, but to a continuous Gaussian process with mean zero and the covariance given by the limit of the covariance of the empirical process. (Received August 16, 2011)

1077-60-272 **Qi He*** (qhe@wayne.edu), 656 W.Kirby St, Fab 1256, Detroit, MI 48201, and **George Yin** and **Qing Zhang**. *Large Deviations for Two-Time-Scale Systems Driven by Nonhomogeneous Markov Chains and Associated Optimal Control Problems.*

This presentation deals with the large deviations principles for systems driven by a continuous-time Markov chain with two-time scales and related optimal control problems. A main characteristic of our setup is the Markov chain is time inhomogeneous. The use of two-time-scale formulation stems from our effort of reducing computational complexity in a wide variety of applications in control, optimization, and systems theory. Starting with a rapidly fluctuating Markov chain, under irreducibility conditions, we derive both large deviations upper and lower bounds first for a fixed terminal time and then for time-varying dynamic systems. Finally we present an example of application of this result in controlled dynamic systems. (Received August 17, 2011)

1077-60-330 **G. Yin** and **Yu Sun*** (ysun@wayne.edu), Department of Mathematics, 1150 Faculty/Administration Building, 656 W. Kirby, Detroit, MI 48202, and **Le Yi Wang**. *Asymptotic Properties of Consensus-Type Algorithms for Networked Systems with Regime-Switching Topologies.*

In this talk, we consider asymptotic properties of consensus-type algorithms for networked systems whose topologies switch randomly. The regime-switching process is modeled as a Markov chain. The consensus control is achieved by using algorithms of stochastic approximation type. In the setup, the regime-switching process (the Markov chain) contains a rate parameter ϵ in the transition probability matrix that characterizes how frequently the topology switches. Meanwhile, the consensus control algorithm utilizes a stepsize μ that defines how fast the network states are updated. Depending on their relative values, three distinct scenarios emerge. Under suitable conditions, we treat each of the cases. Simulation results are also presented. This is a joint work with G. Yin and Le Yi Wang (WSU). (Received August 22, 2011)

1077-60-414 **Pao-Liu Chow*** (plchow@math.wayne.edu), Department of Mathematics, Wayne State University, Detroit, MI 48202. *Stationary Solutions of Parabolic Equations in Gauss-Sobolev Space.*

The talk is concerned with a class of parabolic equations related to some stochastic evolution equation in a Hilbert space H with a unique Gaussian invariant measure μ. They consist of Kolmogorov type of equations perturbed by a linear or nonlinear term. Let $\mathbf{V}$ denote the Gauss-Sobolev space of functions on H whose first devatives are square-integrable with respect to μ. In the Sobolev space setting, under suitable conditions, the Cauchy problem for the parabolic equation has a unique solution in $\mathbf{V}$ in a variational sense. It will be shown that, as the time t tends to infinity, the solution converges to a stationary solution which is a mild solution of the reduced elliptic equation. Some analytical questions about the solutions of the elliptic problem will also be discussed. (Received August 30, 2011)

1077-60-443 **Martial Longla*** (martiala@mail.uc.edu), 203 Erkenbrecher ave, Apt. 2, Cincinnati, OH 45229, and **Magda Peligrad**. *Some aspects of modelling dependence in copula based Markov Chains.*

Dependence coefficients have been widely studied for Markov processes defined by a set of transition probabilities and an initial distribution. This work clarifies some aspects of the theory of dependence structure of Markov chains generated by copulas that are useful in time series econometrics and other applied fields. The main aim of this paper is to clarify the relationship between the notions of geometric ergodicity and geometric ρ-mixing; namely, to point out that for a large number of well known copulas, such as Clayton, Gumbel or Student, these notions are equivalent. Some of the results published in the last years appear to be redundant if one takes into account this fact. We apply this equivalence to show that any mixture of Clayton, Gumbel or Student copulas generate both geometrically ergodic and geometric ρ-mixing stationary Markov chains, answering in this way an open question. We shall also show that a sufficient condition for ρ-mixing, used in the literature, actually implies Doeblin recurrence. We also provide a new set of theorems to check geometric ergodicity and exponential ρ-mixing for copula-based Markov chains. These rates are important for the derivation of limit theorems, inference and confidence intervals in large sample studies. (Received September 01, 2011)

1077-60-555 **Richard Durrett***, Box 90320, Durham, NC 27708-0320, and **Kaveh Danesh**, **Laura Havrilesky** and **Evan Myers**. *Branching Process Models of Ovarian Cancer Progression.* Preliminary report.

Ovarian cancer is the fifth leading cause of cancer death among women in the United States with 21,800 new cases and 13,850 deaths in 2010. 75% of women have metastasized disease at the time of diagnosis and five year survival rate of less than 30%. In order to evaluate the effectiveness of proposed screening strategies in silico we have developed a multitype branching process model of ovarian cancer and calibrated the model by comparing its predictions with published studies and the SEER data base. (Received September 07, 2011)

1077-60-595 **C. Y. Zhang***, Department of Mathematical Sciences, Xi'an Jiaotong-Liverpool University, Suzhou, Jiangsu 215123, Peoples Rep of China. *Rate of Convergence of Weak Euler Approximation for Nondegenerate Itô Diffusion and Jump Processes.*

The paper studies the rate of convergence of the weak Euler approximation for Markov processes with Hölder-continuous generators. The main part of the jump intensity measure has a nondegenerate density with respect to the Lévy measure of a spherically-symmetric stable process. It covers a variety of stochastic processes including the nondegenerate diffusions and a class of SDEs driven by spherically-symmetric stable processes. To estimate the rate of convergence of the weak Euler approximation, the existence of a unique solution to the corresponding backward Kolmogorov equation in Hölder space is first proved. It then shows that the Euler scheme yields positive weak order of convergence. (Received September 08, 2011)

1077-60-606 **Maria C.A. Leite*** (Maria.Leite@utoledo.edu), **Nikola P. Petrov .Petrov** and **Ensheng Weng Weng**. *Stationary distributions of semistochastic processes with disturbances at random times and with random severity.*

We consider a semistochastic continuous-time continuous-state space random process that undergoes downward disturbances with random severity occurring at random times. Between two consecutive disturbances the evolution is deterministic, given by an autonomous ordinary differential equation. The times of occurrence of the disturbances are distributed according to a general renewal process and at each disturbance the process gets multiplied by a continuous random variable (severity). The inter-disturbance time intervals and the severities are assumed to be independent random variables that also do not depend on the history. I will discuss, in the context of carbon content of an ecosystem, the derivation of explicit expressions for the conditional density connecting two consecutive post-disturbance levels and for the stationary distribution of the random process. (Received September 08, 2011)

1077-60-609 **Gregory F Lawler*** (lawler@math.uchicago.edu), Department of Mathematics, University of Chicago, 5734 University Ave., Chicago, IL 60637-1546. *Fractal properties of the Schramm-Loewner evolution.*

In his book Fractal Geometry of Nature, Benoit Mandelbrot observed that the outer boundary of random walks looked very similar to self-avoiding random walks. This was one of the first observations of a beautiful phenomenon that occurs in certain two-dimensional systems. The mathematical object in the continuum limit, which was discovered later, is now known as the Schramm-Loewner evolution (SLE). Many nontrivial facts about the fractal and multifractal behavior of these random curves can be proved. I will give a survey of these results. (Received September 08, 2011)

1077-60-648 **Steven C McKelvey*** (mckelvey@stolaf.edu), St. Olaf College, 1520 St. Olaf Ave., Northfield, MN 55057, and **Frank H Koch**, **William D Smith** and **Kelly R Hawley**. *A Bayesian Model Identifying Locations At Risk From Human-Transported Exotic Pathogens.*

A two-phase Bayesian model is presented for updating risk assessments for locations susceptible to infection by exotic pathogens. Human transportation from previously infected regions to uninfected regions is the main dispersal mechanism. Information embedded in patterns within the transportation flow are exploited in the update process. We explore the sensitivity of the model's outputs to changes in inputs. A sample application of the model to sudden oak death, using fictitious infection data, is performed. (Received September 09, 2011)

1077-60-695 **Fariborz Asadian*** (asadianf@fvsu.edu), Fort Valley State University, 1005 State University Drive, Department of Mathematics & Computer Science, Fort Valley, GA 31030. *Smooth Measures and Stochastic Analysis in Abstract Wiener Space.*

In this talk, we discuss smoothness properties of measures (in the sense of Fomin) generated by solutions of infinite dimensional stochastic differential equations driven by a Wiener process in a separable Banach space. We consider ordinary stochastic equations as well as semi-linear equations with drift coefficients containing unbounded terms. The main tool used in this investigation is the infinite dimensional version of Girsanov Theorem. The results obtained will be applied to explore regularity properties of the solutions of infinite dimensional forward parabolic equations. (Received September 10, 2011)

1077-60-746 **Brian M. Whitehead*** (whiteheadb@easternct.edu). *Occupation Times for Stable-like Processes.*

We consider a class of pure jump Markov processes in Euclidean space whose jump kernels are comparable to those of symmetric stable processes. It can be shown that a support theorem holds, as well as a lower bound on the occupation times of sets. (Received September 12, 2011)

1077-60-786 **Nicholas M. Ercolani** and **Virgil U. Pierce***, piercevu@utpa.edu. *Random matrix methods for the enumeration of 3-valent maps.*

The partition function of $N \times N$ hermitian random matrices has a natural interpretation in terms of a tau-function for the Toda lattice hierarchy. They also satisfy a sequence of discrete equations, the so-called string equations. Continuum limits of both the Toda hierarchy and string equations induce equations governing the behavior of the terms in the asymptotic expansion of partition functions. These terms are also generating functions for the enumeration of maps (or ribbon graphs) partitioned by their genus. We have recently carried out this procedure in the case of maps with vertices of degree 3. This is an important sub case, not covered in previous work, which corresponds to stable maps. Results include closed form expressions for the low genus terms in terms of an auxiliary variable with an interesting combinatoric meaning. Results agree with the work of Bleher and Deaño. (Received September 12, 2011)

1077-60-808 **Yuh-Jia Lee*** (yjlee@nuk.edu.tw), 700, Kaohsiung University Rd., Kaohsiung, 811, Taiwan. *The Clark Formula of Generalized Lévy Functionals.* Preliminary report.

In this talk, we formulate the Clark formula for generalized Lévy functionals via white noise analysis. It is shown that the S-transform SF of a generalized Lévy functionals F satisfies the following formula

$$SF(\eta) = \mathbb{E}[F] + \int_0^1 \frac{d}{dt}\, SF(P_t(\eta))dt,$$

where, for $t \in \mathbb{R}$ and $h \in L^2_c(\mathbb{R}^2, \lambda)$, $P_t(h) = h \cdot 1_{(-\infty,t]\times\mathbb{R}}$ and $\mathbb{E}[\cdot]$ denote the generalized expectation. Then the Clark formula is obtain immediately by taking the inverse S-transform. (Received September 13, 2011)

1077-60-898 **Murad S. Taqqu*** (murad@bu.edu), Department of Mathematics and Statistics, 111 Cummington St., Boston, MA 02215. *The Weierstrass function and Fractional Brownian motion.*

Benoit Mandelbrot suggested that Weierstrass' nowhere differentiable function can be modified and randomized so as to approximate fractional Brownian motion, which is a Gaussian self-similar process whose paths are almost surely non-differentiable. The randomization involves introducing independent and identically distributed random variables with finite variance in the definition of the Weierstrass function. We will show how one then obtains fractional Brownian motion in the limit.

If time allows we will describe various modifications and indicate what happens if, for example, one introduces in the above randomization strongly dependent random variables instead of independent ones or if one uses infinite variance random variables instead of finite variance ones.

This is joint work with Vladas Pipiras. (Received September 14, 2011)

1077-60-915 **Fariborz Asadian*** (asadianf@fvsu.edu), Fort Valley State University, Department of Mathematics & Computer Science, 1005 State University Drive, Fort Valley, GA 31030. *Stochastic Differential Equations of the Wick Type.* Preliminary report.

In this talk, we will present the properties of the Wick product and formulate the laws of Wick calculus in the context of an abstract Wiener space. Properties of Wick product will be applied to investigate infinite dimensional stochastic differential equations of the Wick type. Some examples of these types of equation will be discussed. (Received September 14, 2011)

1077-60-952 **Naotaka Kajino*** (nkajino@math.uni-bielefeld.de), Department of Mathematics, University of Bielefeld, Postfach 10 01 31, 33501 Bielefeld, Germany. *On-diagonal oscillation of the heat kernels on p.c.f. self-similar fractals.*

It is a general belief that the heat kernels on fractals should exhibit highly oscillatory behaviors. For example, on a class of finitely ramified fractals, called (affine) nested fractals, a canonical *"Brownian motion"* has been constructed and its transition density (heat kernel) $p_t(x, y)$ satisfies

$$c_1 \le t^{d_s/2} p_t(x, x) \le c_2, \qquad t \in (0, 1]$$

for any point x of the fractal; here $c_1, c_2 \in (0,\infty)$ are some constants and d_s is called the spectral dimension. Then it is natural to ask whether the limit

$$\lim_{t\downarrow 0} t^{d_s/2} p_t(x, x)$$

exists or not, and it is conjectured NOT to exist by many people.

In this talk, we will present partial affirmative answers to this conjecture. First, for a general (affine) nested fractal, the non-existence of the limit $\lim_{t\downarrow 0} t^{d_s/2} p_t(x, x)$ is shown to be true for a "generic" (in particular, almost every) point x. Secondly, the same is shown to be valid for ANY point x of the fractal in the particular cases of the d-dimensional standard Sierpinski gasket with $d \ge 2$ and of the N-polygasket with $N \ge 3$ odd, e.g. the pentagasket ($N = 5$) and the heptagasket ($N = 7$). (Received September 14, 2011)

1077-60-1001 **Liang Zhang***, JWB129 155 S 1400 E, Salt Lake City, UT 84108. *Packing dimension of images of additive Lévy processes.*

For an N-parameter additive Lévy process $\{X(t)\}_{t\in\mathbb{R}^N_+}$, we generalize the packing dimension profile defined by Khoshnevisan, Schilling, and Xiao to high dimensions and use it to compute the packing dimension of images of the process X. In particular, we find that for any bounded Borel set $F \subset \mathbb{R}^N_+$, with probability one, the packing dimension of the random set $X(F)$ equals the packing dimension profile of F. Our results also yield a probabilistic interpretation of many of the packing dimension profiles defined by Falconer and Howroyd in the study of orthogonal projections. (Received September 15, 2011)

1077-60-1003 **Janusz S Golec*** (golec@fordham.edu), Department of Mathematics, Fordham University, Bronx, NY 10458. *Stability properties of stochastic logistic models.* Preliminary report.

The standard logistic model can be generalized to various stochastic versions. We consider stability properties of such generalizations. In particular, systems with a delay and reflected systems will be considered. (Received September 15, 2011)

1077-60-1064 **Andrzej Korzeniowski*** (korzeniowski@uta.edu), Department of Mathematics, University of Texas at Arlington, P.O. Box 19408, Arlington, TX 76019. *Diffusions switched by Markov chains.* Preliminary report.

We consider hybrid geometric Brownian motion whose drift and diffusion coefficients depend on continuous-time, N-state Markov chain. Unlike typical Markov state space $\{1, 2, ..., N\}$, the states are represented by unit vectors in N dimensions. This allows for a unified approach in treating the hybrid system dynamics through a stochastic process having both continuous and jump components - subject to generalized Ito formula for noncontinuous semimartingales. Solution representation for a class of the underlying SDE's and applications to optimal stopping will be discussed. (Received September 15, 2011)

1077-60-1065 **Henri Schurz*** (hschurz@math.siu.edu), Department of Mathematics, MC4408, Southern Illinois University (SIU-C), 1245 Lincoln Drive, Carbondale, IL 62901. *Qualitative Analysis of Stochastic Theta Methods for SDEs.*

The families of balanced inner and outer Theta methods for the numerical integration of stochastic differential equations are presented. We review several qualitative features of those numerical methods: consistency, stability, convergence, positivity, oscillations, contractivity and its correct replication of total energy. (Received September 15, 2011)

1077-60-1100 **Alexei Borodin*** (borodin@math.mit.edu), Department of Mathematics, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139. *Integrability of random growth models.*

The goal of the talk is to survey recent progress in understanding large time asymptotics of certain growth models, including exclusion processes and directed polymers in one space dimension, achieved via a remarkable connection to representation theory and integrable systems. (Received September 16, 2011)

1077-60-1103 **Steven A Bleiler*** (bleilers@pdx.edu), Fariborz Maseeh Dept. Of Math and Stat, Portland State University, P.O. Box 751, Portland, OR 97207-0751, and **Thomas R Fielden**. *The NW Power Conservation Council's Regional Portfolio Model and the R-tic PHOX computation environment – Overview.* Preliminary report.

The R-tic PHOX computation environment was developed as an alternative to sampling based methods for uncertainty, sensitivity, and risk analysis of certain models. At the time, these were models of regulatory regimes for carbon abatement under consideration by the California Air Resources Board under California AB32. While limited to a certain class of models, the environment is independent of application, and is now being put to use regarding the NW Power Conservation Council's Regional Portfolio Model. This model describes the behavior of the power generation, transmission, and conservation for the states of Oregon, Washington, Idaho, and Montana and uses statistical distributions to describe hourly behavior over a multi-year time frame. In an effort to address both the "clusters and gaps" of randomly sampled inputs and "histogram binning problem" over the outputs of sampling based methods, this model is in the process of being incorporated into the R-tic PHOX environment. This talk will overview some of the mathematical issues involved. (Received September 16, 2011)

1077-60-1105 **Steven A Bleiler*** (bleilers@pdx.edu), Fariborz Maseeh Dept. of Math and Stat, Portland State University, P.O. Box 751, Portland, OR 97207-0751, and **Thomas R Fielden**. *Optimization under Uncertainty and Algorithmic Correlation of Random Variables – Theory.* Preliminary report.

Many algorithms (e.g. linear programming) are well understood when the inputs are sharp. An entirely different situation arises when inputs are replaced with random variables. In these situations Monte Carlo and other sampling based methods are typically employed for uncertainty, sensitivity, and risk analyses. Recent advances in the theory of how certain algorithms (including linear programming) induce correlations among the intermediate and terminal model variables produced as the algorithm proceeds now allow an alternative approach. In this approach random variables are represented directly (i.e. without sampling) and outputs appear as similarly represented random variables. This development avoids both the "clusters and gaps" of randomly sampled inputs and "histogram binning problem" over the outputs that are hallmarks of sampling based methods. (Received September 16, 2011)

1077-60-1169 **Marco Bertola*** (bertola@mathstat.concordia.ca), 1455 de Maisonneuve St. W, Montreal, QC H3G 1M8, Canada, and **Mattia Cafasso** (cafasso@math.univ-angers.fr), H3G 1M8 Angers, France. *The Riemann–Hilbert approach to the gap probabilities in multi-time random point processes of Airy and Pearcey type.*

In the general framework of random determinantal point processes the main object of interest are the "gap probabilities", namely, the probability that no particles are found in subsets of the configuration space at certain times. It is a common denominator that these probabilities are expressed in terms of Fredholm determinants of matrix-valued kernels. A general theory developed in the nineties by Its, Izergin, Korepin and Slavnov shows how to naturally associate a Riemann-Hilbert problem to the construction of the resolvent operator of the kernel, which is used then to derive variational formulas for the determinant (probabilities) using Jacobi formula, and ultimately derive a set of ODEs or PDEs in the relevant parameters. The theory only applies to kernel of a special form, which is not the one in which the Pearcey and Airy kernels (scaling limits of the Dyson process, i.e. random eigenvalues of matrices undergoing Brownian diffusion) are presented. We show how this can nevertheless be accomplished, paving the way to the use of methods like the nonlinear steepest descent method of Deift and Zhou to analyze asymptotic behaviors of these determinants.

This is a joint work with Mattia Cafasso (Angers, France). (Received September 17, 2011)

1077-60-1191 **John K McSweeney*** (john.mcsweeney80@gmail.com), 1414 Inglis ave, Columbus, OH 43212, and **Lea Popovic**. *Effects of cell division on stochastic intracelluar chemical reaction systems.*

The classical theory of chemical reactions involves setting up systems of (deterministic) ODEs to describe the dynamics of the interacting species, an approach warranted by the fact that the number of molecules involved is typically very large. However, for certain biochemical processes such as gene expression, the numbers are small enough that the randomness inherent in chemical reaction processes can no longer be ignored. Randomness also arises during cell division due to the potentially unbalanced distribution of elements to each daughter cell. In this paper we set up a toy stochastic model to show how the reaction kinetics can interact with the division process to achieve stochastic bistable behavior - where the cell will, at random times, switch abruptly between two states where one chemical species or another is dominant. We exhibit two bistable behaviors that macroscopically loook similar, but have very different causes - one that is driven purely by noise, and the other by small amounts of bias present in the reactions. (Received September 19, 2011)

1077-60-1206 **Jody Trapier Shipp*** (jodytshipp@gmail.com), 4773 Gainsborough Dr, Fairfax, VA 22032. *Mean-reverting pricing models.* Preliminary report.

We examine changes to a standard pricing model used in finance and economics. This model is a mean-reverting (Ornstein-Uhlenbeck) stochastic process where fluctuations in supply and demand occur but a drift pushes the price back towards a mean value, giving rise to a Gaussian price distribution.

Hysteresis refers to memory-dependent or non-reversible effects. For example, an agent may switch their investment position due to a price change but, in the presence of non-zero transaction costs, they will not immediately switch back if the price change reverses. We add hysteretic economic agents to an Ornstein-Uhlenbeck process and numerically simulate the system using the Euler-Maruyama method. We then compare the statistics of Ornstein-Uhlenbeck processes with and without hysteresis-type effects. (Received September 17, 2011)

1077-60-1213 **Seung Yeop Lee*** (duxlee@caltech.edu), 1200 E. California Boulevard, 253 Sloan, MC 253-37, Caltech, Pasadena, CA 91125, and **Nikolai Makarov** (makarov@caltech.edu), 1200 E. California Boulevard, 253 Sloan, MC 253-37, Caltech, Pasadena, CA 91125. *β ensemble on a Jordan curve.* Preliminary report.

We consider Dyson gas over a real analytic Jordan curve for an arbitrary β. This work is a generalization of the papers by Kriecherbauer-Shcherbina (unpublished) and Johansson ('98) which are for the Dyson gas on the real axis. This is a joint work with Nikolai Makarov. (Received September 18, 2011)

1077-60-1243 **John C Wierman*** (wierman@jhu.edu), Dept. of Applied Mathematics & Statistics, 100 Whitehead Hall, Johns Hopkins University, Baltimore, MD 21218. *Percolation threshold bounds derived by the substitution method without a reference lattice.* Preliminary report.

In percolation theory, the clustering behavior in an infinite random lattice graph model is studied. An important quantity is the percolation threshold, often interpreted as a phase transition point, above which infinite clusters form. Past applications of the substitution method used stochastic ordering to derive rigorous upper and lower bounds for the percolation threshold of a lattice graph by comparison with a percolation model on an exactly-solved lattice graph. For a class of dual pairs of graphs, an approach that does not require a reference lattice will be presented. (Received September 18, 2011)

1077-60-1255 **Dan Dumitru Betea*** (dan.betea@caltech.edu), 1200 E California Blvd, Caltech Math 253-37, Pasadena, CA 91125. *Elliptic distributions on 3D Young diagrams, elliptic special functions and elliptic Painleve.* Preliminary report.

We describe bridges between combinatorial (dimer) models and elliptic special functions, focusing on algebraic aspects. We look at elliptically distributed lozenge tilings of a hexagon and nonagon. In the hexagon case, the partition function can be computed leading to elliptic Macmahon identity; in the nonagon case it leads to the elliptic Painleve equation. With hexagonal boundary conditions, the N-point function in the particle interpretation generalizes the GUE distribution in random matrix theory and is related to Rains' multivariate elliptic biorthogonal functions. The process associated to the hexagon can be interpreted in terms of the elliptic difference operators introduced by Rains. In this respect we obtain new processes useful for an exact sampling algorithm from the distribution. The processes are determinantal with Christopher-Darboux-like correlation kernels in terms of elliptic biorthogonal functions that generalize the (Askey and) q-Askey scheme of orthogonal polynomials. With nonagonal boundary conditions, the partition function is a tau function for the elliptic Painleve equation, which follows from certain E_8 symmetries satisfied by the order I elliptic beta integral. Combinatorial interpretations of such symmetries may be given, time permitting. (Received September 18, 2011)

1077-60-1304 **Arnaud Durand*** (arnaud.durand@math.u-psud.fr) and **Stephane Jaffard**. *Multifractal analysis of Lévy fields.*

We are interested in the study of the pointwise regularity of the Lévy fields introduced by T. Mori, which are a very natural extension of Lévy processes to the multivariate setting. We determine their spectrum of singularities, and we show that their Hölder singularity sets satisfy a large intersection property in the sense of K. Falconer. As shown by Mori, these random fields may be written as the sum of a linear drift, a Gaussian component and a jump component, in a way that is similar to the Lévy-Itō decomposition of Lévy processes. While the study of the Gaussian part makes use of standard tools such as entropy bounds, the examination of the jump part calls upon a precise knowledge of the location of its singularities and a description of the size and large intersection properties of the fractal set formed by the points that are approximated at a certain rate by random hyperplanes distributed in a Poissonian way. (Received September 19, 2011)

1077-60-1307 **Mark Burgin** and **Alan Krinik*** (ackrinik@csupomona.edu), 3801 West Temple Avenue, Department of Mathematics and Statistics, Cal Poly Pomona, Pomona, CA 91768, and **David Luu**. *The Gambler's Ruin Problem for a Class of Non-stationary Markov Chains.*

A special type of non-stationary, birth-death Markov chain on a finite state space is shown to have well-defined ruin probabilities along the lines of the classical Gambler's Ruin Problem. Ruin probabilities are calculated for some specific examples of non-stationary Markov chains. This result was originally motivated by considering periodic hyper-probabilities. However, our proof technique makes use of characterizations of strongly ergodic Markov chains as well as results on dual processes. (Received September 19, 2011)

1077-60-1332 **Ambar Niel Sengupta*** (sengupta@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70808. *Free noise stochastics and geometry.*

Recent ideas and results involving a free probability analog of Gaussian white noise in geometric quantum field theories will be presented. (Received September 19, 2011)

1077-60-1336 **Hui-Hsiung Kuo** (kuo@math.lsu.edu), Department of Mathematics, 303 Lockett Hall, Louisiana State University, Baton Rouge, LA 70803, **Anuwat Sae-Tang** (anuwat.sae@kmutt.ac.th), Department of Mathematics, Faculty of Science, King Mongkut's University of Technology, Thonburi, Bangkok, Thailand, and **Benedykt Szozda*** (benny@math.lsu.edu), Department of Mathematics, 303 Lockett Hall, Louisiana State University, Baton Rouge, LA 70803. *New Itô formula with application to linear SDEs with anticipating initial conditions.*

In [1,2] Ayed and Kuo presented a new approach to stochastic integration of a special class of anticipating stochastic processes. Their approach is based on the decomposition of the integrand into the adapted part and instantly independent part, and is an extension of the Itô theory of stochastic integration. In this talk we will present an Itô formula for the new stochastic integral defined by Ayed and Kuo. We will also give a solution of a linear stochastic differential equation with anticipating initial condition of a special form.

References. [1] Ayed, W. and Kuo, H.-H.: An extension of the Itô integral *Communications on Stochastic Analysis* **2** (2008) 323–333.
[2] Ayed, W. and Kuo, H.-H.: An extension of the Itô integral: Toward a general theory of stochastic integration, *Theory of Stochastic Processes* **16**(32) (2010) N1 17-28.
[3] Kuo, H.-H., Sae-Tang, A., and Szozda, B.: A stochastic integral for adapted and instantly independent stochastic processes, *to appear in "Festschrift in honour of Professor Robert Elliott."* (Received September 22, 2011)

1077-60-1376 **Divine T Wanduku*** (dwanduku@mail.usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, PHY, Tampa, FL 33620-5700, and **Gangaram S Ladde** (gladde@usf.edu), Department of Mathematics and Statistics, University of South Florida, 4202 East Fowler Avenue, PHY, Tampa, FL 33620-5700. *Stability of stochastic two-scale network delayed SIR epidemic dynamic model with temporary immunity period.*

Complex population structure and the large-scale inter-patch connection human transportation underlie the recent rapid spread of infectious diseases of humans. Furthermore, the fluctuations in the endemicity of the diseases within patch dwelling populations are closely related with the hereditary features of the infectious agent. We present an SIR delayed stochastic epidemic dynamic process in a two-scale population dynamic structure. The disease confers temporary natural or infection-acquired immunity to recovered individuals. The time delay accounts for the time-lag during which naturally immune individuals become susceptible. We investigate the stochastic asymptotic stability of the disease free equilibrium of the scale structured mobile population, under random environmental fluctuations and the impact on the emergence, propagation and resurgence of the disease. The presented results are demonstrated by numerical simulation results. (Received September 19, 2011)

1077-60-1425 **Hong Yin*** (hyin@brockport.edu), Department of Mathematics, State University of New York, Brockport, NY 14420. *Solvability of Forward-Backward Stochastic Partial Differential Equations.*

In this talk we study the solvability of a class of fully-coupled forward-backward stochastic partial differential equations (FBSPDEs). These FBSPDEs cannot be put into the framework of stochastic evolution equations in general, and the usual decoupling methods for the Markovian forward-backward SDEs are difficult to apply. We prove the well-posedness of the FBSPDEs, under various conditions on the coefficients, by using either the method of contraction mapping or the method of continuation. These conditions, especially in the higher dimensional case, are novel in the literature. Moreover, we show that the usual monotonicity assumption can be removed, in the case of method of continuation, by a change of the diffusion term. (Received September 19, 2011)

1077-60-1431 **P. Sundar***, Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Ergodic control for two-dimensional stochastic Navier-Stokes equations.* Preliminary report.

After a brief introduction to solvability and ergodic behavior of stochastic Navier-Stokes equations, the existence of optimal ergodic controls will be established. A controlled martingale problem with relaxed controls will provide the framework for this study. Further properties of the optimal control will be discussed. (Received September 19, 2011)

1077-60-1446 **Elisabeth Kemajou*** (isakema@siu.edu). *A Stochastic Delay Model for Pricing Corporates Liabilities.*

We consider that the price of a firm follows a non linear stochastic delay differential equation. We also assume that any claim value whose value depends on firm value and time follows a non linear stochastic delay differential equation. Using self-financed strategy and duplication we are able to derive a formula for debt value and loan guarantees of a levered company. Further, we analyze the risk structure in the complete market. (Received September 22, 2011)

1077-60-1461 **Davar Khoshnevisan*** (davar@mah.utah.edu), Department of Mathematics, University of Utah, Salt Lake City, UT 84112. *Correlation-length bounds, and estimates for intermittent islands in parabolic SPDEs.*

We consider the nonlinear stochastic heat equation in one dimension. Under some conditions on the nonlinearity, we show that the “peaks” of the solution are rare. We also provide an upper bound on the length of the “islands”, the regions of large values. These results are obtained by analyzing the *correlation length* of the solution.

This is joint work with Daniel Conus, Mathew Joseph, and Shang-Yuan Shiu. (Received September 19, 2011)

1077-60-1475 **Zhaochi Zhang*** (ztong@otterbein.edu), Department of Mathematics, Northwestern Polytechnical University, Xian, Peoples Rep of China, and **Zengxiang Tong** (ztong@otterbein.edu), Department of Mathematical Sciences, Otterbein University, Westerville, OH 43081. *Target Shooting and Normal Distribution.* Preliminary report.

This presentation will analyze the real life example of target shooting, model it mathematically, and derive a beautiful theorem characterizing normal distribution.

This talk is very valuable for all college instructors and textbook writers of probability theory.

Binomial distribution, Possion distribution, and normal distribution are most important and fundamental distributions in probability theory and statistics. Many textbooks do wonderful jobs in introducing binomial and Possion distributions by (a) Describing real life examples in everyday life leading to these distributions, (b) modeling these examples mathematically, and (3) deriving the probability distribution functions rigorously from the mathematical models. However, almost no book introduce normal distribution from real life examples with rigorous mathematical reasoning. We hope that our presentation provides valuable example and understandable mathematical reasoning, which should be adopted by all calculus-based probability textbooks. (Received September 19, 2011)

1077-60-1484 **Qiang Zhen*** (q.zhen@unf.edu), 1 UNF Dr, Bldg. 14/2731, Jacksonville, FL 32224, and **Charles Knessl**. *On Spectral Properties of Certain Large Matrices That Arise in the Study of Processor Shared Queues.*

We consider sojourn or response times in processor-shared queues that have a finite population of potential users. Computing the response time of a tagged customer involves solving a finite system of linear ODEs. Writing the system in matrix form, we study the eigenvectors and eigenvalues in the limit as the size of the matrix becomes large. This corresponds to finite population models where the total population is $N \gg 1$. Using asymptotic methods we reduce the eigenvalue problem to that of a standard differential equation, such as the Hermite or Airy equation. The dominant eigenvalue leads to the tail of a customer's sojourn time distribution. (Received September 20, 2011)

1077-60-1556 **Bing Li**, **Narn-Rueih Shieh** and **Yimin Xiao*** (xiao@stt.msu.edu), Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824. *Hitting Probabilities and Packing Dimensions of the Random Covering Sets.* Preliminary report.

By applying the method of limsup type random fractals, as illustrated in Khoshnevisan, Peres and Xiao (2000), we determine the hitting probabilities and packing dimensions of the Dvoretzky random covering sets on the circle. Our result also provides an alternative way to obtain the Hausdorff dimensions of such sets, which can be obtain by the mass transference principle of Beresnevich, and S. Velani (2006) and was proved by Durand (2010) in another way recently. (Received September 20, 2011)

1077-60-1561 **Kumer Pial Das*** (kumer.das@lamar.edu), 200 G Lucas Engineering Building, PO Box 10047, Lamar University, Beaumont, TX 77710. *Modeling Healthcare Data Using Markov Decision Process.* Preliminary report.

A Markov decision process (MDP) is a 4-tuple (a set of states, a set of actions, a set of rewards, and a transition probability function). MDPS are used to study a wide range of randomization problems. MDPs find optimal solutions to sequential and stochastic decision problems. An MDP binds previous, current, and future system decisions through the proper definition of system states. The use of MDPs for modeling and solving medical treatment decisions has been increased significantly in recent years. This study gives an overview of MDP models and solution techniques.We describe MDP modeling in the context of healthcare data. (Received September 20, 2011)

1077-60-1659 **Thomas R Fielden*** (tom@tomfielden.com), 615 SW Rustica Ter, Portland, OR 97225, and **Steven A Bleiler**. *Optimization under Uncertainty and Algorithmic Correlation of Random Variables - Practice.*

Building on the discussion of theory, this talk focuses on the numerical environment that allows the replacement of sharp inputs by random variables in certain optimization algorithms. An example of the power of this idea will be demonstrated with a classical elementary resource optimization comparing results under both sharp and random variable inputs. (Received September 20, 2011)

1077-60-1748 **Marina Skyers*** (mas207@lehigh.edu). *Primitive Recursive Representations of "Skorokhod Sequences" for the Standard Normal.*

For $n > 1$ and $0 < x < 1$, $S_n(x) := \sum_{i=1}^{n} R_{n,i}(x)$, with $R_{n,i}(x) := -1^{1+x_i}$, where x_i is the ith dyadic coefficient for x (for dyadic rationals, choose the tail of 0's). With $X_n := \frac{S_n}{\sqrt{n}}$, $(X_n|n > 1)$ converges in distribution to the standard normal on $(0, 1)$ (CLT), but almost sure convergence fails badly. Skorokhod's construction gives $\widetilde{X_n}$ equal in distribution to X_n, such that $\left(\widetilde{X_n}|n > 1\right)$ converges almost surely to the standard normal. With $\widetilde{S_n} := \sqrt{n}\widetilde{X_n}$, we give an explicit computation of $\widetilde{S_n}$ and show that, for some sequences $\widetilde{\mathbf{R}_n} := \left(\widetilde{R_{n,i}}|i = 1, \ldots, n\right)$ of independent random variables taking on values $-1, 1$ with equal probability, and depending only on the first n dyadic coefficients, $\widetilde{S_n} = \sum_{i=1}^{n} \widetilde{R_{n,i}}$. We further show there are many representations of each $\widetilde{\mathbf{R}_n}$ that are close to those for the $(R_{n,i}|i = 1, \ldots, n)$, above. We have isolated a family of such representations that in a suitable sense is uniformly primitive recursive and has other pleasant properties. (Received September 21, 2011)

1077-60-1797 **Son Luu Nguyen*** (snguyen@math.carleton.ca), 1125 Colonel By Drive, Ottawa, Ontario K1S 5B6, Canada, and **George Yin**, 1150 Faculty/Administration Building, 656 W. Kirby, Detroit, MI 48202. *Pathwise Convergence Rate for Numerical Solutions of Stochastic Differential Equations.*

Devoted to numerical solutions of stochastic differential equations (SDEs), this work constructs a sequence of re-embedded numerical solutions having the same distribution as that of the original SDE in a new probability space. It is shown that the re-embedded numerical solutions converge pathwise strongly to the solution of the SDE. Different from the well-known results in numerical solutions of SDEs, in lieu of the usually employed Brownian motion increments in the algorithm, an easily implementable sequence of independent and identically distributed random variables is used. (Received September 21, 2011)

1077-60-1842 **Armando Arciniega*** (armando.arciniega@utsa.edu) and **Edward Allen**. *Shooting Methods for Numerical Solution of Linear and Nonlinear Stochastic Boundary Value Problems.*

Numerical methods are developed for approximate solution of linear and nonlinear stochastic boundary value problems. First, a shooting method procedure is developed for numerically solving linear systems of Stratonovich boundary value problems. Then, the shooting method procedure is described for numerically solving nonlinear stochastic boundary value problems. These stochastic shooting methods are analogous to standard shooting methods for numerical solution of ordinary deterministic boundary value problems. It is shown that the shooting method techniques provide accurate approximations for numerical solution of linear and nonlinear stochastic boundary value problems. Error analyses are performed and computational simulations are described. (Received September 21, 2011)

1077-60-1872 **Jean-Claude Pedjeu*** (jpedjeu@mail.usf.edu), 13287 Arbor Pointe Circle, Apt #203, Tampa, FL 33617-1110, and **G. S. Ladde**. *On Higher Order Stochastic differential equations.*

In real life, mathematical models of several dynamic random processes are influenced by not only their state but also rates of change of states leading to higher (n>1) order linear or nonlinear homogeneous stochastic differential equations. This talk is concerned with finding exact or close form solution processes to such equations. (Received September 21, 2011)

1077-60-1957 **Paul H Bezandry*** (pbezandry@howard.edu), 2441 6th Street, NW, Washington, DC 20059, **Toka Diagana** (tdiagana@howard.edu), 2441 6th Street, NW, Washington, DC 20059, and **Saber Elaydi** (selaydi@trinity.edu), One Trinity Place, San Antonio, TX 78212. *On the Stochastic Beverton-Holt Difference Equation with Survival Rates.*

We consider a stochastic Beverton-Holt difference equation, in which both the recruitment function and the survival rate vary randomly. In this talk we develop a basic theory of mean almost periodic random sequences on $\mathbb{Z}_+$ and provide a method to constructing mean almost periodic random sequences on $\mathbb{Z}_+$. These techniques are, subsequently, used to find some sufficient conditions for the existence and uniqueness of a mean almost periodic solution of the Beverton-Holt equation. (Received September 21, 2011)

1077-60-2072 **Vindya Kumari Pathirana***, Department of Mathematics and Statistics, University of South Florida, 4202 E. Fowler Ave., Tampa, FL 33620, and **Kandethody M Ramachandran**, Department of Mathematics and Statistics, University of South Florida, 4202 E. Fowler Ave., Tampa, FL. *Forecasting Foreign Exchange rates with Simultaneous Nearest Neighbor Algorithm using Mahalanobis Distance as the Distance Measure.* Preliminary report.

Given that exchange rates series exhibit high volatility, it is widely recognized that they are extremely difficult to forecast. Besides, FX data are non-linear and one of the noisiest. Forecasting through non-linear dynamical systems is becoming more and more relevant due to these natures of the data. Nearest Neighbor Algorithms are such most popular non-linear pattern recognition methods that outperform the available linear forecasting methods. Simultaneous nearest neighbor algorithm an extended version of nearest neighbor algorithm that uses a set of simultaneous time series along with real time series. In this paper we suggest to adapt simultaneous nearest neighbor algorithm with Mahalanobis distance to predict highly correlated FX rates. Mahalanobis distance is used due to high correlation between vectors resulting form time series segments. We compare the performance of Mahalanobis distance based algorithm with popular Euclidean and absolute distance based methods. (Received September 21, 2011)

1077-60-2101 **Fernanda Cipriano*** (cipriano@cii.fc.ul.pt), Av. Prof. Gama Pinto, 2, 1649-003 Lisboa, Portugal. *On the 2D Navier-Stokes and Euler equations: A statistical study.*

We present a statistical study for the two dimensional stochastic Navier-Stokes and Euler equations. We prove the existence of weak solutions for the associated Kolmogorov equations. The question of the vanishing viscosity limit is also considered. (Received September 21, 2011)

1077-60-2105 **Iulia Hociota*** (ihociot1@asu.edu), Arizona State University, Tempe, AZ 85287, and **Bruno D Welfert**, Arizona State University, Tempe, AZ 85287. *Stochastic Reduction of an SIR Model.*

The SIR model is often used to simulate the spread of contagious diseases in a given population. The contact rate between susceptible and infected populations plays a critical role in determining the outcome of the disease, yet is rarely known precisely. The contact rate is often defined in an ad-hoc way, such as a superposition of white noise accounting for random population interactions and harmonic terms corresponding to seasonal variations.

In this study we consider contact rates modeled by a Markov process varying on a fast time scale, according to a given transition probability. A direct simulation of the resulting system requires a time discretization consistent with the fast time scale and is not efficient. We present a reduction technique to enable a simulation at a slower time scale by converting information contained in the Markov process to an Ito process over larger time intervals. The main advantage in the new formulation is the scalability of the Ito increments.We illustrate the technique on the propagation of the flu with various types of transition probabilities corresponding to different noise colorings and compare results with existing studies. (Received September 21, 2011)

1077-60-2126 **Yanyan He*** (yhe2@math.fsu.edu), 307 Pennell Circle, Apt. 1, TALLAHASSEE, FL 32310, and **Yousuff Hussaini** and **Jonghoon Bin**. *Uncertainty quantification in the simulation of quasi-one-dimensional nozzle flow.* Preliminary report.

Uncertainty quantification in computational fluid dynamics is crucial due to the inherent variability of the parameters of the physical system and/or an incomplete knowledge of the system embodied in the model. In this presentation, a method is proposed to deal with parametric (aleatory) and model (epistemic) uncertainty in simulations and demonstrated in the case of quasi-one-dimensional flow. Quasi-one-dimensional nozzle problem is a simple example of aerodynamic flows. As this problem possesses an exact exists, it can be used as a test-bed for uncertainty quantification and propagation methods. In a quasi-one-dimensional (convergent-divergent) nozzle shocked flow, the uncertain inlet condition, exit pressure and nozzle geometry impact the shock position. The uncertainty in the shock position is quantified using Dempster-Shafer theory combined with the conventional techniques in probability theory, such as Monte-Carlo method and polynomial chaos. Sensitivity analysis is also carried out to study how the variation of different input parameters affects the uncertainty in the output of our interest. (Received September 21, 2011)

1077-60-2152 **Mark Goldfarb*** (mark.goldfarb@asu.edu) and **Bruno Welfert** (welfert@asu.edu). *Black-Scholes Model with Markov Parameters.*

The price of a stock follows the well known Black-Scholes model:

$$\frac{dS}{S} = \mu dt + \sigma dW_t$$

where $\frac{dS}{S}$ is the relative change of the stock price, μ is the interest rate, σ is the volatility of the stock, and dW_t is a Wiener process with variance dt. While this model generally explains the variability of many stocks, it does not account for rapidly variable rates and volatilities. Several models expand on the Black-Scholes model, including the Heston model (with stochastic volatility) and more recently, the Chen model (with stochastic rate and volatility).

In this study, we capture the connection between the original Black-Scholes model with the rate and volatility defined as Markov models based on transition probabilities with the Heston and Chen models. More specifically, we determine an equivalence between the two formulations. We illustrate the connection between the two approaches with numerical examples. (Received September 21, 2011)

1077-60-2170 **Alan Edelman*** (edelman@math.mit.edu), 77 Mass Ave Room 2-343, Cambridge, MA 02139. *What are the eigenvalues of the sum of two Hermitian matrices? A quantum information inspired answer.*

The purpose of this talk is to bring the excitement of free analysis into applications. Consider eig(A+B) and the connection to eig(A) and eig(B). Free probability tells us mathematically about the infinite n limit under certain circumstances. We describe how joint work with Ramis Movassagh on a quantum information problem has shown us from an applied point of view that one can use the results of free probability in contexts far wider than current mathematics suggest. This talk should be suitable both for experts and those not familiar with free probability. (Received September 21, 2011)

1077-60-2208 **Vince Lyzinski*** (lyzinski@ams.jhu.edu), 306-B Whitehead Hall, Dept. of Applied Mathematics and Statistics, 3400 N. Charles St., Baltimore, MD 21218, and **Anant Godbole** (GODBOLEA@mail.etsu.edu), **Chang Mou Lim** (changmou@math.uchicago.edu) and **Nicholas George Triantafillou** (ngtriant@umich.edu). *Random Additive Bases and Mixed Sidon Sets.*

A set $\mathcal{A} \subseteq [n] \cup \{0\}$ is said to be a 2-additive basis for $[n]$ if each $j \in [n]$ can be written as $j = x+y, x, y \in \mathcal{A}, x \leq y$. If we pick each integer in $[n] \cup \{0\}$ independently with probability $p = p_n \to 0$, thus getting a random set $\mathcal{A}$, what is the probability that we have obtained a 2-additive basis? We can address this question using arithmetic modulo n, or, alter the question so that the target sum-set is $[\frac{n}{2}, \frac{3n}{2}]$ (or $[(1-\alpha)n, (1+\alpha)n]$ for some $0 < \alpha < 1$). Under either model, the Stein-Chen method of Poisson approximation is used to tease out a very sharp threshold for the emergence of a 2-additive basis. Generalizations to 3- and h-additive bases are then given. Finally, we define a class $B_{h,k}$ of Sidon-like sets and derive thresholds for the emergence of these, under the same probability model as before. We do this so as to motivate the notion of (h, k)-additive bases. (Received September 21, 2011)

1077-60-2222 **Mark A Adler*** (adler@brandeis.edu), Brandeis University, Mathematics Department, P.O. Box 9110, Waltham, MA 02454-9110. *Dyson's Brownian Motions and Critical Diffusions.*

We survey critical diffusions relating to Dyson's Brownian motions, from the Airy process to the tacnode process, via both continuous and discrete models. (Received September 21, 2011)

1077-60-2327 **Constantine Georgakis*** (cgeorgak@depaul.edu), Constantine Georgakis, Department of Mathematics, DePaul University, Chicago, IL 60614. *On the Volatility of Binomial Option Pricing Model.* Preliminary report.

The Binomial option pricing model describes the movement of the price of an asset that trades at equally spaced points in time and serves as the discrete analogue of geometric Brownian motion. The model assumes that the price of the asset the end of each trade moves up by a factor u with probability p and down by a factor d with probability 1-p. At the end of n trades the price Y(n) of the asset can be represented by an exponential of a Binomially distributed random variable T(n) with parameters (n, p). An inequality for the volatility of Y(n) that provides sharp upper and lower bounds for the ratio of the variance of Y(n) to the variance of T(n) in terms of the parameters of the model. This inequality carries over to the geometric Brownian motion in the limiting case. (Received September 22, 2011)

1077-60-2405 **Samuel N Stechmann***, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Dr, Madison, WI 53706, and **J David Neelin**. *A stochastic model for tropical rainfall and extreme events.*

Recently it has been discovered that tropical rainfall patterns, on scales of 20-200 km or larger, have statistics that resemble critical phenomena from statistical physics. Through, for instance, the power-law distributions and long-range correlations in these statistics, the characteristics of extreme rainfall events can be quantified.

To gain further insight into these statistics and extreme events, a stochastic model is designed and analyzed to reproduce the statistics that are local in space (and evolving in time). The model includes the interaction of a stochastic jump process and Gaussian processes to represent different aspects of tropical convection, a highly complex system that, if fully resolved, involves nonlinear turbulent interactions of fluid dynamics and moist thermodynamics. The stochastic model can be thought of as a simplified subgrid-scale parameterization of moist convection for atmospheric models with grid spacings of 20-200 km. (Received September 22, 2011)

1077-60-2407 **Habib Ouerdiane*** (habib.ouerdiane@fst.rnu.tn), Faculty of Sciences of Tunis, Campus universitaire, 1060 Tunis, Tunis, Tunisia. *Unitarizing measure for the representation of a Lie group.*

Consider a Lie group with a unitary representation into a space of holomorphic functions defined on a domain $\mathcal{D}$ of C and in $L^2(\mu)$, the measure μ is the unitarizing measure of the representation. On finite dimensional examples, we show that this unitarizing measure is also the invariant measure for some differential operators on $\mathcal{D}$. We calculate these operators and we develop the concepts of unitarizing measure and invariant measure for an *OU operator (differential operator associated to the representation)* in the following elementary cases:
A) The commutative groups $(R, +)$ and $(R^* = R - 0, \times)$.
B) The multiplicative group M of 2×2 complex invertible matrices and some subgroups of M.
C) The three dimensional Heisenberg group.
(Received September 22, 2011)

1077-60-2480 **Robert D Wooster***, Department of Mathematical Sciences, Building 601, West Point, NY 10996. *Numerical methods for stochastic differential equations.*

Stochastic differential equations (SDEs) are used in a variety of applications including population dynamics and finance. With the advances in computing technology over the last several decades, there has been a growing interest in the study of numerical methods for SDEs. In this talk we look at Itô-Taylor schemes, and how they can be applied to stochastic differential equations where the driving stochastic process has jumps. (Received September 22, 2011)

1077-60-2511 **Thomas Albert Laetsch*** (tlaetsch@math.ucsd.edu), 9500 Gilman Dr #0112, La Jolla, CA 92037-0112. *An L^2 metric limit theorem for Wiener measure on manifolds with non-positive sectional curvature.*

An interpretation is given for the informal path integral expression

$$\frac{1}{Z}\int_{\sigma\in H(M)} f(\sigma)e^{-E(\sigma)}\mathcal{D}\sigma,$$

where Z is a "normalization" constant and $H(M)$ is the collection of paths on M with energy $E(\sigma) < \infty$. Given an equally spaced partition, $\mathcal{P}$, of $[0, 1]$, we let $H_{\mathcal{P}}$ be the finite dimensional manifold consisting of piecewise geodesic paths adapted to $\mathcal{P}$, which is given the L^2 metric, G. It is proved that

$$\frac{1}{Z_{\mathcal{P}}}e^{-\frac{1}{2}E(\sigma)}d\,\mathrm{Vol}_G(\sigma) \to \exp\left(-\frac{1}{10}\int_0^1 \mathrm{Scal}(\sigma(s))ds\right)d\nu(\sigma)$$

where $Z_{\mathcal{P}}$ are appropriate normalization constants and ν is the Wiener measure associated to M. (Received September 22, 2011)

1077-60-2523 **Valerio Lucarini*** (valerio.lucarini@zmaw.de), Klimcampus, University of Hamburg, Grindelberg 5, 20144 Hamburg, Hamburg, Germany. *Bistable systems with Stochastic Noise: Virtues and Limits of effective Langevin equations for the Thermohaline Circulation strength.*

The understanding of the statistical properties and of the dynamics of multistable systems is gaining more and more importance in a vast variety of scientific fields. This is especially relevant for the investigation of the tipping points of complex systems. Sometimes, in order to understand the time series of given observables exhibiting bimodal distributions, simple 1D Langevin models are fitted to reproduce the statistical properties, and used to investingate the projected dynamics of the observable. In this paper, we propose a framework for encasing this kind of studies and show, using simple box models of the oceanic circulation and choosing as observable the strength of the thermohaline circulation. We study the statistical properties of the transitions between the two modes of operation of the thermohaline circulation under symmetric boundary forcing and test their agreement with simplified one-dimensional phenomenological theories. We extend our analysis to include stochastic resonance-like amplification processes. We conclude that fitted 1D Langevin models, when closely scrutinised, may result rather ad-hoc. They should be treated with care, more as an empiric descriptive tool than as methodology with predictive power. (Received September 22, 2011)

1077-60-2529 **Jinqiao Duan*** (jduan@ipam.ucla.edu), 460 Portola Plaza, Box 957121, Los Angeles, CA 90095-7121. *Impact of Non-Gaussian Random Boundary Conditions on a Burgers-Boussinesq System.*

Complex systems are sometimes under the influence of environmental fluctuations. To gain understanding of the impact of random boundary conditions on system evolution, a Burgers-Boussinesq fluid system is considered.

A numerical procedure is presented to simulate this system with random Gaussian (Brownian motion) or non-Gaussian ($\alpha-$stable Lévy motion) boundary conditions. To quantify the impact of noise, exit time and their distributions are computed with varying parameters such as noise intensity and α values. Certain dependence of exit time on these parameters are characterized, and some differences in the impact between Gaussian and non-Gaussian noises are observed.

This is a joint work with Shengqiang Xu and Guowei He. (Received September 22, 2011)

1077-60-2532 **Yuriy Mileyko***, Department of Mathematics, Duke University, Box 90320, Durham, NC 27708, and **Sayan Mukherjee** and **John Harer**. *Probability measures on the space of persistence diagrams.*

Persistence diagrams are topological summaries that provide useful information about the topology and geometry of data and play a crucial role in topological data analysis. However, the problem of quantifying the uncertainty, noise, and reproducibility of these topological summaries, which is a fundamental aspect of the classical data analysis, has not been well studied. In this talk, we shall show that the space of persistence diagrams has properties that allow for the definition of probability measures which support expectations, variances, percentiles and conditional probabilities. This provides a theoretical basis for a statistical treatment of persistence diagrams, for example computing sample averages and sample variances of persistence diagrams, and allows us to extend the theory of topological persistence to a much larger set of applications. (Received September 22, 2011)

1077-60-2533 **Yumin Wang*** (wangyumin@umsl.edu), St Louis, MO 63121, and **Zuo Jin** and **George Yin**. *Numerical solutions of quantile hedging for guaranteed minimum death benefits under a regime-switching jump-diffusion formulation.*

This work develops numerical approximation methods for quantile hedging involving mortality components for contingent claims in incomplete markets, in which guaranteed minimum death benefits (GMDBs) could not be perfectly hedged. A regime-switching jump-diffusion model is used to delineate the dynamic system and the hedging function for GMDBs, where the switching is represented by a continuous-time Markov chain. Using Markov chain approximation techniques, a discrete-time controlled Markov chain with two component is constructed. Under simple conditions, the convergence of the approximation to the value function is established. Examples of quantile hedging model for guaranteed minimum death benefits under linear jumps and general jumps are also presented. (Received September 22, 2011)

1077-60-2613 **Matthew R. A. Sedlock*** (msed84@jhu.edu), 100 Whitehead Hall, 3400 North Charles St., Baltimore, MD 21218, and **John C Wierman**. *On the directions for which directional critical exponents are equal in inhomogeneous percolation models.* Preliminary report.

We extend a previous result on the range of directions for which equality of the directional critical exponents β can be established in inhomogeneous percolation models. In particular, we show that by looking at a certain, larger subgraph of the square lattice, we can increase the range of directions for which equality can be shown from a quadrant to a region larger than a quadrant. (Received September 22, 2011)

1077-60-2749 **Jennifer D Herdan*** (jherdan07@winona.edu), 604 Hill St W, St. Joseph, MN 56374, and **Melinda Lanius**. *Encoding and Counting Strings.*

Consider any possible combination of letters and spaces 950 characters long. Did you know you can find this word as a nonconsecutive subsequence of the string of letters that form the novel War and Peace? In this talk, I will discuss the construction of such strings. I will also describe how to find words in larger strings. Specifically, I will discuss an encoding method developed to count these strings. (Received September 22, 2011)

1077-60-2751 **Lee R Gibson** (MathDoctorG@gmail.com) and **Melanie A Pivarski*** (mpivarski@roosevelt.edu). *The rate of decay of the Wiener sausage in a local Dirichlet space.* Preliminary report.

Given a heat kernel diffusion which admits a Gaussian type estimate with parameter b on a local Dirichlet space, we will consider the log asymptotic behavior of the negative exponential moments of the Wiener sausage. We show that the log asymptotic behavior up to time $t^b V(x;t)$ is $V(x;t)$, where $V(x;t)$ represents the mass of the ball of radius t about a point x. This result provides the first such asymptotics for several contexts, including diffusions on complete Riemannian manifolds with non-negative Ricci curvature. (Received September 22, 2011)

1077-60-2953 **James M Haley*** (kapucensko51@comcast.net). *How fed policy makes financial markets chaotic or not.*

A simpler way exists to model the recent financial crisis, as a nonlinear evolution of forecast errors of the real stock return, the forecast errors of inflation, plus the coordination errors of excess bond returns. Specifically, a Sprott system perturbed by noise can be derived by targeting excess demand for real money to be consistent with the Taylor rule, a monetary policy that has failed so far to stabilize financial markets. There is another bifurcation of policy, which guides the economy's search for a rational expectations equilibrium, such that the long-term bond return should be targeted to equal a fixed short-term nominal interest rate of 2%, assuming a zero inflation expectation. This policy peg, unlike the varying interest rate target of the Taylor Rule, makes the forecast errors of the real stock return behave like a Langevin error-correcting, differential equation. This evolution of errors smoothly and quickly converges to a normal density with a bounded variance and a mean of zero. (Received September 23, 2011)

1077-60-2960 **Erin P.J. Pearse*** (ep@ou.edu). *Self-similar fractals as boundaries of networks.*

For a given pcf self-similar fractal, a certain network (weighted graph) is constructed whose ideal boundary is (homeomorphic to) the fractal. This construction is a Representation of a connected self-similar fractal as the boundary of a reversible Markov chain (i.e., a simple random walk on a network), and builds on earlier work of Denker & Sato, Kaimanovich, Kigami, and relates to current work by Lau, Ju, Ngai, and Wang. In this case, however, the network is actually constructed using the iterated function system that defines the original fractal set. The boundary construction is effected using certain functions of finite energy which behave like bump functions on the boundary and which replace the more standard Martin kernels. The simple random walk converges to the boundary almost surely, with respect to the standard measure on its trajectory space. The usual graph energy is a Dirichlet form on the network whose trace to the boundary can be understood as a Dirichlet form on the fractal associated to a certain jump process. (Received September 27, 2011)

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1077-62-13 **Bradley Efron***. *A 250-year argument: Belief, behavior, and the bootstrap.*

The year 2013 marks the 250th anniversary of Bayes rule, one of the two fundamental inferential principles of mathematical statistics. The rule has been influential over the entire period, and controversial over most of it. Its reliance on prior beliefs has been challenged by frequentism, which focuses instead on the behavior of specific estimates and tests under repeated use. Twentieth Century statistics was overwhelmingly behavioristic, especially in applications, but the Twenty-First Century has seen a resurgence of Bayesianism. I will use some simple examples to show what's at stake in the argument. The bootstrap, a computer-intensive inference machine, helps connect Bayesian and frequentist practice. No advanced statistical background is required. (Received April 07, 2011)

1077-62-53 **Raymond N. Greenwell*** (matrng@hofstra.edu), Department of Mathematics, 103 Hofstra University, Hempstead, NY 11549, and **Anna E. Bargagliotti** (abargag@yahoo.com), Department of Mathematics, Loyola Marymount University, Los Angeles, CA 90045. *Combinatorics and statistical issues related to the Kruskal-Wallis statistic.*

We examine combinatoric and statistical questions related to the Kruskal-Wallis statistic. We compare the number of possible combinations of ranks with the number of different column rank sums. There is a closed formula for the former, but not for the latter. We give inequalities that the column rank sums must satisfy, give a closed formula for the special case with 2 columns, and relate the general case to the number of score sequences in tournaments. We indicate that the rejection probability for the null hypothesis approaches 1 when random collections of column rank sums are taken. We give a continuity correction for the Kruskal-Wallis statistic that is useful in general and makes all of these calculations more accurate. Finally, we look at the special case where the matrix is row-ordered, and use the hook length theorem for Young tableaux to calculate the number of combinations of ranks when the matrix of ranks is both row- and column- ordered. (Received July 11, 2011)

1077-62-112 **Jacob A Gagnon*** (jgagnon@wpi.edu), Department of Mathematical Sciences, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609. *Identifying Gene Set Differences Between B-cell and T-cell Acute Lymphocytic Leukemia.* Preliminary report.

Gene set analysis allows us to determine which groups of genes are expressed differently when comparing two groups of individuals. For example, a researcher might want to compare a diseased group with a control group or compare two subtypes of a given disease. In this talk, we propose a new gene set analysis approach using a logistic kernel machine. This approach has some key advantages over previous work, namely the modeling of complex pathway effects, gene-gene interactions, and covariate effects. Results from simulation studies show that our estimation approach is comparable to better than Bayesian approaches at a much lower computational cost. As for hypothesis testing, simulation results show an increased power compared to a score test approach. Finally, we apply our methods to determine gene set differences between B-type and T-type Acute Lymphocytic Leukemia. (Received July 27, 2011)

1077-62-119 **Lu Lu*** (lu.lu@uconn.edu), University of Connecticut, Storrs Mansfield, CT 06269. *Law of the iterated logarithm for the L_2 error of the wavelet density estimator.* Preliminary report.

Let $X_1, X_2, ..., X_n$ be a sequence of i.i.d random variables with common probability density function f. Wavelet density estimation is a nonparametric way to estimate f. We establish the law of the iterated logarithm (LIL) for the L_2 error of a linear wavelet density estimator. The main tools to study kernel density estimators such as tail estimations of degenerate U-statistics and approximation by a Gaussian chaos can also be applied here due to the similarities between the two estimators. But more assumptions on the underlying density f are needed to compute the asymptotic variance. (Received July 28, 2011)

1077-62-138 **Ping Ye*** (pingye7@gmail.com), Mathematics Department, Quincy University, 1800 College Ave., Quincy, IL 62301, and **Bhaskar Bhattacharya**. *A Study on Tests of Symmetry with Ordered Alternatives in Higher Dimensional Contingency Tables.*

The major facet of this paper is to explore statistical testing procedures of partial symmetry versus various biases in higher dimensional tables, especially for three-dimensional cases. The maximum likelihood estimates of the cell probabilities and the asymptotic distribution of the likelihood ratio test statistic have been studied for the cases of partial symmetry and proportional symmetry. Simulation studies are used to investigate the sizes and powers of the tests. The methodologies developed are applied on real data sets. (Received July 30, 2011)

1077-62-144 **Jeremy Entner*** (jentner@syr.edu), Mathematics Department, 215 Carnegie Building, Syracuse University, Syracuse, NY 13244-1150. *Multivariate Nonparametric Ranking and Selection.* Preliminary report.

In the talk, we give a basic introduction to ranking and selection methods in one variable. Then using the multivariate quantiles defined by Tukey's depth function, we propose a non-parametric asymptotic procedure for selecting one of several multivariate populations. Simulation results will be presented to illustrate the efficiency of our procedure. (Received August 01, 2011)

1077-62-269 **Paul L. Goethals*** (paul.goethals@usma.edu), **Gregory L. Boylan** and **Byung Rae Cho**. *Solving Tolerance Optimization Problems for Complex Manufacturing Systems.*

Within an industrial environment, the optimal process settings often translate directly to improvements in product quality or a reduction in the number of defects. In the traditional design of the tolerance optimization problem, the ideal settings are sought based upon a set of fixed costs and specific values for the model parameters, such as the mean and variance. The production costs, however, may be highly variable over a manufacturing period and the parameter measures may shift or drift as time passes. Hence, the robustness and credibility of the results that are generated may be questionable without repeatedly solving the optimization problem. In order to gain greater predictability in tolerance design, this research examines the relationship between the tolerance region and changing costs or parameter shifts. A nonlinear optimization scheme with an economic objective is utilized to demonstrate a potential research methodology. (Received August 17, 2011)

1077-62-424 **David J. Marchette*** (dmarchette@gmail.com), **Carey E. Priebe**, **Rebecca F. Goldin** and **Giorgio A. Ascoli**. *Investigation of a Random Graph Model for Neuronal Connectivity.*

It has been hypothesized that mammalian brains contain a reduced set of neuron classes which, to first order, determine the connectivity of the neurons. A key requirement for testing this hypothesis is the ability to infer the classes from the connectivity. Since mammalian brains have 10^8 to 10^{11} neurons, this inference must be performed on very large directed graphs. We describe a random graph model that, when combined with model based clustering, provides an estimate of both the number and membership of the classes. The random graph model uses sparse matrix techniques to fit the parameters, allowing the estimation to be performed on large graphs. We discuss the algorithm and present recent results proving its consistency. We illustrate the algorithm through simulation of a plausible set of classes and connections, for graphs of order 2^{13} through 2^{18} and discuss the issues involved in applying these techniques to much larger graphs. (Received August 31, 2011)

1077-62-428 **Andrey Rukhin*** (andrey.rukhin@navy.mil), 18444 Frontage Road, Bldg. 1470, Suite 327, Room 2311, Dahlgren, VA 22448. *Invariant Theory for Hypothesis Testing on Graphs.*

Hypothesis testing on graphs has application in areas as diverse as connectome inference (wherein vertices are neurons or brain regions), social network analysis (wherein vertices represent individual actors or organizations), and text processing (wherein vertices represent authors or documents). Graph invariants are functions on graphs that do not depend on the particular labeling of the vertices and can be used as test statistics for deciding between a null versus an alternative model. However, even for simple models the exact distribution is unavailable for most invariants. Furthermore, comparative analyses of statistical power at some given Type I error rate for competing invariants, via both Monte Carlo and large sample approximation, demonstrate that simple settings can yield interesting comparative power phenomena.

In this talk the limiting null and alternative distributions for various invariants under various latent position models for attributed graphs [3] are derived, and power comparisons are performed using limit theory to provide large sample approximations. Monte Carlo analyses augment the limit theory. (Received August 31, 2011)

1077-62-1198 **Eric R Ruggieri*** (ruggierie@duq.edu), 600 Forbes Avenue, Pittsburgh, PA 15282. *A More Efficient Approach to Bayesian Variable Selection.*

In this talk, we describe an efficient, exact Bayesian algorithm applicable to both variable selection and model averaging problems. A fully Bayesian approach provides a more complete characterization of the posterior ensemble of possible sub-models, but presents a computational challenge as the number of candidate variables increases. While several approximation techniques have been developed to deal with problems that contain a large numbers of candidate variables, including BMA, IBMA, MCMC and Gibbs Sampling approaches, here we focus on improving the time complexity of exact inference using a recursive algorithm [Exact Bayesian Inference in Regression, or EBIR] that uses components of one sub-model to rapidly generate another. Testing against simulated data shows that EBIR significantly reduces compute time without sacrificing accuracy, while comparisons to the results obtained by two MCMC approaches on the Crime and Punishment data set yield similar results. Finally, we illustrate how the BIC approximations employed in the BMA and IBMA procedures depart from the equivalent complexity, exact Bayesian inference of EBIR. (Received September 17, 2011)

1077-62-1436 **Etaf Alshawarbeh*** (alsha1e@cmich.edu), **Felix Famoye** and **Carl Lee**. *Beta-cauchy distribution and its applications.* Preliminary report.

A four parameter beta-Cauchy distribution is defined which generalizes the Cauchy distribution. Various properties of the distribution are examined. The distribution is found to be unimodal and has a unimodal hazard function. We give necessary and sufficient conditions for the existence of the moments of the beta-Cauchy distribution. The usefulness of the new distribution is illustrated by applying it to several empirical data sets and comparing the results to some existing distributions. The beta-Cauchy distribution is found to provide great flexibility in modeling symmetric and skewed heavy-tailed data sets. (Received September 19, 2011)

1077-62-1802 **Nils S Nelson*** (nils.nelson@aggiemail.usu.edu), 755 East 800 North #2, Logan, UT 84321, and **Haimeng Zhang**. *Relative Efficiencies of the Maximum Partial Likelihood Estimators Under Sampling Schemes.*

Cox's regression model is widely used in epidemiology and medical research to assess the influence of exposure variables and other covariates on mortality or morbidity. Such study and analysis often requires to collect a large cohort of subjects over a long period of time. Sampling schemes, which only process the raw covariate data on a small portion of sampled subjects, not only offer substantial savings, but ultimately become the only practical alternative.

In this project, we compare the performance of the so-called maximum partial likelihood estimator from two popular sampling schemes, the case-cohort sampling design and the nested case-control sampling design, along with that from the full cohort under finite sample through extensive numerical simulations. This comparison is then applied to the analysis of a real data set. Finally, we investigate the relative efficiency of the nested case-cohort sampling design under highly stratified models. (Received September 21, 2011)

1077-62-2037 **Rhonda D Ellis*** (rdellis@nsu.edu) and **Chris Gennings**. *Deriving Optimal Composite Scores: Relating Observational/Longitudinal Data with a Primary Endpoint.*

In numerous clinical studies, multiple endpoints are measured on each subject. It is often not clear which of these endpoints should be designated as of primary importance. The desirability function approach is a way of combining multiple responses into a single unitless composite score. Each response variable is transformed to a unitless scale with zero representing a completely undesirable response and one representing the ideal value. In desirability function methodology, weights on individual components can be incorporated to allow different levels of importance to be assigned to outcomes. Assignment of weight values are subjective and based on expert opinion. It is our goal to find the weights that optimize an external empirical objective criterion. In particular, we find optimal weights that minimize the generalized variance of a prediction regression model relating the score and response of an external variable. For application of the weighting scheme, initial weighting values must be obtained then calculation of the corresponding value of the composite score follows. Based on the selected empirical model for the analyses, parameter estimates are found using iterative algorithms. A direct search algorithm is then used for the minimization of a given objective criterion. (Received September 21, 2011)

1077-62-2202 **Dhiman Bhadra*** (dbhadra@wpi.edu), Department of Mathematical Sciences, Worcester Polytechnic Institute, Worcester, MA 01609, and **Michael Joseph Daniels**, **Sung Duk Kim**, **Malay Ghosh** and **Bhramar Mukherjee**. *A Bayesian Semiparametric Approach for Incorporating Longitudinal Information on Exposure History for Inference in Case-Control Studies.*

Case-control studies primarily compare the exposure distribution of a group of subjects having a particular disease to a group of disease-free subjects to identify potential risk factors. In a typical case-control study, exposure information is collected at a single time point for the cases and controls. However, case-control studies are often embedded in existing cohort studies containing a wealth of longitudinal exposure history on the participants. Recent medical studies have indicated that incorporating past exposure history, when available, may lead to more precise estimates of the disease risk. In this paper, we propose a flexible Bayesian semiparametric approach to jointly model the time-varying exposure profiles of the cases and controls and also the influence pattern of the exposure profile on the disease status. This enables us to analyze how the present disease status of a subject is influenced by his/her past exposure history conditional on the current ones. Analysis is carried out in a hierarchical Bayesian framework using Reversible jump Markov chain Monte Carlo (RJMCMC) algorithms. The proposed methodology is applied to a nested case-control study of prostate cancer where longitudinal biomarker information is available for the cases and controls. (Received September 21, 2011)

1077-62-2496 **George P Yanev***, University of Texas - Pan American, 1201 West University Drive, Edinburg, TX 78539, and **M Ahsanullah**. *Characterizations of Logistic Distribution via Distributional Properties of Order Statistics.* Preliminary report.

Utilizing distributional relations between adjacent and non-adjacent order statistics with exponential shifts, we extend some known and obtain new characterization of the standard logistic distribution. (Received September 22, 2011)

1077-62-2870 **Daniel Vasiliu*** (daniel.vasiliu@cnu.edu), Department of Mathematics, Christopher Newport University, 1st University Place, Newport News, VA 23606. *On a hybrid method for variable selection.*

A problem of absolute importance for high-dimensional statistical modeling is the variable selection with simultaneous estimation. The methods developed to address this problem are based on geometric analysis of data and optimization of the main objective with constraints. In this respect the ridge regression method (Hoerl & Kennard 1998) has prediction advantages over the lasso method and the elastic net regularization (Zou & Hastie 2005) shows further improvement in many situations. The lasso method is a penalized least squares method imposing a ℓ_1- penalty on the regression coefficients whereas the ridge regression method imposes a ℓ_2-penalty. The elastic net method combines the two types of penalizations in a linear way and presents computationally demonstrated advantages for improving the statistical prediction. The adaptive elastic net method (Zou & Zhang 2009) combines linearly the ℓ_1 and ℓ_2 penalties. The main benefit from this onset is the fact that the solution achieved has oracle properties. We propose a new form of penalization for the variable selection problem and study its statistical properties in the context of previously developed models. (This research is in collaboration with T. Dey from the College of William and Mary.) (Received September 22, 2011)

1077-62-2927 **Axel Munk*** (munk@math.uni-goettingen.de), Axel Munk, Institute for Mathematical Stochastics, Goldschmidtsr. 7, Goettingen, 37077. *Statistical Multiscale Analysis: From Signal Detection to Nanoscale Photonic Imaging.*

In this talk we will discuss a general concept of statistical multiscale analysis in the context of signal detection and imaging. This provides a large class of fully data driven regularisation methods which allow to localize global measures of regularisation in a locally adaptive manner. We address computational issues as well as the required extreme value theory of the multiscale statistics. A major example will be locally adaptive total variation regularization for deconvolution problems. Our method is applied to problems from nanoscale biophotonic cell microscopy. (Received September 23, 2011)

1077-62-2957 **Dmitry Andreevich Sumkin*** (dmitry.sumkin@phystech.edu), 28a, Pervomaiskaya st., Moscow, 141701, Russia. *The resulting weighted ranking.* Preliminary report.

In judgmental forecasting there is a type of judgment which is called a weighted ranking. We find the algorithm of finding the resulting ranking of experts' judgments which are presented in the form of weighted rankings. The algorithm of calculating the resulting ranking is based on Kemeny median approach. Kemeny median is a solution of optimization problem of finding the minimum of the functional which is a sum of distances between the experts' judgments and any variable on the set of alternatives. The resulting weighted ranking is additive even if initial data, in general, could not be additive. This approach allows to determine a group judgment being the aggregation of experts' opinions. (Received September 23, 2011)

65 ► Numerical analysis

1077-65-17 **David P Nicholls** and **Jun Niu***, jniu3@uic.edu. *A Field Expansions Method for Acoustic Scattering by a Doubly Crossed Multilayered Media.*

In this talk we discuss the generalization to three dimensions of a Field Expansion method for the numerical simulation of acoustic scattering by crossed diffraction gratings. The method is an extension of Malcolm and Nicholls' recent work in two dimensions, and Bruno and Reitich's algorithm to multiple layers. We give full details of the algorithm and display numerical results which show the efficiency and accuracy of our new method. (Received May 16, 2011)

1077-65-21 **Fred J Hickernell*** (hickernell@iit.edu), Room E1-208, Applied Mathematics, Illinois Institute of Technology, 10 W. 32nd Street, Chicago, IL 60616. *The Reliability of Error Estimates for Multivariate Numerical Integration.*

When solving a problem numerically one would like to obtain an approximate answer within a specified error tolerance of the true answer, and by expending a reasonable amount of effort. Standard error analyses bound the error of the algorithm in terms of some measure of the size of the input, e.g. some norm of the input function. The larger the size of the function, the more effort is needed. Unfortunately, the size of the function is typically not known a priori and must be estimated. Ones ability to estimate the function size depends on how nasty the function is. We present an example for multivariate numerical integration where this nastiness can be defined explicitly. Although any numerical algorithm can be fooled, our results mean that the desired accuracy can be guaranteed, provided that the integrand is not too nasty. (Received June 2, 2011)

1077-65-105 **Oksana Bihun** (obihun@cord.edu), **Austin Bren*** (asbren@cord.edu), **Michael Dyrud** (mdyrud@cord.edu) and **Kristin Heysse** (keheysse@cord.edu). *Trigonometric Interpolation for Numerical Solution of Differential Equations.*

We use trigonometric interpolation to approximate solutions of a differential equation $Qu = f$, whose differential operator Q with domain $D(Q)$ is a formal polynomial of operators $\{1, x, d/dx\}$. A solution u is projected onto the space T_n of trigonometric polynomials of degree n. The projection Tu, defined as a trigonometric interpolant of u, is identified with a vector $\hat{u}$ of its values at partition points via an isomorphism π. The operator Q is represented by a square matrix $\hat{Q}$ defined implicitly by $\hat{Q}\hat{v} = \pi TQTv$ for all $v \in D(Q)$. The original equation is approximated by a system of linear equations $\hat{Q}\hat{u} = \hat{f}$, where $\hat{f} = \pi Tf$.

We prove that if $Q = a_0 + a_1\frac{d}{dx} + \ldots + a_s\frac{d^s}{dx^s}$, then $\operatorname{rank}\hat{Q} = \dim\hat{Q} + |\text{sign } a_0| - 2m - 1$, where $m \geq 0$ is the number of solutions, in the set $\{1, 2, \ldots, n\}$, of a certain system of polynomial equations . Our numerical tests show high accuracy and fast convergence of the method applied to several boundary and eigenvalue problems for differential equations.

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1077-65-432 **Fuhua Chen*** (fhchen66@ufl.edu), **Yunmei Chen** (yun@math.ufl.edu) and **Xiaojing ye** (xye@ufl.edu). *Bi-direction Projected PDHG based Multi-phase Soft Segmentation.*

Soft segmentation is more flexible than hard segmentation. But the membership functions are usually sensitive to noise. In this paper, we proposed a multiphase soft segmentation model for nearly piecewise constant images based on stochastic principle, where pixel intensities are modeled as random variables with mixed Gaussian distribution. The novelty of this paper lies in three aspects. First, unlike some existing models where the mean of each phase is modeled as a constant and the variances for different phases are assumed to be the same, the mean for each phase in the Gaussian distribution in this paper is modeled as a product of a constant and a bias field, and different phases are assumed to have different variances, which makes the model more flexible.

Second, we developed a bi-direction projected primal dual hybrid gradient (PDHG) algorithm for iterations of membership functions. Third, we also developed a novel algorithm for explicitly computing the projection from R^K to simplex Δ_{K-1} for any dimension K using dual theory, which is more efficient in both coding and implementation than existing projection methods. (Received August 31, 2011)

1077-65-460 **Xinghui Zhong*** (xinghui_zhong@brown.edu), 182 George Street, Providence, RI 02912, and **Chi-Wang Shu**. *A simple WENO limiter for Runge-Kutta Discontinuous Galerkin method.*

We investigate using WENO methodology as limiters for RKDG methods, with the goal of obtaining a robust limiting procedure to simultaneously obtain uniform high order accuracy and sharp, nonoscillatory shock transition for RKDG methods. (Received September 02, 2011)

1077-65-480 **Mikheil Tutberidze*** (mikheil.tutberidze@iliauni.edu.ge), 3/5 Kakutsa Cholokashvili ave., 0162 Tbilisi, Rep of Georgia. *On the Numerical Solution of One Nonlinear Parabolic Equation.*

The author constructs the difference scheme for initial-boundary value problem to following Nonlinear Parabolic partial differential equation

$$\frac{\partial U}{\partial t} = a\left(x,\, t,\, U\right)\frac{\partial^2 U}{\partial x^2} + b\left(x,\, t,\, U\right)\left(\frac{\partial U}{\partial x}\right)^2 + f\left(x,\, t\right).$$

The coefficients $a\left(x,\, t,\, U\right)$ and $b\left(x,\, t,\, U\right)$ are to satisfy the condition $a\left(x,\, t,\, U\right) > L\left|b\left(x,\, t,\, U\right)\right|$ for some positive constant L and for each U. For the mentioned difference scheme the theorem of existence of the solution and the theorem of convergence of the solution of difference scheme to the solution of the source problem are proved. The rate of convergence is established and is equal to $O\left(\tau + h^2\right)$. (Received September 04, 2011)

1077-65-528 **Bernardo Cockburn** and **Jintao Cui*** (jcui@ima.umn.edu), 114 Lind Hall, 207 Church St. SE, Minneapolis, MN 55455. *HDG Methods for the Vorticity-Velocity-Pressure Formulation of the Stokes Problem.*

In this talk we discuss the hybridizable discontinuous Galerkin (HDG) method for solving the vorticity-velocity-pressure formulation of the three-dimensional Stokes equations of incompressible fluid flow. The idea of the a priori error analysis consists in estimating a projection of the errors that is tailored to the very structure of the numerical traces of the method. We show that the approximated vorticity and pressure, which are polynomials of degree k, converge with order $k+1/2$ in L^2-norm for any $k \geq 0$. Moreover, the approximated velocity converges with order $k+1$. (Received September 06, 2011)

1077-65-635 **Runchang Lin***, Department of Mathematics, TAMIU, 5201 University Blvd, Laredo, TX 78041, and **Martin Stynes**, Department of Mathematics, National University of Ireland, Cork, Ireland. *A balanced finite element method for singularly perturbed reaction-diffusion problems.*

Consider the singularly perturbed linear reaction-diffusion problem $-\varepsilon^2\Delta u + bu = f$ in $\Omega \subset \mathbb{R}^d$, $u = 0$ on $\partial\Omega$, where $d \geq 1$, the domain boundary $\partial\Omega$ is (when $d \geq 2$) Lipschitz-continuous, and $0 < \varepsilon \ll 1$. It is argued that for this type of problem, the standard energy norm is too weak a norm to measure adequately the errors in solutions computed by finite element methods: the multiplier ε^2 gives an unbalanced norm whose different components have different orders of magnitude. A balanced and stronger norm is introduced, then for $d \geq 2$ a mixed finite element method is constructed whose solution is quasi-optimal in this new norm. By a duality argument it is shown that this solution attains a higher order of convergence in the L_2 norm. Error bounds derived from these analyses are presented for the cases $d = 2, 3$. For a problem posed on the unit square in $\mathbb{R}^2$, an error bound that is uniform in ε is proved when the new method is implemented on a Shishkin mesh. Numerical results are presented to show the superiority of the new method over the standard mixed finite element method on the same mesh for this singularly perturbed problem. (Received September 09, 2011)

1077-65-665 **James Brian Hall*** (j9hall@math.ucsd.edu), Department of Mathematics, University of California, San Diego (UCSD), 9500 Gilman Drive #0112, La Jolla, CA 92093. *Spectral Variational Integrators.* Preliminary report.

Variational integrators form a general class of structure preserving numerical algorithms for simulating Hamiltonian and Lagrangian dynamics. These methods offer numerical solutions to Hamiltonian and Lagrangian systems that are extremely stable, even over very large time scales and for large time steps. Because of these excellent properties, there has been significant recent interest in developing high order variational integrators. This talk will present a new variational integrator, which combines techniques from classical spectral methods with the

Galerkin variational integrator framework. This integrator, in addition to being symplectic and momentum preserving, exhibits geometric convergence to the true flows of Hamiltonian and Lagrangian systems, and is stable even over time steps several orders of magnitude larger than typical time steps for standard symplectic methods. The theoretical properties of this method are verified through several standard benchmark numerical examples. (Received September 09, 2011)

1077-65-956 **James V Lambers*** (James.Lambers@usm.edu), 118 College Dr #5045, Hattiesburg, MS 39406-0001. *Solution of Time-Dependent PDE Through Component-Wise Approximation of Matrix Functions.* Preliminary report.

Krylov subspace spectral (KSS) methods are high-order accurate, explicit time-stepping methods for linear PDE with stability characteristic of implicit methods. This "best-of-both-worlds" compromise is achieved by computing each Fourier coefficient of the solution using an individualized approximation, based on techniques from "matrices, moments and quadrature" for computing bilinear forms involving matrix functions. In this talk, it will be shown how this approach can be generalized to obtain high-order accuracy in time, with favorable scalability properties, for nonlinear PDE. (Received September 14, 2011)

1077-65-996 **Oksana Bihun*** (obihun@cord.edu). *A Projective Method for Numerical Solution of Differential Equations.*

We solve boundary and eigenvalue problems for ordinary and partial linear differential equations by projecting their solution spaces onto an n-dimensional space of algebraic or trigonometric polynomials H_n, which we identify with $\mathbb{R}^n$ via an isomorphism $\psi : H_n \to \mathbb{R}^n$. Let A be a differential operator from the enveloping algebra of $\oplus_{i=1}^{d}\{1, x_i, \frac{\partial}{\partial x_i}\}$ whose domain is a subset of a suitable Hilbert space H. The projection $P_n : H \to H_n$ is defined via Lagrangian interpolation or using partial sums of a Fourier series. The differential equation $Au = f$ is reduced to a system of linear equations $A_n u_n = f_n$, where $A_n \in \mathbb{R}^{n\times n}$ is a representation of A, $f_n = \psi P_n f$, and $u_n \in \mathbb{R}^n$ approximates the projection $\psi P_n u$ of a solution u. The dimension of the solution space of the reduced problem depends on the rank of the representation A_n. We prove several formulas that allow to compute the rank of matrix representations of certain linear differential operators. We prove approximation estimates and perform numerous numerical tests, which show a fast convergence rate and high accuracy of the method. (Received September 15, 2011)

1077-65-1029 **Susanne C. Brenner**, **Eun-Hee Park*** (epark2@math.lsu.edu) and **Li-yeng Sung**. *A nonoverlapping domain decomposition preconditioner for a symmetric interior penalty Galerkin method.*

In this talk we will discuss a preconditioner for a symmetric interior penalty Galerkin method for second order elliptic problems. This preconditioner is based on balancing domain decomposition by constraints (BDDC). Theoretical results on the condition number estimate of the preconditioned system will be presented along with numerical results. (Received September 15, 2011)

1077-65-1069 **Volker Michel*** (michel@mathematik.uni-siegen.de), Geomathematics Group, University of Siegen, Walter-Flex-Str. 3, Siegen, 57068. *Regularization of Tomographic Inverse Problems in Geophysics.*

Examples for tomographic problems in geophysics are the modeling of the Earth's interior and the detection of mass transports from GRACE data. Classical approaches such as a subdivision into blocks or the expansion in orthogonal polynomials have well-known disadvantages such as numerical instabilities or an insufficient flexibility with respect to inhomogeneous data sets.

This talk presents an overview of the following regularization methods based on localized trial functions developed by the speaker and his research group. These tools are able to overcome the drawbacks of classical approaches.

- A wavelet method uses hat-functions with varying hat-widths providing a multiresolution analysis.
- A spline method uses a different set of hats, which are constructed in correspondence with the data grid, such that the resolution of the result is locally adapted to the data density.
- The Regularized Functional Matching Pursuit represents a novel algorithmic approach, which can combine the advantages of splines and wavelets and avoids some of their drawbacks. In particular, very large data sets (e.g., from satellite missions) can be handled and heterogeneous systems of trial functions may be used.

(Received September 16, 2011)

1077-65-1112 **Tiara D. Turner*** (tdturner09@students.desu.edu), Department of Mathematical Sciences, Delaware State University, Dover, DE 19901, **Jiguang Sun** (jsun@desu.edu), Department of Mathematical Sciences, Delaware State University, Dover, DE 19901, and **Xia Ji** (jixia@lsec.cc.ac.cn), Institute of Computational Mathematics and, Scientific/Engineering Computing, Chinese Academy of Science, Beijing, 100190, Peoples Rep of China. *A mixed finite element method for Helmholtz transmission eigenvalues.*

The transmission eigenvalue problem has important applications in inverse scattering. Since the problem is not self-adjoint, the computation of transmission eigenvalues needs special treatment. Based on a fourth order reformulation of the transmission eigenvalue problem, we choose a mixed finite element method. The method has two major advantages: 1) the formulation leads to a generalized eigenvalue problems naturally without the need to invert a related linear system, and 2) the non-physical zero transmission eigenvalue, which has an infinitely dimensional eigenspace, is eliminated. To solve the resulting non-Hermitian eigenvalue problem, we propose an iterative algorithm using restarted Arnoldi method. To make the computation efficient, the search interval is decided using a Fabra-Khan 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 be modified to compute transmission eigenvalues for other models such as elasticity problem. (Received September 16, 2011)

1077-65-1153 **Kirk E Jordan*** (kjordan@us.ibm.com), 1 Rogers Street, Cambridge, MA 02142. *The Importance of the Math Formulation for Modeling and Simulation of Industrial Strength Problems on Peta and Exascale Systems.*

As industry scientists and engineers tackle more complex problems involving multiphysics and multiscales and then seek to solve these problems through computation, the math formulations which incorporate and more closely approximate the complex physical or biological phenomena being modeled will also be important to unlocking the approach taken on future computer systems. I will describe some of the challenges that will need to be considered in designing Petascale and eventually Exascale systems. Through the combination of High Performance Computing (HPC) hardware coupled with novel mathematical and algorithmic approaches emerging from the original formulations some efforts toward breakthroughs in industrial strength science and engineering are described. While there is progress, many challenges for the mathematical and computational science community to apply HPC to science problems of industry with impact on society remain. In conclusion, some discussion not only on the most obvious way to use ultra-scale, multi-core HPC will be given but also some thoughts on incorporating more physics in the algorithms derived from the math models and a glimpse at how to make such systems more accessible which might allow us to better use them to tackle previously intractable problems. (Received September 16, 2011)

1077-65-1210 **Mohamed Ben Romdhane*** (mbenromd@vt.edu), Department of Mathematics, 460 McBryde Hall, Virginia Tech, Blacksburg, VA 24061, and **Slimane Adjerid** and **Tao Lin**. *Immersed Finite Element Spaces with an Interior Penalty Method For Elliptic Interface Problems.*

We present piecewise quadratic immersed finite element (IFE) spaces that are used with an interior penalty (IP) method for solving two dimensional second-order elliptic interface problems without requiring the mesh to be aligned with the material interfaces. The use of an IP formulation with the IFE method is necessary to handle the discontinuity of the IFE shape functions across the mesh edges cut by the interface. The errors in the proposed IFE spaces yield optimal $\mathcal{O}(h^3)$ and $\mathcal{O}(h^2)$ convergence rates in the L^2 and broken H^1 norms, respectively, under mesh refinement. Numerical experiments are presented to validate our theory and show the optimality of the proposed IP-IFE method. We conclude that numerical solutions in the proposed IFE spaces are able to optimally represent the non-smooth behavior of the solution across the interfaces without requiring the mesh to be aligned with the discontinuity. The extensions of the developed quadratic IFE spaces to higher-order IFE spaces are discussed as well. (Received September 18, 2011)

1077-65-1218 **Tao Xiong*** (jingt@mail.ustc.edu.cn), 59 Pitman Street, Apt. 2, Providence, RI 02906, and **Chi-Wang Shu** and **Mengping Zhang**. *WENO Scheme with Subcell Resolution for Computing Nonconservative Euler Equations.*

Nonconservative hyperbolic systems are more difficult to approximate numerically than conservative ones. High order path-conservative schemes were developed in the literature for solving nonconservative hyperbolic systems in [Pares:2006, Castro:2006, Castro:2009], however, it has been demonstrated in [Abgrall:2010] that this approach has some computational issues and shortcomings. In this work, a modified high order path-conservative scheme which is based on the high order finite volume WENO scheme with subcell resolution and utilizes the

exact Riemann solver to catch the right paths at the discontinuities, has been developed to overcome these shortcomings. Application to one-dimensional compressible two-medium flows of nonconservative or primitive Euler equations is studied to show the effectiveness of this new approach. (Received September 18, 2011)

1077-65-1285 **Homer F. Walker*** (walker@wpi.edu), Worcester Polytechnic Institute, Mathematical Sciences Department, 100 Institute Road, Worcester, MA 01609-2280. *Anderson Acceleration for Fixed-Point Iterations.*

Fixed-point iterations occur naturally and are commonly used in a broad variety of computational science and engineering applications. In practice, fixed-point iterates often converge undesirably slowly, if at all, and procedures for accelerating the convergence are desirable. This talk will focus on a particular acceleration method that originated in work of D. G. Anderson [J. Assoc. Comput. Machinery, 12 (1965), 547-560] and has been independently re-invented on at least two occasions. This method has enjoyed considerable success in a few applications (notably in electronic-structure computations, where it is known as *Anderson mixing*) but seems to have been untried or underexploited in many other important applications. Moreover, while other acceleration methods have been extensively studied by mathematicians and numerical analysts, Anderson acceleration has received relatively little attention from them until recently, despite there being many significant unanswered mathematical questions. In this talk, I will outline Anderson acceleration, discuss some of its theoretical properties, and demonstrate its performance in several PDE applications. This work is joint in part with P. Ni and in part with P. A. Lott, C. S. Woodward, and U. M. Yang. (Received September 18, 2011)

1077-65-1314 **Bernd Hofmann*** (hofmannb@mathematik.tu-chemnitz.de), Chemnitz University of Technology, Department of Mathematics, Reichenhainer Str. 39/41, 09107 Chemnitz, Germany. *Methods for the treatment of indirect noisy data.*

This talk presents joint work with S.V.Pereverzyev (Linz/Austria) and analyzes some new aspects for the treatment of indirect measurement problems with applications in geodesy. Such problems are in general ill-posed and regularization approaches are required for the stable approximate solution. Among other aspects we also discuss the case that the information about the noise level of the data is not available and that the information about the forward operator is imprecise. In this context, we outline the chances and limitations of the method of approximate source conditions based on distance functions for estimating linear functionals of the not directly observable physical quantity. (Received September 19, 2011)

1077-65-1315 **Bernd Hofmann*** (hofmannb@mathematik.tu-chemnitz.de), Chemnitz University of Technology, Department of Mathematics, Reichenhainer Str. 39/41, Chemnitz, Germany. *Expressions of smoothness in regularization.*

The talk presents a couple of new results on the role of smoothness and source conditions for Tikhonov type regularization in Banach spaces. Also motivated by some aspects of sparsity alternative variational inequalities and appropriate error measures are required for finding convergence rates results. (Received September 19, 2011)

1077-65-1344 **Sirui Tan*** (sirui_tan@brown.edu), Division of Applied Mathematics, Brown University, Providence, RI 02912, and **Chi-Wang Shu** (shu@dam.brown.edu), Division of Applied Mathematics, Brown University, Providence, RI 02912. *Inverse Lax-Wendroff procedure for numerical boundary conditions of hyperbolic equations.*

We develop a high order accurate numerical boundary condition based on finite difference methods for solving hyperbolic equations on Cartesian grids, while the physical domain can be arbitrarily shaped. The challenges are the wide stencil for the high order scheme and the fact that the physical boundary does not usually coincide with grid lines. Our method is based on an inverse Lax-Wendroff procedure for the inflow boundary conditions. We repeatedly use the partial differential equations to write the normal derivatives to the inflow boundary in terms of the tangential derivatives and the time derivatives of the given boundary condition. With these normal derivatives, we can impose accurate values of ghost points near the boundary by a Taylor expansion. At the outflow boundaries, we use a high order weighted essentially non-oscillatory (WENO) type extrapolation. Our method is high order accurate, stable under the standard CFL conditions determined by the interior schemes, and easy to implement. We show applications in simulating interactions between compressible inviscid flows and rigid (static or moving) boundaries. (Received September 19, 2011)

1077-65-1347 **Daniel B. Szyld** (szyld@temple.edu), 1805 N. Broad Street, Department of Mathematics, Temple University, Philadelphia, PA 19122, and **Fei Xue*** (fxue@temple.edu), 1805 N. Broad Street, Department of Mathematics, Temple University, Philadelphia, PA 19122. *Local convergence analysis of several inexact Newton-type algorithms for general nonlinear eigenvalue problems.* Preliminary report.

We study the local convergence of several inexact numerical algorithms closely related to Newton's method for the solution of a simple eigenpair of the general nonlinear eigenvalue problem $T(\lambda)v = 0$. We analyze the impact of the tolerances chosen for the approximate solution of the linear systems arising in these algorithms on the order of the local convergence rates. We show that the inexact algorithms can achieve the same order of convergence as the exact methods if appropriate decreasing sequences of tolerances are applied to the inner solves. When the local symmetry of $T(\lambda)$ is present, the use of a nonlinear Rayleigh functional is shown to be fundamental in achieving higher order of convergence rates. (Received September 19, 2011)

1077-65-1355 **James Baglama** (jbaglama@math.uri.edu), University of Rhode Island, Department of Mathematics, 5 Lippitt rd, Kingston, RI 02881, and **Daniel Richmond*** (dan@math.uri.edu), University of Rhode Island, Department of Mathematics, 5 Lippitt rd, Kingston, RI 02881. *A Preconditioned LSQR Algorithm.*

We will present a preconditioned LSQR algorithm for solving large sparse least squares problems $\min_x ||Ax-b||_2$. Our method calculates the preconditioner using a restarted Lanczos bidiagonalization method, then applies the preconditioner to the LSQR algorithm. This preconditioner can be calculated efficiently using a small storage space for the Lanczos bidiagonalization method. The restarting is carried out by augmenting the Krylov subspaces that arise naturally in the Lanczos bidiagonalization method, with the Harmonic Ritz vector approximations to the singular vectors associated with the smallest singular values. Numerical examples show this method to be competitive with existing methods. (Received September 19, 2011)

1077-65-1358 **Michael Parks** (mlparks@sandia.gov), Computer Science Research Institute, P.O. Box 5800, MS 1320, Albuquerque, NM 87185-1320, and **Kirk M. Soodhalter*** (ksoodha@temple.edu), Department of Mathematics, 1805 North Broad Street, 6th Floor Wachman Hall, Philadelphia, PA 19122. *Block Krylov Subspace Recycling: Theory and Application in a Newton Iteration.*

The GCRODR algorithm (GMRES with subspace recycling) for linear systems, presented by Parks and colleagues [SIAM J. Sci Comput, 2006] has been shown to offer significant acceleration of convergence over restarted GMRES. The method is particularly effective when solving a slowly-changing sequence of linear systems. We derive a version of this algorithm for use in the block Krylov setting. We call this method block GCRODR (block GMRES with recycling). We then demonstrate this method's effectiveness as a solver embedded in a Newton iteration arising in fluid density functional theory, where we use our method to accelerate each Newton step through the introduction of fictitious right-hand sides. (Received September 19, 2011)

1077-65-1372 **Jangwoon Lee*** (llee3@umw.edu), 1301 College Avenue, Fredericksburg, VA 22401, and **Hyung-Chun Lee**. *Galerkin Finite Element Approximations of an Optimal Control Problem for Elliptic PDEs with Random Input Data.*

In the last decade, people in the scientific computing community have taken great interest in the stochastic partial differential equations and its solver called the Stochastic Galerkin Method (SGM). In this talk, we discuss the use of SGM to analyze an optimal control problem subject to stochastic elliptic partial differential equations and the development of its solver using the finite element method. (Received September 19, 2011)

1077-65-1385 **Debojyoti Ghosh*** (ghosh@umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20740, and **James D. Baeder** (baeder@umd.edu), Department of Aerospace Engineering, University of Maryland, College Park, MD 20740. *High Order Compact Reconstruction Scheme with Weighted Essentially Non-Oscillatory Limiting.*

Hyperbolic partial differential equations admit discontinuous solutions and high order accurate numerical schemes need limiters to avoid spurious oscillations across discontinuities. The Weighted Essentially Non-Oscillatory (WENO) scheme uses adaptive stenciling to achieve high order accuracy in smooth regions of the flow and yield non-oscillatory interpolation across discontinuities. A new compact-reconstruction WENO scheme is proposed where candidate interpolations are implicit resulting in compact stencils. The new scheme is expected to be non-oscillatory as well as have better spectral resolution as expected from compact interpolation. The new scheme is applied to the advection equation and the inviscid Burgers equation. The errors and orders of convergence are measured for smooth problems. Discontinuous solutions are used to analyze the non-oscillatory nature of

the new scheme. It is observed that the new scheme shows significantly lower error than the traditional WENO scheme of the same order. The new scheme results in less smearing for discontinuities and extrema are captured with higher resolution since compact schemes have lower dissipation and dispersion errors. The scheme is also applied to the Euler equations of fluid dynamics and similar observations are made. (Received September 19, 2011)

1077-65-1405 **Andrew N Zemke*** (drew.zemke@gmail.com), School of Mathematical Sciences, Rochester Institute of Technology, 85 Lomb Memorial Drive, Rochester, NY 14623, and **Akhtar Khan**. *Identification of Certain Parameters in Fourth Order Boundary Value Problems.*

This talk will focus on the inverse problem of identification of certain variable parameters in fourth order boundary value problems. The main emphases will be on the use of the generalized output least-squares functional for solving the inverse problem. Regularization will be used to handle the data perturbation. The case of smooth as well as non-smooth coefficients will be considered. Finite element based numerical examples will be presented. (Received September 19, 2011)

1077-65-1465 **Hans-Werner van Wyk***, hvanwyk@vt.edu. *The Statistical Estimation of Uncertain Parameters in Elliptic PDEs.*

Recent successes in the use of stochastic Galerkin methods and collocation-based approaches to solving partial differential equations with random coefficients at a lower cost than traditional Monte Carlo methods have led to questions relating to their use in associated inverse problems. We consider the problem of statistically estimating the random diffusion coefficient of a second order elliptic PDE, given the statistical description of the model output. Besides addressing the questions of existence of minimizers and necessary optimality conditions, we formulate the associated inverse problem within a large-scale deterministic setting. In order to mitigate the curse of dimensionality, we propose a two-step parallelizable numerical method in which a global basis for the parameter space is statistically estimated, leading to a significantly simpler inverse problem to solve. (Received September 19, 2011)

1077-65-1472 **Sanjay Mehrotra** and **David Papp*** (dpapp@iems.northwestern.edu), 2145 Sheridan Rd, C210, Evanston, IL 60208. *Finding moment-matching cubature formulas using optimization techniques, with applications in stochastic optimization.*

Stochastic optimization problems translate to finding the optimal value of a function that is expressible as an integral of some given function. These integrands are often high-dimensional, and sometimes expensive to compute; however, they often have a sparse structure or other special characteristics that may be exploited by numerical methods. Consequently the traditional cubature formulas, which use a large number of points and are aimed at matching all moments of the underlying measure up to a certain degree, are insufficient to approximate these integrals. We propose a flexible method based on convex optimization that can generate cubature formulas that match any prescribed set of moments, and thereby exploit the special properties of the integrand. The method is compared to Monte Carlo and quasi-Monte Carlo methods on both integration and stochastic optimization problems. (Received September 19, 2011)

1077-65-1482 **Holst Michael** (mholst@math.ucsd.edu), 9500 Gilman Dr., Dept. #0112, La Jolla, CA 92093, **Ryan Szypowski** (rszypows@math.ucsd.edu), 9500 Gilman Dr., Dept. #0112, La Jolla, CA 92093, and **Yunrong Zhu*** (zhu@math.ucsd.edu), 9500 Gilman Dr., Dept. #0112, La Jolla, CA 92093. *A Two-grid Method for Semilinear Interface Problems.* Preliminary report.

In this talk, we consider solving semilinear elliptic equations with discontinuous diffusion coefficients by a two-grid method. The algorithm consists of a coarse grid solver for the original nonlinear problem, and a fine grid solver for a linearized problem. We analyze the quality of the approximations generated by the algorithm, which provides a guideline of choosing coarse-grid problem such that the approximation quality is asymptotically as good as solving the original nonlinear problem on the fine grid. (Received September 19, 2011)

1077-65-1492 **Xu Zhang*** (xuz@vt.edu), 460 McBryde Hall, Virginia Tech, Blacksburg, VA 24061, and **Tao Lin**. *Immerse Finite Element Methods for Solving Parabolic Type Moving Interface Problems.*

In science and engineering, many simulations are carried out over domains consisting of multiple materials separated by curves/surfaces. This often leads to the so-called interface problems of partial differential equations whose coefficients are piecewise constants. Using conventional finite element methods, convergence cannot be guaranteed unless meshes are constructed according to the material interfaces. Geometrically, this means each element needs to be essentially on one side of a material interface. Due to this reason the mesh in a conventional finite element method for solving an interface problem has to be unstructured to handle non-trivial interface configurations. This restriction usually causes many negative impacts on the simulations if material interfaces evolve. In this presentation, we will discuss how the recently developed immersed finite elements (IFE) can alleviate this limitation of conventional finite element methods. We will present both semi-discrete and fully discrete IFE methods for solving parabolic equations whose diffusion coefficient is discontinuous across a time dependent interface. These methods can use a fixed structured mesh even the interface moves. Numerical examples will be provided to demonstrate features of these IFE methods. (Received September 20, 2011)

1077-65-1506 **Sergei Pereverzev*** (sergei.pereverzyev@oeaw.ac.at), Johann Radon Institute (RICAM), Altenbergerstrasse, 69, 4040 Linz, Austria. *Recent trends in Multi-parameter Regularization.*

We are going to discuss recent developments in multi-parameter regularization. We will consider the schemes with several a priori given penalty terms as well as the schemes with adaptively chosen penalty. New regularization multi-parameters choice rules will be proposed and analyzed. Moreover, numerical illustrations from several application areas will be demonstrated. (Received September 20, 2011)

1077-65-1579 **Andrew T. Barker*** (andrewb@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803-4918, and **Susanne C. Brenner** and **Li-Yeng Sung**. *Domain decomposition preconditioners for the discontinuous Petrov-Galerkin method.* Preliminary report.

The discontinuous Petrov-Galerkin method allows for use of nearly optimal test functions at a reasonable computational cost, because the test functions can be solved for locally. The resulting methods can be very effective and show good stability properties, but solution of the resulting ill-conditioned linear systems is a challenge. We explore the effectiveness of domain decomposition preconditioning for linear systems arising from the DPG discretization, considering both their theoretical properties and their practical efficiency on parallel computers. (Received September 20, 2011)

1077-65-1583 **Aycil Cesmelioglu*** (aycil.cesmelioglu@gmail.com), **Bernardo Cockburn**, **Ngoc Cuong Nguyen** and **Jaime Peraire**. *Analysis of HDG methods for the Navier-Stokes equations.* Preliminary report.

In this work, we propose and analyze a hybridizable discontinuous Galerkin (HDG) method for the incompressible stationary Navier-Stokes problem. First, we analyze the corresponding method for the Oseen equations which can be thought of as a linearized version of the Navier-Stokes equations. In fact, to approximate the Navier-Stokes flow, a common approach is to use Picard iterations where an Oseen problem is solved at each step. We first show that the HDG method for the Oseen problem yields optimal convergence for the velocity, its gradient and the pressure if we use the same polynomial degree to approximate all of the unknowns. With a special projection and postprocessing, we further obtain a H(div)-conforming, divergence-free velocity which converges with an additional order. We show numerical examples to validate the theoretical convergence rates. Finally, we extend these results to the Navier-Stokes case by solving a sequence of Oseen equations. (Received September 20, 2011)

1077-65-1626 **Ingrid Daubechies** (ingrid@math.duke.edu), 111 Physics, Mathematics Department, Duke University, Box 90320, Durham, NC 27708-0320, and **Sergey Voronin*** (svoronin@princeton.edu), The Program in Applied and Computational Math, Princeton University, Fine Hall, Washington Road, Princeton, NJ 08544-1000. *Iteratively Re-weighted Least Squares Methods for Inverse Problems with Sparsity Constraints.*

We propose a new iterative scheme for inverse problems with sparsity constraints. The scheme is simple to implement, easy to parallelize, and is effective for large inverse problems. The idea behind the scheme is to rewrite penalization norms in terms of a re-weighted two norm. This way, when applied to the ℓ_1 penalized functional, the scheme avoids the use of soft thresholding but offers similar performance to the popular FISTA scheme. Moreover, the weights of the scheme may be adjusted so that different parts of the solution vector are penalized differently. This is illustrated through an inverse problem in Geophysics where wavelets offer a natural subdivision: certain scales of the wavelet transformed solution are more crucial than others to the reconstruction and small coefficients that may be destroyed by thresholding can account for important features. This thinking leads to a regularizing functional $||Ax-b||_2^2 + \sum_{l=1}^{N} \lambda_l |x_l|^{q_l}$. We first introduce a scheme to minimize the ℓ_1 functional and then show how a scheme of the same form, with adjusted weights can be used to minimize the more general functional above. We go over details of convergence, and show numerical examples of the new schemes. (Received September 20, 2011)

1077-65-1730 **Ian H Sloan*** (i.sloan@unsw.edu.au). *Integration and approximation on the sphere.*

Global integration and approximation problems arise naturally in many applications of mathematics to planet Earth. In this talk we survey recent developments and challenges relevant to geomathematics, with an emphasis on polynomial and radial basis function methods. (Received September 20, 2011)

1077-65-1732 **Zhu Wang*** (wangzhu@vt.edu), 407 E McB Hall, Virginia Tech, Blacksburg, VA 24061, and **Traian Iliescu**. *Proper Orthogonal Decomposition Nonlinear Closure Models of Engineering Flows.*

Proper orthogonal decomposition is one of the most commonly used methods to generate reduced-order models for turbulent flows dominated by coherent structures. To balance the low computational cost required by a reduced-order model and the complexity of the targeted turbulent flows, appropriate closure modeling strategies need to be employed. We introduce novel nonlinear closure models for complex engineering flows. The new models are supported by extensive numerical experiments such as 3D turbulent flow past a circular cylinder problem. We also prove rigorous error estimates for the finite element discretization of the reduced-order models. (Received September 20, 2011)

1077-65-1754 **Susanne C. Brenner**, **Li-yeng Sung**, **Hongchao Zhang** and **Yi Zhang*** (yzhang24@math.lsu.edu). *Finite Element Methods for the Displacement Obstacle Problem of Clamped Plates.*

The displacement obstacle problem of clamped plates is an example of a fourth order variational inequality whose numerical analysis is more subtle than that of second order variational inequalities. In this talk we will introduce a general framework for finite element methods for this problem. Both error estimates and numerical results will be discussed. (Received September 22, 2011)

1077-65-1770 **Yalchin Efendiev**, **Juan Galvis** and **Seul ki Kang*** (kang@math.tamu.edu), Department of Mathematics, TAMU, College Station, TX 77843, and **Raytcho Lazarov**. *Multiscale simulations for Richards' equation in high-contrast media and applications.*

In this talk, I will describe multiscale simulation techniques for Richards' equation and applications. I will give a brief overview of coarse-grid approximation techniques that employ local spectral basis functions. Furthermore, I will discuss how these coarse spaces can be used in developing iterative methods that converge independent of the contrast. The iterative techniques that will be discussed will consist of both inner and outer iterations. We will show that both inner and outer iterations do not depend on the contrast of the media. Furthermore, I will discuss coarse-grid approximation and show that one can achieve accurate approximation by including spectral basis functions. I will mention applications of these problems in soil moisture predictions and uncertainty quantification. This work is joint with Y. Efendiev, Galvis, and Lazarov. (Received September 20, 2011)

1077-65-1814 **Andrei Bourchtein*** (bourchtein@gmail.com), Rua Anchieta 4715, bloco K, ap.402, Pelotas, 96015-420, Brazil, and **Ludmila Bourchtein**. *Time-splitting scheme for nonhydrostatic atmospheric model.*

Complete three-dimensional models of the atmosphere (Navier-Stokes or Euler equations) contain solutions with different space and time scales. It is well-known that the fastest atmospheric waves are the acoustic ones, which do not contain any significant part of the atmospheric energy. The slower gravity waves are more energy valuable, while relatively slow advective processes and Rossby waves carry the main part of the atmospheric energy. In this study, a time-splitting finite difference scheme is proposed for the nonhydrostatic atmospheric model, which approximates implicitly the fast acoustic and gravity waves, while slow processes are treated explicitly. Such time approximation requires solution of three-dimensional elliptic equations at each time step. Efficient elliptic solver is based on decoupling in the vertical direction and splitting in the horizontal directions. Stability analysis of the scheme shows that the time step is restricted only by the maximum velocity of advection and does not depend on speed propagation of the fast waves. The performed numerical experiments show computational efficiency of the designed scheme and accuracy of the predicted atmospheric fields. (Received September 21, 2011)

1077-65-2038 **Xiuhong Du*** (du@alfred.edu), Alfred University, Division of Mathematics, One Saxon Drive, Alfred, NY 14802, and **Daniel B Szyld**, Temple University, Department of Mathematics, 1815 North Broad Street, Philadelphia, PA 19122. *Varying Iteration Accuracy Using Inexact Conjugate Gradients in Control Problems governed by PDE's.*

This paper considers the solution of certain large scale optimization problems governed by parabolic partial differential equations. A quadratic functional containing a data misfit term is minimized to approximately recover the parameter function. The resulting constrained optimization problem is solved by using the reduced Hessian approach. The conjugate gradient method is employed for the solution of the system involving matrix-vector multiplications which are nontrivial. These matrix-vector products do not need to be computed exactly. In this paper we develop a new computable criterion to establish the allowable reduction of exactness in the matrix-vector product. We show its general application and in particular to the problem at hand. Numerical experiments show that the new computable criteria is effective while other criteria normally used are not as efficient.
(Received September 21, 2011)

1077-65-2066 **Christopher G Baker*** (bakercg@ornl.gov), Oak Ridge National Laboratory, PO Box 2008 MS6003, Oak Ridge, TN 37831-6003. *Optimization-based Approaches to Singular Value and Eigenvalue Problems.*

Many problems in linear algebra can be reformulated as problems in optimization. It follows naturally that many successful solvers from the former domain have ties to successful solvers from the latter. In particular, the Hermitian eigenvalue problem has a well-known characterization as an optimization problem, which has resulted in the application of a number of classical optimization methods, including steepest descent, conjugate gradients, Newton's method, and trust-region methods. Similarly, the related singular value problem has a optimization characterization, though it has seen less explicit attention from optimization-minded researchers. I will review the optimization characteristics of these and other problems from numerical linear algebra, along with some solution methodologies from Euclidean and Riemannian optimization. Emphasis will be given toward the application of these methods at extreme scales of computing. (Received September 21, 2011)

1077-65-2124 **Daniel Peach*** (dpeach@bates.edu), 704 Bates College, Lewiston, ME 04240, and **Ilse Ipsen**, **Thomas Wentworth** and **Colin Gray**. *Matrix Multiplication Approximation Using Orthogonalized Outer Products.* Preliminary report.

We present a prototype algorithm for approximating matrix multiplication for low-rank matrices. Inspired by algorithms introduced by Drineas et al. (2007), we view the multiplication of two arbitrary matrices A and B as the sum of outer products. For our algorithm, we reduce computation time by using only a small subset of these outer products: we approximate the true product AB using a linear combination of this subset. We determine the optimal linear weights for our chosen outer products by projecting the true product AB onto the vector space spanned by the outer products; we use the Frobenius inner product and the Gram-Schmidt process to orthogonalize our outer products and then project AB onto this new basis. For $n \times n$ matrices, our algorithm cannot be computed exactly in less than $O(n^3)$ time. However, we introduce a randomized pseudo-inner product which models the Frobenius inner product: our pseudo-inner product substantially reduces our computation time but does not jeopardize the accuracy of our algorithm. Finally, we discuss optimal methods of choosing outer products. (Received September 21, 2011)

1077-65-2140 **Qiang Du*** (qdu@math.psu.edu), University Park, PA 16802. *Finite dimensional approximations of nonlocal diffusion and peridynamic models.*

We discuss mathematical and computational issues related to some nonlocal diffusion and peridynamic models. We address questions concerning finite dimensional approximations of such nonlocal models, such as convergence, a priori and a posteriori error analysis and conditioning of nonlocal stiffness matrices. This is a joint work with Kun Zhou, Max Gunzburger, Rich Lehoucq, Li Tian, Lili Ju and Xuying Zhao (Received September 21, 2011)

1077-65-2184 **Ethan Wyatt Lockhart*** (ewlockha@ncsu.edu), **Arundhati Bagchi Misra** and **Hyeona Lim**. *Modified Chambolle Method for Speckle Image Denoising.*

Image denoising is an important image processing procedure for various real world applications. It is often necessary as a pre-processing for other imaging techniques such as segmentation and zooming. Chambolle has produced a quick dual approach algorithm based on partial differential equations, and the method minimizes the total variation norm for image denoising. However, this algorithm is intended for images with synthetically added Gaussian noise only. We develop a new denoising model and associated numerical methods for natural speckle noise images based on the Chambolle algorithm. We enhance the new method using central difference

methods for computational accuracy and texture free residual (TFR) parameterization to preserve textures and fine structures. Our computational results compare favorably to the original Chambolle algorithm and other conventional denoising methods. (Received September 21, 2011)

1077-65-2219 **Qingshan Chen*** (qchen3@fsu.edu), **Max Gunzburger** and **Todd Ringler**. *A new staggering approach towards shallow water simulations.* Preliminary report.

A new staggering approach towards constructing numerical schemes for geophysical flows is presented. The finite volume scheme constructed with this approach is shown to be able to faithfully simulate various wave modes inherent in the flow. In addition, the scheme for the nonlinear shallow water equations is also shown to be energy conserving. (Received September 21, 2011)

1077-65-2220 **Anna L. Mazzucato**, **Victor Nistor** and **Qingqin Qu*** (qu@math.psu.edu), 109 McAllister Building, University Park, PA 16802. *A non-conforming Generalized Finite Element Method for Transmission Problems.*

We obtain "h^m-quasi-optimal rates of convergence" for transmission (or interface) problems on domains with curved boundaries using a non-conforming Generalized Finite Element Method (GFEM). The sequence of approximation spaces (GFEM spaces) S_μ, are assumed to satisfy: (1) nearly zero boundary and interface matching conditions, and (2) approximability conditions. Under these conditions, if $u_\mu \in S_\mu$, $\mu \geq 1$, is a sequence of Galerkin approximations of the solution u to our transmission problem, then $\|u - u_\mu\|_{\hat{H}^1(\Omega)} \leq Ch_\mu^m \|f\|_{\hat{H}^{m-1}(\Omega)}$, where the *broken Sobolev spaces* $\hat{H}^p(\Omega)$ are defined by $\hat{H}^p(\Omega) := \{u \in L^2(\Omega), u \in H^p(\Omega_j),\ \text{for } j = 1, \ldots, K, \Omega = \cup_j \Omega_j\}$ with norm $\|u\|^2_{\hat{H}^p(\Omega)} = \sum_j \|u\|^2_{H^p(\Omega_j)}$. We give an explicit construction of GFEM spaces S_μ for which our two assumptions are satisfied, and hence for which the h^m-quasi-optimal rates of convergence hold. We also present some numerical experiments to demonstrate the theoretical results. (Received September 21, 2011)

1077-65-2230 **Guangming Yao*** (yao@rowan.edu), Department of Mathematics, Rowan University, 201 Mullica Hill Road, Glassboro, NJ 08028, and **Joseph Kolibal**, Department of Mathematics, University of Southern Mississippi, 118 College Drive, #5045, Hattiesburg, MS 39406. *Implementing the localized method of approximate particular solutions using a Schultz-Jones-Mayer algorithm.*

The localized method of approximate particular solutions (LMAPS) allows the use of a small neighborhood of points to find the approximate solution of many kinds of PDEs. Furthermore, this approach becomes much more amenable to solving large-scale problems in engineering and the applied sciences. In this approach, only small matrices with the dimension of the number of nodes included in the domain of influence, S_n, have to be inverted for each node. Studies show that there is a marginal improvement in accuracy due to increasing S_n using LMAPS, however, make S_n to large increases computational costs.

On the other hand, LMAPS with inverse multiquadric radial basis functions yields relatively small, dense symmetric matrices, that can be diagonally dominant for suitable shape parameters. After pre-conditioning the eigenvalues of these matrices can be bounded appropriately to allow the Schulz-Jones-Mayer (SJM) algorithm to more efficiently solve these systems in $O(n^2)$ operations, allowing the use of a larger number of points in every local domain.

The improved version of LMAPS has been applied to solve Poisson's problem and modified Helmholtz problem. Computational accuracy and efficiency are compared with LMAPS. (Received September 21, 2011)

1077-65-2268 **Juan Galvis*** (jugal@math.tamu.edu), 3404 TAMU, Texas A&M University, College Station,, TX 77843-3404, and **Efendiev**. *Multiscale methods for high-contrast problems using local spectral basis functions.*

We study multiscale finite element methods (MsFEMs) using spectral multiscale basis functions that are designed for high-contrast problems. Multiscale basis functions are constructed using eigenvectors of a carefully selected local spectral problem. This local spectral problem strongly depends on the choice of initial partition of unity functions. The resulting space enriches the initial multiscale space using eigenvectors of local spectral problem. The eigenvectors corresponding to small, asymptotically vanishing as the contrast increases, eigenvalues detect important features of the solutions that are not captured by initial multiscale basis functions. Multiscale basis functions are constructed such that they span these eigenfunctions that correspond to small, asymptotically vanishing, eigenvalues. We present a convergence study that shows that the convergence rate (in energy norm) is proportional to $(H/\Lambda*)^1/2$, where $\Lambda*$ is proportional to the minimum of the eigenvalues that the corresponding eigenvectors are not included in the coarse space. Numerical results are presented. (Received September 22, 2011)

1077-65-2441 **Lloyd N. Trefethen*** (trefethen@maths.ox.ac.uk), Oxford Mathematical Institute, 28 St. Giles, Oxford, OX13LB, England. *Robust rational interpolation and least-squares.*

Rational approximations are notoriously fragile. In different contexts they may fail to exist, fail to be unique, or depend discontinuously on the data. Some approximations show forests of seemingly meaningless pole-zero pairs or "Froissart doublets", and when these artifacts should not be there in theory, they often appear in practice because of rounding errors on the computer. Here, in joint work with Pedro Gonnet and Ricardo Pachon, we present a method for getting around most of these problems using the singular value decomposition. (Received September 22, 2011)

1077-65-2444 **M. Badawy*** (mbadawy@math.ku.edu) and **Erik S. Van Vleck** (evanvleck@math.ku.edu). *Perturbation theory for the approximation of stability spectra by QR methods for products of linear operators on a Hilbert space.*

In this talk, we go over the results that we obtained in a recent paper where we establish a quantitative perturbation theory for stability spectra (Lyapunov exponents and Sacker-Sell spectrum), based upon the so-called discrete QR technique, for sequences of linear operators on an infinite dimensional Hilbert space. In particular, we obtain component-wise bounds on the unitary and upper triangular factors under the assumption of either having the integral separation, or non-integral separation (but stable Lyapunov exponents) of the upper triangular operators. Integral separation is a natural analogue for products of matrices (in the finite dimensional case) to having gaps between eigenvalues of a matrix. We study the discrete mapping problem of non-autonomous infinite dimensional dynamical systems formulated as sequence of operators acting on a complex Hilbert space, making the results applicable to certain linear non-autonomous partial differential equations. We achieve the error bounds by formulating the existence of the unitary operators as a zero-finding problem, then apply the Newton-Kantorvich theorem, which not only gives us the sufficient conditions for the existence of a solution, but also yields bounds on the error in the unitary operators. (Received September 22, 2011)

1077-65-2497 **Matthew A Beauregard*** (matthew_beauregard@baylor.edu), Department of Mathematics, One Bear Place # 97328, Baylor University, Waco, TX 76710, and **Qin Sheng** (Qin_Sheng@baylor.edu), Deptartment of Mathematics, One Bear Place # 97328, Baylor University, Waco, TX 76710. *An Adaptive Compact Scheme for the Quenching Solution of Reaction-Diffusion Equations.*

The numerical solution of nonlinear, degenerate reaction-diffusion equations of the quenching type is investigated. An adaptive compact scheme is employed to obtain solutions for the discretized sytstem. The temporal step is determined adaptively through a suitable arc-length monitor function. It is shown that the numerical solution acquired preserves the positivity and monotonicity of the analytic solution. Strong stability is proven in a Von-Neumann sense via the ℓ^2-norm. Computational examples are given to illustrate our results. (Received September 22, 2011)

1077-65-2595 **Nairat Kanyamee*** (nairat@su.ac.th), Department of Mathematics, Silpakorn University, Muang, NakonPatom 73000, Thailand. *Spectral Methods For The Nonlinear Hamiltonian Systems.*

The Hamiltonian system is one of the most important dynamical systems that typically arises as models of conservative physical systems and has many applications in classical mechanics, molecular dynamics, astronomy, and other scientific fields. The system has two significant properties which are energy conserving along the trajectories and symplectic structure preserving. In this talk, we will present spectral methods in solving nonlinear Hamiltonian systems with an emphasis on the three-body problem. Numerical evidences have demonstrated that the proposed spectral methods preserve both energy and symplectic structure up to the machine error in each time step, and therefore have a better long time behavior. (Received September 22, 2011)

1077-65-2692 **Jinfeng Wei*** (jwei@maryville.edu). *A Non-linear Least Squares Estimator of Bühlmann Credibility.* Preliminary report.

It is well known that Bühlmann credibility estimator is a linear least squares estimator. In this talk, a non-linear least squares estimator is used to determine the pure premium for a group of insurance contracts. A numerical example demonstrates this algorithm. (Received September 22, 2011)

1077-65-2705 **James J Brannick**, **Yao Chen*** (chen_y@math.psu.edu) and **Ludmil T Zikatanov**. *On the construction of optimal piece-wise constant coarse spaces in algebraic multigrid method.*

We consider aggregation based two-level and multilevel methods for solving linear systems with symmetric positive (semi)-definite matrices. In a two-level setting we define the coarser space to be the space of functions that are piece-wise constants with respect to the aggregation. We then devise an algorithm to optimize the shape of the aggregates so that we have faster convergence rate. The algorithm utilizes a measure which is optimized locally in order to reshape the aggregates. The measure depends on the smoother used in the two-level method.

This aggregation algorithm has the potential to work with any smoother and does not use test vectors to guide the aggregation as other coarsening methods do. We present several numerical tests on the solutions of the discretized elliptic PDEs with anisotropic coefficients. The numerical tests include both two level and multilevel methods and clearly show the robustness of the algorithm. At the end we also discuss parallel implementations of such algorithm in both communication cost and computational cost (number of flops). This is a joint work with James Brannick and Ludmil Zikatanov. (Received September 22, 2011)

1077-65-2713 **John P Roop*** (jproop@ncat.edu), Department of Mathematics, North Carolina A & T SU, 1601 E. Market St., Greensboro, NC 27410, **Traian Iliescu**, Department of Mathematics, Virginia Tech, McBryde Hall, Blacksburg, VA 24061, and **Zhu Wang**, Department of Mathematics, Virginia Tech, McBryde Hall, Blacksburg, VA 24061. *Variational Multiscale and SUPG Stabilization of Proper Orthogonal Decomposition Approximation for a Generalized Oseen Problem.*

The Proper Orthogonal Decomposition reduced-order modeling technique for the approximation of partial differential equations has several well-documented drawbacks. One of the drawbacks indicated is the numerical instability inherited in convection-dominated problems. In a recent paper, Iliescu and Wang analyzed the the numerical solution using POD for a convection-dominated convection diffusion problem, showing numerical estimates thereof. In this paper, we discuss the extension of this concept to a generalized Oseen problem. We derive numerical estimates for the POD solution, when applying both the variational multiscale (VMS) as well as the streamline upwind Petrov-Galerkin (SUPG) stabilization technique to the reduced-order variational problem. (Received September 22, 2011)

1077-65-2775 **John A.W.B. Costanzo***, abc1699@rit.edu, and **Nathan D. Cahill**. *A Survey of the Feasibility of Similarity Measures for use in Rigid Registration.*

Image registration is the process of finding a geometric transformation that brings two images into a single coordinate system. This has applications in medical imaging, whereby two three-dimensional images of the same region are aligned such that the physical areas represented in one image are linked to the corresponding areas in the other image. Rigid registration is a type of image registration in which two images can be translated and rotated in space but not distorted. The registration problem can be solved by optimizing a similarity measure relating the images over the space of valid transformations.

In this talk we discuss the application of similarity measures in rigid registration. Skerl *et al.* discuss a method by which a similarity measure can be analyzed for feasibility. This method analyzes the risk of nonconvergence, accuracy of the global minimum, distinctiveness of the global minimum, number of false local minima surrounding the optimum alignment, and maximum range that two images can be misaligned to ensure convergence. Using this method we analyzed roughly 80 similarity measures for the task of rigidly registering computed tomography (CT) and magnetic resonance (MR) images of the brain and found several that work well. (Received September 22, 2011)

1077-65-2777 **Victoria Marsh*** (vmarsh3@yahoo.com), Department of Mathematics and Statistics, 1250 Bellflower Blvd. - MS1403, Long Beach, CA 90840-1403, and **Jen-Mei Chang** and **Stephen Mezyk**. *Numerical Methods for Optimizing Chemistry Kinetic Parameters.*

The focus of this research is to find an analytic function representing experimental data by creating a computer program capable of optimizing the corresponding chemistry reaction kinetic parameters. The program will initially solve for the kinetic parameters of a specific reaction problem, a first order growth and second order decay reaction, simplified as $A \to B$, $2B \to C$. Using numerical analysis to generate an analytic function fitting the measured kinetic data, along with the differential equations corresponding to the reactions, an over-determined system of equations can be created. Using the measured reaction data values to solve this system of equations for the unknown kinetic parameters allows the program to calculate parameter estimations. By minimizing error, the program will then optimize the parameter estimators to best fit the experimental data. Preliminary results using a cubic spline approximation of the kinetic data yields an analytic function fitting the data with minimal error. In conclusion, by fitting experimental kinetic data, the program will optimize the corresponding kinetic parameters and allow for an analytic function to be created. The program will ultimately be expanded to handle more complex reaction systems. (Received September 22, 2011)

1077-65-2804 **Katharine F Gurski*** (kgurski@howard.edu), Dept of Mathematics, ASB-B 204, Howard University, Washington, DC 20059. *Explicit Extended Stability Time Stepping Methods.*

We consider explicit methods for systems of ordinary differential equations which have stiffness due to imaginary eigenvalues. We present a cost, stability region, and numerical comparison of super time stepping and dyadic extended time schemes used to overcome the CFL stability condition limitation on time steps. We include a new explicit method that combines dyadic time stepping with a skew-stabilized method that maintains a low computational cost through the method's ability to maintain a reasonable time step size due to stiffness due to disparate eigenvalue sizes. The skew-stabilization allows a relaxation of the positive definite requirement of the symmetric portion of the Jacobian matrix when the imaginary component of the eigenvalue is large in comparison to the real eigenvalue. (Received September 22, 2011)

1077-65-2949 **Jia Liu*** (jliu@uwf.edu), Department of Mathematics and Statisitcs, 11000 University Pkwy, Pensacola, FL 32514. *A fast numerical solver for the unsteady Oseen problems in rotation form.*

We study the preconditioned iterative method for the unsteady Navier-Stokes equations. The rotation form of the Oseen system is considered. We apply an efficient preconditioner which is derived from the Hermitian/Skew-Hermitian preconditioner to the the Krylov subspace iterative method. Numerical experiments show the robustness of the preconditioned iterative methods with respect to the mesh size, Reynolds numbers, time step and algorithm parameters. The preconditioner is efficient and easy to apply for the unsteady Oseen problems in rotation form. (Received September 23, 2011)

68 ► Computer science

1077-68-127 **Julia T Upton*** (uptonj@husson.edu), Husson University, School of Science and Humanities, One College Circle, Bangor, ME 04401. *Turing Machines and Quantum Computation: Building a Quantum Brain.*

The rapidly developing field of Quantum Computation has benefited from Alan Turing's ideas, yet it also posses the most serious challenge to the strong Church-Turing thesis. The impact of Alan Turing's ideas on the field of Quantum Computation is explored. The role of a Quantum Turing Machine, a generalization of the classical probabilistic and deterministic Turing machines, is examined. The notions of the computable, uncomputable, and an oracle are discussed within the framework of Quantum Computation. (Received July 28, 2011)

1077-68-130 **Eric Rowland***, LaCIM, Universite du Quebec, Montreal, QC H2X 3Y7, Canada, and **Charles Brummitt**. *Growth of one-dimensional cellular automata.*

Cellular automata are simple machines consisting of cells that are updated in parallel at discrete time steps. We are interested in cells arranged in an infinite one-dimensional row. Given an initial configuration in which all but finitely many cells are in a constant "background" state, the *length* $\ell(t)$ of row t is the length of the region in row t that differs from the background.

We present the results of a combined automated–manual search for nonlinear growth sequences $\ell(t)$ in a space of 2^{16} cellular automaton rules. Significant new features found among these rules include fractal sets whose boundaries can be described by the fixed points of morphisms.

Many automata in this space have sequences $\ell(t)$ with characteristics of random walks. We attempt to classify these automata by their growth exponent $0 \leq \alpha \leq 1$, where $\ell(t) = \Theta(t^\alpha)$. However, we also show that this classification is not possible in general; indeed, we construct an automaton for which there are subsequences t_{i_n} and t_{j_n} such that $\ell(t_{i_n}) = \Theta(t_{i_n})$ but $\ell(t_{j_n}) = \Theta(\sqrt{t_{j_n}})$. (Received July 28, 2011)

1077-68-384 **Stuart A Kauffman*** (stukauffman@gmail.com). *Answering Descartes: Beyond Turing.*

My talk derives from a chapter, "Answering Descartes: Beyond Turing" in press, 2012, in the Alan Turing Centennial Volume, "The Once and Future Turing: Computing the World", Cambridge University Press, republished online by the European Conference on Artificial Life 11.

I will discuss "Trans-Turing Systems, open quantum systems hovering reversibly between quantum and classical behavior, neither quantum coherent, nor determinate nor random, hence not Turing machines, and not algorithmic. (Received August 28, 2011)

1077-68-398 **Lance Fortnow*** (fortnow@eecs.northwestern.edu), EECS Department, Northwestern Unviersity, Tech L359, 2145 Sheridan Rd, Evanston, IL 60208. *Turing's Influence on Computational Complexity.*

Alan Turing's machine not only gave us the right model of computation but also the right way to measure resources, such as time and memory, needed to perform various computational tasks. This talk will explore how Turing's research influenced the development of the field of Computational Complexity, the P versus NP problem and beyond. (Received August 29, 2011)

1077-68-461 **Vin de Silva*** (vin.desilva@pomona.edu), Department of Mathematics, Pomona College, 610 N College Ave, Claremont, CA 91711-4411. *Topological dimensionality reduction.*

Nonlinear dimensionality reduction (NLDR) methods are widely used in machine learning. Algorithms such as Isomap (Tenenbaum et al), LLE (Roweis & Saul), and Laplacian Eigenmaps (Belkin & Niyogi) provide effective ways of representing a high-dimensional data set in terms of a small number of real-valued coordinate functions. I will discuss a recent variation of this paradigm, in which we seek coordinate functions taking values in the circle (rather than the real line). We use persistent topology and some elementary harmonic analysis to construct smooth, robust circle-valued functions. These methods give new tools for studying experimental or simulated data from periodic and quasiperiodic dynamical systems. This is joint work with Dmitry Morozov, Primoz Skraba, and Mikael Vejdemo-Johansson. (Received September 02, 2011)

1077-68-906 **Daniel S Roche*** (roche@usna.edu). *Finding a polynomial multiple that is sparse.*

Recent work is presented on the problem of computing sparse multiples of polynomials over the rational numbers or a finite field. Specifically, given a (dense) polynomial $f \in \mathsf{F}[x]$, we look for another polynomial $g \in \mathsf{F}[x]$ with $f|g$, such that g has higher degree but fewer nonzero terms than f. Depending on the field F, a bound on the degree of the multiple g, or on the coefficient sizes, is also required.

This problem has important applications in cryptography and extension field arithmetic. Though a few heuristic approaches have previously been developed, our interest is in the existence or nonexistence of polynomial-time algorithms in the *size* of the polynomials (that is, the number of nonzero terms, the logarithm of degree, and the size of the coefficients). We provide such polynomial-time algorithms for certain cases, and prove NP-hardness in other cases.

This is joint work with Mark Giesbrecht and Hrushikesh Tilak at the University of Waterloo. (Received September 14, 2011)

1077-68-973 **Amanda Pascoe Streib*** (apascoe3@math.gatech.edu). *Markov chains for sampling weighted permutations.*

The question of sampling permutations is very natural, and has been widely studied. For example, it is known that the following Markov chain is efficient for sampling from the uniform distribution over permutations; the Markov chain M selects neighboring elements i and j in the permutation and swaps them. Benjamini et al. studied a biased version of M in which the probability $p_{i,j}$ of putting a neighboring pair (i,j) in increasing order is proportional to some parameter p. A natural question is whether M is efficient when the probability $p_{i,j}$ of putting i and j in order is allowed to vary depending on i and j.

We provide a simple new proof that the local Markov chain M is rapidly mixing in the above two cases (the uniform distribution and the distribution where the biases are all equal to p) as well as the case that $p_{i,j}$ depends only on $\min\{i,j\}$. That is, $p_{i,j} = p_{i,k}$ if $i < j, i < k$. In our proof, we introduce a new Markov chain which operates on the inversion table of a permutation. We also identify a wider class of $p_{i,j}$'s where we can infer rapid mixing from the above analysis, together with a decomposition of the local Markov chain into a cross-product of disjoint copies of a simpler instance of the problem. (Received September 15, 2011)

1077-68-1057 **Swastik Kopparty**, **Shubhangi Saraf** and **Sergey Yekhanin*** (yekhanin@microsoft.com), 1065 La Avenida, Mountain View, CA 94043. *High-rate Codes with Sublinear-time Decoding.*

Locally decodable codes are error-correcting codes that admit efficient decoding algorithms: They give a method to encode k-bit messages into n-bit codewords such that even after a constant fraction of the bits of the codeword get corrupted any bit of the original message can be recovered by only looking at $r(k)$ bits of the corrupted codeword. The tradeoff between the rate of a code and the locality/efficiency (the function $r(k)$) of its decoding algorithms has been studied extensively. However most prior work has focused on codes with very small r (e.g., constant functions), and the resulting constructions suffer from poor rate.

In this talk we give a new class of codes with very high rates (close to 1) and with strong local decoding properties ($r(k) = k^{\epsilon}$), thereby giving new performance tradeoffs between the rate and locality of decoding. These codes, which we call multiplicity codes, are based on evaluating multivariate polynomials and their derivatives. Multiplicity codes extend traditional multivariate polynomial based codes; and at the same time achieve better tradeoffs and flexibility in the rate and decodability.

Based on joint work with Swastik Kopparty (Rutgers) and Shubhangi Saraf (IAS). (Received September 15, 2011)

1077-68-1157 **László Babai** and **Youming Qiao*** (jimmyqiao86@gmail.com), Room 4-609 FIT Building,Tsinghua University, Beijing, Beijing 100084, Peoples Rep of China. *Polynomial-time isomorphism test for groups with abelian Sylow towers.* Preliminary report.

We consider the complexity of testing isomorphism of groups of order n given by Cayley tables. While this can trivially be accomplished in $n^{\log n}$ time, no polynomial-time algorithm is known. Solvable groups appear to present the hardest cases. We present a polynomial-time algorithm for the largest class of solvable groups to-date, namely, for groups with abelian Sylow towers, defined as follows. A *Sylow tower* in a group G is a normal chain where each quotient is isomorphic to a Sylow subgroup of G. A Sylow tower is *abelian* if all Sylow subgroups are abelian. To achieve polynomial time, we reduce isomorphism testing to certain representation-theoretic problems, and further to a parameterized setwise stabilizer problem. The latter can be solved adapting Luks's dynamic programming technique for hypergraph isomorphism. Furthermore, a detailed analysis of p'-automorphisms of abelian p-groups, both theoretically (by M. E. Harris) and algorithmically (by A. Ranum), is required. We build on prior work by F. Le Gall and by Y. Qiao, J. M. N. Sarma, and B. Tang. (Received September 20, 2011)

1077-68-1207 **Maggie Habeeb*** (mhabeeb@gc.cuny.edu), CUNY Graduate Center, Mathematics Department, New York, NY 10016, and **Delaram Kahrobaei**. *On the Dimension of Matrix Representations of Nilpotent Groups.*

It is well known that any polycyclic group, and hence any finitely generated nilpotent group, can be embedded into $GL_n(\mathbb{Z})$ for an appropriate $n \in \mathbb{N}$; that is, each element in the group has a unique matrix representation. An algorithm to determine this embedding was proposed by W. Nickel. In this talk, we explain the algorithm, give its complexity, give a bound on the dimension of the matrices produced and provide a slightly more efficient algorithm than the one proposed by W. Nickel. (Received September 18, 2011)

1077-68-1230 **Eli Ben-Sasson** and **Elena Grigorescu*** (elena@cc.gatech.edu), 266 Ferst Drive, KACB 2113, Atlanta, GA 30332, and **Ghid Maatouk**, **Amir Shpilka** and **Madhu Sudan**. *On Sums of Locally Testable Affine Invariant Properties.*

Affine invariant properties are collections of functions mapping a large field to a subfield, that are invariant under affine transformations of the domain. These properties generalize well-studied codes such as Hadamard, Reed-Muller and BCH. Almost all known 'locally testable' affine-invariant properties have a structural property called 'single-orbit characterization', which means that they are generated as a vectors space by one function and its translations under the affine group. In this talk I will describe new affine invariant families that have a single-orbit characterization. By previous results these families form the most general examples of locally testable affine invariant codes known so far. I will further describe some intriguing open questions suggested by these results. (Received September 18, 2011)

1077-68-1334 **László Babai** (laci@cs.uchicago.edu), **Paolo Codenotti*** (paolo@ima.umn.edu) and **Youming Qiao** (jimmyqiao86@gmail.com). *Permutational isomorphism of permutation groups.*

We present an algorithm to test permutational isomorphism of permutation groups in time polynomial in the order of the groups and simply exponential in the degree. In the case of transitive groups we in fact list all permutational isomorphisms within the stated time bound. The algorithm involves an analysis of a structure tree (imprimitivity hierarchy), estimates for primitive groups, and special handling of the case when the alternating or symmetric group acts at a node of the tree. The general case reduces to the transitive case via the "twisted code equivalence" problem. A *code* of length n is a set of strings of length n over a finite alphabet. An *equivalence* of codes A and B is a permutation $\pi \in S_n$ such that $A^\pi = B$ (permuting the positions). *Twisted code equivalence* additionally allows a group action on the alphabet. Our solution to this problem generalizes Luks's dynamic programming algorithm for hypergraph isomorphism.

The transitive case of our result is a key ingredient in our polynomial-time isomorphism test for semisimple groups (groups with no non-trivial abelian normal subgroups), given by their Cayley tables. The best previous bound for this class was $n^{\log \log n}$ by the present authors and J. Grochow. (Received September 20, 2011)

1077-68-1496 **Nicholas F Travers*** (ntravers@math.ucdavis.edu) and **James P Crutchfield**. *A characterization theorem for exact, unifilar hidden Markov models, and a polynomial time test for exactness.*

A hidden Markov model (HMM) is *unifilar* if the next state is completely determined by the current state and next output symbol generated. A HMM is *exactly synchronizable* (or *exact*) if there exists a synchronizing word w such that an observer knows the machine state exactly after observing w. We present a characterization theorem for exact, unifilar HMMs, and use it to construct an algorithm for testing exactness. The algorithm is closely based on the DFA table filling algorithm, and runs in polynomial time. More precisely, the total run time is of order AN^2, where A is the number of alphabet symbols and N is the number of states. (Received September 20, 2011)

1077-68-1611 **Ali Pinar***, 7011 East Avenue MS9159, Livermore, CA 94583, and **Seshadhri Comandur** and **Tammy Kolda**. *Scalable Methods for Characterizing and Generating Large Graphs.*

Despite their growing importance as the standard model for interconnected systems, our understanding of graphs is still limited. Most notably we do not have models that can characterize these graphs. Such models are crucial, since they can provide insights into generative processes, properties, and evolution of these graphs; enable anomaly detection; and guide statistical sampling Moreover due to unavailability of real data, generative models are critical for developing better algorithms at various scales and properties. We propose the Blocked Two-level Erdos-Renyi (BTER) model, which is motivated by two observations on real-world graphs: skewed degree distributions (few nodes with very high degrees and many nodes with small degrees) and high clustering coefficients (two nodes are more likely to be connected if they have common neighbors). We have observed that these two properties imply existence of specific structures in the graph, in the form of tightly connected communities of vertices with similar degrees. Exploiting this property, we take a degree distribution as input and start with forming such communities. Then we add edges randomly to preserve the given degree distribution. Our initial results show striking similarities between the generated graph and the original. (Received September 20, 2011)

1077-68-1657 **Patricia D. Hough*** (pdhough@sandia.gov). *Simulation-Based Optimization and Uncertainty Quantification Methods and Software at Sandia National Labs.*

Many questions arise regarding the design and performance of engineered systems. Time and resource constraints make it impossible to conduct the number of physical experiments needed to fully understand multiple designs or all possible operating conditions. Therefore, physics-based modeling and simulation are used to perform much of the required analysis. I will give a very brief introduction to how computational mathematics supports these simulation efforts and then discuss in more detail the roles of nonlinear optimization and uncertainty quantification in conducting advanced simulation-based analysis. I will describe some of the methods we have developed as well as the software framework through which they are deployed. Finally, I will give some examples of our experiences and lessons learned applying these methods to engineering problems at the lab. (Received September 20, 2011)

1077-68-1790 **Anastasios Sidiropoulos*** (sidiropo@gmail.com), 6045 S. Kenwood Ave. Office 421, Chicago, IL 60637. *Optimal stochastic planarization.*

We show that any graph of genus $g > 0$ can be stochastically embedded into a distribution over planar graphs with distortion $O(\log g)$. Given a drawing of the graph into a genus-g surface, the embedding can be computed in polynomial time. Among other consequences, our result implies a black-box reduction for a large class of geometric optimization problems from instances on genus-g graphs, to corresponding ones on planar graphs, with a $O(\log g)$ loss factor in the approximation guarantee. (Received September 20, 2011)

1077-68-1943 **Mikhail Belkin**, **Qichao Que**, **Yusu Wang*** (yusu@cse.ohio-state.edu) and **Xuanyuan Zhou**. *Toward understanding complex data: graph Laplacians on singular manifolds.*

In manifold learning, algorithms based on graph Laplacian constructed from data have received considerable attention both in practical applications and theoretical analysis. Much of the existing work has been done under the assumption that the data is sampled from a manifold without boundaries and singularities or that the functions of interest are evaluated away from such points. At the same time, it can be argued that singularities and boundaries are an important aspect of realistic data. For example, singularities appear when two different manifolds intersect or if a process undergoes a "phase transition", changing non-smoothly as a function of a parameter.

In this talk I will present some results from our recent study of the behavior of graph Laplacians on singular manifolds. In particular, we consider boundaries and two types of singularities: intersections, where different manifolds come together and sharp "edges", where a manifold sharply changes direction. We show that the behavior of graph Laplacian near these singularities is qualitatively different from that in the interior of the manifolds. Understanding such behavior will lead to interesting applications in learning and analyzing complex data. This is joint work with M. Belkin, Q. Que, and X. Zhou. (Received September 21, 2011)

1077-68-1967 **Josh Koslosky**, **Stacey Levine** and **Glenn Sidle*** (sidleg@duq.edu), 440 College Hall, Department of Mathematics & Computer Science, Duqusne University, Pittsburgh, PA 15282. *Image Fusion Using Gaussian Mixture Models.* Preliminary report.

In recent years, many image processing tasks such as denoising, inpainting, and deblurring have been solved by finding optimal sparse image representations in a (possibly redundant) dictionary. Yu, Sapiro, and Mallat have shown that related representations can be found using Gaussian Mixture Models (GMMs). In this talk we demonstrate how the GMM approach can easily be applied to solve the image fusion problem, and compare some of its results to those using sparse and redundant image representations. (Received September 21, 2011)

1077-68-2091 **Daniele Micciancio*** (daniele@cs.ucsd.edu), UCSD, 9500 Gilman Dr., Mail Code 0404, La Jolla, CA 92093. *Lattice Cryptography and Pseudorandomness.*

Most lattice cryptography is based on the evaluation of simple linear functions like $f_a(x_1,\ldots,x_n)=\sum_i a_i\cdot x_i$, where the x_i are small integers and the a_i are randomly chosen elements from an abelian group G which describe the function f_a. The versatility of lattice cryptography in the solution of a wide range of security problems comes from the fact that, not only the function f is typically one-way (i.e., computationally hard to invert), but it also produces a pseudorandom output: it is computationally hard to distinguish $(a_1,\ldots,a_n,f_a(x_1,\ldots,x_n))$ from a randomly chosen sequence of $n+1$ group elements. A fundamental question in lattice cryptography is: for what choices of the group G and input distribution $(x_1,\ldots,x_n)$, it is possible to prove that if f is a one-way function, then its output is pseudorandom? In this talk I will survey the current state of the art regarding this question, present an overview of the known techniques used in the study of this problem, and describe the main open problems in the area. (Received September 21, 2011)

1077-68-2114 **Primoz Skraba*** (primoz.skraba@ijs.si), Artificial Intelligence Laboratory, Jamova 39, 1000 Ljubljana, Slovenia. *Computing Well Diagrams for Vector Fields in* $\mathbb{R}^n$.

The well diagram is related to, but different from the more well-known persistence diagram: given a mapping $f:\mathbb{X}\to\mathbb{Y}$ and a subspace $A\subseteq\mathbb{Y}$, the well diagram encodes the robustness of the homology of $f^{-1}(A)$ with respect to perturbations of the mapping f. Except for a few special cases, there is no general method known to compute a well group. In this talk, I will focus on computing the well diagram for a vector field: mappings with the form $f:\mathbb{R}^n\to\mathbb{R}^n$ in $\mathbb{R}^n$ where $A=\{0\}$. The well diagram is interesting because it is both a quantitative and a stable property of the zeros of the vector field, which are also the critical points of the multivariate function. In this talk, I will show how the rank of a well group is determined by the topological degree of an appropriate mapping, leading directly to a fast algorithm. With the fast algorithm in hand, I will show examples of computed well diagrams for various vector fields in different dimensions as well as discuss extensions to time-varying scenarios and applications of these techniques to other fields, such as visualization. (Received September 21, 2011)

1077-68-2149 **Bob Chen*** (b2chen@ucsd.edu), **Francine Blanchet-Sadri** and **Sinziana Munteanu**. *Subword Languages of Infinite Partial Words.*

Let A be a finite alphabet; an infinite full word is a sequence over A. A partial word is a word that may contain wildcard characters, which match any letter in A. A subword of an infinite word w is a finite full word that matches a substring of w. The set of all subwords of w is the subword language of w. In this paper we give necessary and sufficient conditions for a language over A to be the subword language of an infinite word. In this case, we also construct a representing word for A, and show that in some cases the representation is unique. (Received September 22, 2011)

1077-68-2203 **Prasad Tetali***, 686 Cherry St., Atlanta, GA 30332-0160. *Approximaing Minimum Linear Ordering Problems.* Preliminary report.

We introduce the Minimum Linear Ordering Problem (MLOP): Given a nonnegative set function f on a finite set V, find a linear ordering on V such that the sum of the function values for all the suffixes is minimized. This problem generalizes well-known problems such as the Minimum Linear Arrangement, Min Sum Set Cover, Minimum Latency Set Cover, and Multiple Intents Ranking. Extending a result of Feige, Lovász, and Tetali

(2004) on Min Sum Set Cover, we show that the greedy algorithm provides a factor 4 approximate optimal solution when the cost function f is supermodular. We also present a factor 2 rounding algorithm for MLOP with a monotone submodular cost function, using the convexity of the Lovász extension.

In addition, we provide a randomized rounding algorithm for the Min Sum Vertex Cover problem of factor 1.79, improving over the factor 2 algorithm described by Feige, Lovász, and Tetali (2004). This is joint work with Satoru Iwata (Kyoto University) and Pushkar Tripathi (Georgia Tech.) (Received September 21, 2011)

1077-68-2460 **Erin Chambers*** (`echambe5@slu.edu`). *Computing interesting topological features on surface embedded graphs.*

Recently, there have been many algorithms developed for surfaced embedded graphs. In general, these algorithms exploit the extra information gained from an embedding on some underlying surface to speed up computations. In particular, problems which compute non-trivial cycles (either under homology or homotopy) have been of interest, particularly since they have such natural applications in graphics. These problems also have interesting connections to computing maximum flows or minimum cuts, which is a classical optimization problem with numerous applications. We will survey recent techniques and results in this area. (Received September 22, 2011)

1077-68-2755 **Erik D. Demaine*** (`edemaine@mit.edu`), MIT CSAIL, 32 Vassar St., Cambridge, MA 02139. *Recent Results in Computational Geometry.*

Computational geometry is the study of algorithms that compute, analyze, and manipulate geometric structures—typically, sets of points, segments, and polygons in 2D or 3D—with guaranteed performance and quality. For example, how can we design optimal origami that folds the smallest possible square of paper into a desired 3D surface? When and how can we accurately reconstruct a 3D surface given just a set of points on the surface measured by a 3D scanner? How can we quickly detect when moving vehicles in a video game collide and thus need their physical reaction to be computed? How can we triangulate an airfoil while guaranteeing that all triangles are close to equilateral, to enable scientific computation? How can we efficiently compute the shortest route from one point on a map to another, and when drawing the map, which city names should we print while avoiding overlaps between the labels? All of these questions have been (at least partially) answered by computational geometry, with mathematical theorems about computational algorithms. This talk aims to sample a breadth of recent results in this exciting field.

Those who find the field interesting and want to see more in depth should check out the SIAM Minisymposium on Computational Geometry (Thursday at 8-11am). (Received September 22, 2011)

1077-68-2759 **Peter W. Shor*** (`shor@math.mit.edu`), Room 2-369, 77 Mass. Ave., Cambridge, MA 02139. *Quantum Money from Knots.*

Quantum money is a cryptographic protocol in which a mint can produce a quantum state, anyone (with a quantum computer) can verify that the state came from the mint, and nobody, even knowing the verification procedure, can copy the quantum state. We present a concrete quantum money scheme based on quantum superpositions of knot diagrams that encode oriented links having the same polynomial-time computable knot invariant (such as the Alexander polynomial). We will try to distill what kinds of classical algorithms for manipulating knots and knot diagrams would permit the breaking of this protocol for quantum money. This is joint work with Edward Farhi, David Gosset, Avinatan Hassidim and Andrew Lutomirski. (Received September 22, 2011)

1077-68-2919 **Glencora Borradaile**, **Jennifer Iglesias**, **Theresa Migler**, **Antonio Ochoa*** (`aochoa@csupomona.edu`), **Gordon Wilfong** and **Lisa Zhang**. *Egalitarian Graph Orientations.*

Given an undirected graph, one can assign directions to each of the edges of the graph, thus *orienting* the graph. We consider the problems of orienting a graph so that the resulting orientation achieves an egalitarian distribution of indegrees among its vertices and finding a strongly-connected orientation that minimizes the maximum indegree. Specifically, we present polynomial-time algorithms for: finding an orientation that minimizes the lexicographic order of the indegrees and finding a strongly-connected orientation that minimizes the maximum indegree. (Received September 23, 2011)

70 ► Mechanics of particles and systems

1077-70-1960 **Dan Li*** (dli@math.fsu.edu), 208 Love Building 1017 Academic Way, Tallahassee, FL 32306. *The algebraic geometry of Harper operators.*

Following an approach developed by Gieseker, Knörrer and Trubowitz for discretized Schrödinger operators, we study the spectral theory of Harper operators in dimension two and one, as a discretized model of magnetic Laplacians, from the point of view of algebraic geometry. We describe the geometry of an associated family of Bloch varieties and compute their density of states. Finally, we also compute some spectral functions based on the density of states.

We discuss the difference between the cases with rational or irrational parameters: for the two dimensional Harper operator, the compactification of the Bloch variety is an ordinary variety in the rational case and an ind-pro-variety in the irrational case. This gives rise, at the algebro-geometric level of Bloch varieties, to a phenomenon similar to the Hofstadter butterfly in the spectral theory. In dimension two, the density of states can be expressed in terms of period integrals over Fermi curves, where the resulting elliptic integrals are independent of the parameters.

In dimension one, for the almost Mathieu operator, with a similar argument we find the usual dependence of the spectral density on the parameter, which gives rise to the well known Hofstadter butterfly picture. (Received September 21, 2011)

1077-70-2090 **Alexander Panchenko*** (panchenko@math.wsu.edu) and **Lyudmyla Barannyk**. *Mesoscopic continuum mechanics of particle systems.* Preliminary report.

The main question addressed in the talk is how to obtain closed form continuum equations governing spatially averaged dynamics of many-particle systems. The underlying ODEs are classical Newton equations of motion. The continuum balance equations for the average density, momentum, and energy were derived by Noll, Hardy, Murdoch and others. These equations are exact, but they do not form a continuum model in the true sense of the word: calculation of stress and heat flux requires solving the underlying ODE system. To produce continuum equations that can be simulated without resolving particle dynamics, we developed a closure method based on the use of regularized deconvolutions. We also present results of numerical experiments showing good agreement between our closed form flux approximations and their exact counterparts. (Received September 21, 2011)

1077-70-2598 **Gareth E Roberts*** (groberts@radius.holycross.edu), **Marshall Hampton** (mhampton@d.umn.edu) and **Manuele Santoprete** (msantoprete@wlu.ca). *Relative Equilibria in the Four-Vortex Problem with Two Pairs of Equal Vorticities.* Preliminary report.

We consider the set of relative equilibria in the four-vortex problem for which two pairs of vortices have equal strength, that is, $\Gamma_1 = \Gamma_2 = 1$ and $\Gamma_3 = \Gamma_4 = m$ where $m \in \mathbb{R} - \{0\}$ is a parameter. Our main result is that for $m > 0$, the convex configurations all contain a line of symmetry, either a rhombus or an isosceles trapezoid. The rhombus family exists for all m but the isosceles trapezoid case exists only for m positive. In fact, an asymmetric convex family exists when $m < 0$. In contrast with the Newtonian 4-body problem, where the main symmetry result stated above is still unproven, the equations in the vortex case are simpler and allow a complete classification of all solutions. (Received September 22, 2011)

74 ► Mechanics of deformable solids

1077-74-230 **Hui Li*** (huili@math.umn.edu), 127 Vincent Hall, 206 Church St. Se., Minneapolis, MN 55455. *The von Kármán theory for incompressible elastic shells.*

Starting from the 3d nonlinear elasticity, we rigorously derive the von Kármán thin film theory for incompressible materials. In case of thin plates, the Euler-Lagrange equations of the limiting energy functional give the incompressible version of the classical von Kármán equations, obtained formally in the limit of Poisson's ratio $\nu \to 1/2$. Our analysis applies as well to more general case of shells, i.e. thin films with midsurface of arbitrary geometry, as long as they satisfy the following approximation property: C^3 first order infinitesimal isometries are dense in the space of all $W^{2,2}$ infinitesimal isometries. The class of surfaces with this property includes: subsets of $\mathbb{R}^2$, convex surfaces, developable surfaces and rotationally invariant surfaces. Our analysis relies on the modern methods of calculus of variations and analysis.

This is a joint work with Marta Lewicka. (Received September 01, 2011)

1077-74-250 **Meredith Hegg*** (mhegg1@temple.edu), mhegg1@temple.edu. *Exact Results for Effective Tensors of Fiber-Reinforced Elastic Composites.*

Predicting the effective elasticity of a composite material based on the elasticity of the constituent materials is extremely difficult, even when the microstructure is known. However, there are special cases, called exact relations, where certain properties in the constituents will be maintained in the composite regardless of microstructure. In a related situation, sometimes two composites that have the same microstructure but different constituent materials will have related effective tensors. In this case we say that the tensors are linked. In this work we apply the general theory of exact relations and links to find all such results for polycrystalline fiber-reinforced elastic composites. (Received September 21, 2011)

1077-74-516 **Anna Zemlyanova*** (azem@math.tamu.edu). *The effect of a surface tension on the stress field near a curvilinear crack.*

We consider a thin plate with a curvilinear crack under the action of in-plane stresses. A linear elasticity model is assumed for the behavior of the material of the plate in the bulk. A non-linear boundary condition with the consideration for a surface tension dependent on the curvature of the crack is given on the crack surface. Using Muskhelishvili's formulas for stresses and displacements and Savruk's integral representations of complex potentials the problem is reduced to a complex singular integrodifferential equation. The regularization of this equation by reduction to the system of two real Fredholm equations is presented. (Received September 06, 2011)

1077-74-1305 **Matthias Augustin*** (augustin@mathematik.uni-kl.de), University of Kaiserslautern, Department of Mathematics, P. O. Box 30 49, 67653 Kaiserslautern, Germany. *Stress field simulations in geothermal reservoirs.* Preliminary report.

It is a well known problem that the fossil fuel resources on earth are diminishing. New sources of energy, especially renewable ones, become more and more important. One of the most promising of these renewables is the heat stored in the earths crust which is used by so-called geothermal facilities. But as with every technology, there are not only benefits but also risks such as depletion of the reservoir, reducing of productivity or seismic events.

In order to minimize the risks, knowledge of the mechanical stresses within the reservoir is crucial. The stress field influences productivity of a reservoir via fracture stimulation as well as fracture growth and determines whether seismic events occur or not. In this talk, the underlying differential equations for modeling the stress field in rocks are presented. Based on these, boundary integral equations (BIE) are developed. These BIE are discussed and similarities to single and double layer approaches which are well-known for the Laplace equation are shown. Further on, numerical solution schemes to simulate stress fields in geothermal reservoirs will be introduced. (Received September 19, 2011)

1077-74-2143 **Charles Yves Daly*** (cdaly4@gmu.edu). *Stability Analysis of Plate Deformation Equations Derived using the Hamiltonian Principle.*

Airplanes, helicopters, and the majority air-crafts rely heavily on wings, which can be modeled by very thin malleable plates. Through the use of the Kirchoff-Love plate theory model we intend to derive the necessary and sufficient conditions for stability of a uniformly dense three dimensional plate. Working with this model, the Green's stress and strain tensor, and the Hamiltonian Principle we derived a set of differential equations whose stability will be examined in thorough detail through the use of an energy norm and stability analysis.
(Received September 21, 2011)

1077-74-2807 **Nicholas O. Kirby*** (nicholas.kirby@uky.edu). *Continuum equations from a model of step-flow.*

In the step-flow regime a crystal surface consists of flat regions, called terraces, separated by steps of atomic height. These steps move due to the attachment of atoms from the adjacent terraces. We present a model of this process in which step motions automatically satisfy the second law of thermodynamics. This model includes a coupling between adjacent terraces that is diffusive. Since the simulation of a large number steps can be computationally expensive, it is of interest to find a model in which the crystal surface is governed by a partial differential equation (PDE). We present the continuum limit of the step-flow model under consideration. The coupling at the step-flow level leads to a continuum model which takes the form of a system of PDE. (Received September 22, 2011)

76 ► Fluid mechanics

1077-76-95 **Ranadhir Roy*** (rroy@utpa.edu), 1201 West University Drive, Edinburg, TX 78539, and **Daniel N Riahi** (rroy@utpa.edu), 1201 Unversity Drive, Edinburg, TX 78539. *Unsteady blood flow in an artery with an overlapping stenosis.*

We consider the problem of unsteady blood flow in an artery and in the presence of an overlapping symmetric stenosis. The blood flow in the arterial tube is assumed to be a suspension of red cells in plasma. The present formulation makes use of the variable fluid viscosity modeling that takes into account the amount of the red cells in the blood fluid flow system. Using both analytical and computational methods, we determine the expressions for various quantities such as the leading order flow velocity, pressure gradient, impedance and shear stress at the throats and at the critical height, and we calculate dependence of these quantities on the temporal and spatial variables as well as on the frequency of the flow oscillation and the main parameters of the flow system. We find, in particular, that the higher value of the frequency can lead to higher values of the magnitude for the quantities such as the axial velocity, the impedance and the wall shear stress in the stenosis zone particularly if the stenosis is less mild. Key Words: arterial flow, blood flow, impedance, unsteady flow, shear stress. (Received July 25, 2011)

1077-76-253 **Anna Zemlyanova*** (azem@math.tamu.edu), Department of Mathematics, Mailstop 336, Texas A&M University, College Station, TX 77843. *A fluid-structure interaction problem for a supercavitating elastic curvilinear foil.*

A problem of a fluid-structure interaction is considered for a curvilinear supercavitating thin elastic foil in a stream of ideal fluid. The Tulin single-spiral-vortex model is used to describe the closure of the cavity. The problem is decoupled with the help of the method of successive approximations. The conformal mapping method together with the Riemann-Hilbert approach is employed for the solution of the fluid mechanics problem. The equations of the thin shell theory are used to describe the deformation of the curvilinear foil. The covergence of the method of successive approximations is investigated. The numerical results including the cavity profile and the displacements of the elastic foil are obtained. (Received August 16, 2011)

1077-76-546 **Kara L Maki*** (kmaki@rit.edu) and **Satish Kumar** (kumar030@umn.edu). *Drying of spreading droplets of colloidal suspensions.*

When a coffee droplet dries on a countertop, a dark ring of coffee solute is left behind, a phenomenon often referred to as "the coffee-ring effect". A closely related yet less-well-explored phenomenon is the formation of a layer of particles, or skin, at the surface of the droplet. In this work, we explore the behavior of a mathematical model that can qualitatively describe both phenomena. We consider a thin axisymmetric droplet of a colloidal suspension on a horizontal substrate undergoing spreading and rapid evaporation. The lubrication approximation is applied, and the colloidal particles are allowed to influence droplet rheology through their effect on the viscosity. By describing the transport of the colloidal particles with the full convection-diffusion equation, we are able to capture depthwise gradients in particle concentration and thus describe skin formation, a feature neglected in prior models of droplet evaporation. Whereas capillarity creates a flow that drives particles to the contact line to produce a coffee-ring, Marangoni flows can compete with this and promote skin formation. Increases in viscosity due to particle concentration slow down droplet dynamics, and can lead to a significant reduction in the spreading rate. (Received September 07, 2011)

1077-76-647 **Dambaru Bhatta*** (bhattad@utpa.edu), 1201 West University Drive, Edinburg, TX 78539. *Computation of the linear and first-order solid fractions for a magneto-convective flow in an active mushy layer.*

We consider a horizontal mushy layer which is treated as an active porous media with variable permeability and in presence of a magnetic field. Solid fraction plays a crucial role in the formation of chimneys during solidification of binary alloys. The flow in the mushy layer can be described by a system of partial differential equations. Using normal mode approach, we obtain a system of ordinary differential equations for the dependent variables. We present our numerical results for linear and first-order solutions for solid volume fraction. (Received September 09, 2011)

1077-76-683 **Wanping Li*** (liwp48@yahoo.com.cn), #1037, Luoyu Road, Hongshan District, Wuhan, Hubei 430074, and **Shuangxi Guo**. *Inverse energy cascade and self-organization in 2-D turbulent channel flow.*

Inverse energy cascade and self-organization in 2-D turbulent channel flow have been investigated in the presentation. Direct numerical simulations (DNS) of forced 2-D turbulent channel flow are performed with the pseudo-spectral method. The results indicate that an obvious self-organization of vortices is existent in 2-D turbulent channel flow. The adjacent and same sign vortices interact with each other and merge to larger ones, and a pair of opposite sign and the largest vortices is formed and maintained ultimately. At the same time, the inverse energy transfer from small structures to larger ones is along with the self-organization process. The differences of mean velocity profiles of 2-D and 3-D turbulent channel flow, and the characteristics of the oceanic circulation like in the Gulf of Aden of Indian Ocean can be explained with the theory of inverse energy cascade and self-organization mechanism. (Received September 10, 2011)

1077-76-705 **Shu-Ming Sun*** (sun@math.vt.edu), Department of Mathematics, Virginia Tech, Blacksburg, VA 24061. *Stability of Solitary Waves on Water of Finite Depth.*

The talk will discuss recent development on the stability of two- and three-dimensional solitary waves on the surface of water with finite depth using various model equations or exact Euler equations. It was known that these equations have solitary-wave solutions and the stability of these waves in many problems is still open. Here, some stability results for these waves will be addressed, such as transverse instability, conditional stability or asymptotic linear and spectral stability. (Received September 10, 2011)

1077-76-809 **Leon Kaganovskiy*** (LEONKAG@GMAIL.COM), 1233 E 19TH ST APT 6J, BROOKLYN, NY 11230, and **Robert Krasny**. *3-D Vortex Rings Instabilities and Collision: Numerical Approach.*

A panel method is presented for computing vortex sheet motion in 3D flow. The sheet is represented as a set of quadrilateral panels with a quad-tree structure. The panels have active particles that carry circulation and passive particles used for adaptive panel subdivision. The method is applied to compute the azimuthal instability of a vortex ring and head on as well as off-center vortex collision. Vorticity isosurfaces are investigated. Results are presented showing the deformation of the ring axis and the presence of local axial flow in the core of the ring as seen in experiments. (Received September 13, 2011)

1077-76-1170 **Walter A Strauss***, wstrauss@math.brown.edu. *Pressure Beneath a Stokes Wave.*

A Stokes wave is a irrotational incompressible periodic 2D steady water wave under the influence of gravity. It is well-known that there is a one-parameter family of such waves. I will prove that the pressure in the fluid strictly increases both (i) with depth and (ii) horizontally toward the crest line. Numerics show that this property of the pressure is sometimes true and sometimes false for rotational flows. (Received September 17, 2011)

1077-76-1172 **Walter A. Strauss*** (wstrauss@math.brown.edu). *Water Waves with Discontinuous Vorticity.*

Classical periodic steady water waves are considered with vorticity that may have jumps or other discontinuities. Thus the velocity of the fluid is not C^1 and the formulation must be a weak one. It is proven that there are waves of large amplitude that bifurcate from a laminar flow. The main tools are classical elliptic theory and degree theory. (Received September 17, 2011)

1077-76-1190 **Kenichi Maruno*** (kmaruno@utpa.edu), 1201 West University Drive, Edinburg, TX 78539, and **Yuji Kodama**, **Hidekazu Tsuji** and **Bao-Feng Feng**. *Two-dimensional interaction of weakly nonlinear solitary waves in shallow water: Mach reflection for the Benney-Luke equation and the KP equation.*

Understanding two-dimensional interaction of nonlinear solitary waves has been an important problem in various fields of physics. In shallow water region, weakly nonlinear water waves are described by the Benney-Luke equation. Assuming weak two-dimensionality, the KP (Kadomtsev-Petviashvili) equation is derived. The KP equation is known as one of integrable systems, and its solutions are written in explicit forms. Various interesting solutions have been found recently in the KP equation, so it is very nice if we can use these exact solutions to understand real water wave phenomena. However, the Benney-Luke equation is not integrable and it is not so clear whether the KP equation is applicable to real shallow water wave phenomena. Thus we need to clarify the difference of solutions of the Benney-Luke and the KP. We propose a method to obtain an approximate 2 soliton solution for the Benney-Luke equation. This method is based on the Hilota's bilinear method and the reductive perturbation method. Using this 2-soliton solution, we compute critical angles of transitions between different solitary wave interactions. These critical angles are confirmed by using direct numerical simulations. We also discuss the application to Mach reflection in shallow water waves. (Received September 17, 2011)

1077-76-1250 **Chongsheng Cao** and **Aseel Farhat*** (afarhat@math.uci.edu), afarhat@math.uci.edu, and **Edriss S. Titi**. *On the Global Well-posedness of a Simplified Reduced Rayleigh-Bénard Convection Model.*

In plasma physics, the 3D Hasegaw-Mima equation is one of the most fundamental models that describe the electrostatic drift waves. In the context of geophysical fluid dynamics, the 3D Hasegawa-Mima equation appears as a simplified model of a reduced Rayleigh-Bénard convection model that describes the motion of a fluid heated from below. Investigating the 3D Hasegawa-Mima model is challenging even though the equations look simpler than the 3D Euler equations. Inspired by these models, we introduce and study a simplified mathematical model that has a nicer mathematical structure. We prove the global existence and uniqueness of solutions of the 3D simplified model as well as a continuous dependence on the initial data result. These results are one of the first results related to the 3D Hasegawa-Mima equation. (Received September 22, 2011)

1077-76-1370 **Sherif M Azeez** (sazeez10@gmail.com), Department of Mathematical Sciences, 1200 N. DuPont Highway, Dover, DE 19901, **Dawn A Lott*** (dlott@desu.edu), Department of Mathematical Sciences, 1200 N. DuPont Highway, Dover, DE 19901, and **Pablo Suarez** (psuarez@desu.edu), Department of Mathematical Sciences, 1200 N. DuPont Highway, Dover, DE 19901. *Analytic solution of the effect of slip condition on magnetohydrodynamic Stokes flow due to an oscillating wall.*

In this paper, we study two dimensional parallel magnetohydrodynamic (MHD) slip flow of an unsteady, viscous, incompressible, electrically conducting fluid bounded by an oscillating wall. We present a closed form analytical solution for the steady periodic and transient velocity. The analytical solution was obtained using the Laplace transform method. The effect of slip and the magnetic field parameters on the Stokes flow was analyzed. It was found that the oscillations in the steady periodic velocity decrease with increase in the slip and the magnetic field parameters. The effect of increasing initial frequency of oscillation increases the period of oscillation in space and is only apparent in short time. (Received September 19, 2011)

1077-76-1394 **Bree Cummins*** (bcummins@tulane.edu). *A regularization technique for oscillating slender bodies in low Reynolds number flow.*

I present a regularization technique for the oscillatory Stokes equations in three dimensions in which the regularization parameter is related to the width of a slender body. The solution to the regularized equations represents the oscillations of a slender body in vanishing Reynolds number flow, or the motion of a slender body through porous media. I discuss the application of this method to a sensory system in crickets and to the feeding appendages of copepods. (Received September 19, 2011)

1077-76-1470 **Hoa V Nguyen*** (hoa.nguyen@tulane.edu). *Hydrodynamic effects of spines: A different spin.*

When placed in a simple linear gradient of velocity, elongate objects, including many phytoplankton, spend the most time with their longest axis aligned with the flow vectors, but they tumble with a frequency that depends on their ratio of length to width. This tumbling is important because it causes relative motion of phytoplankton cells and nearby fluid, thinning chemical boundary layers and thereby speeding diffusive supply of nutrients to the cells, and it also influences phytoplankton encounter rates with grazers. For both oblate and prolate spheroids, shapes resembling a smoothed discus and football, respectively, tumbling frequency can be predicted accurately from simple theory. Many planktonic organisms, however, have complex shapes produced by spines that extend in varying numbers, at varying angles, and to varying distances from the body or cell. We used numerical models to examine how rigid, spiny phytoplankton cells tumble in a simple linear gradient of velocity. We found that their tumbling was in general well approximated by that of the smallest oblate or prolate spheroid that could contain both the cell and its spines. Investigations that examine the tumbling of cells with flexible spines remain to be done. (Received September 19, 2011)

1077-76-1557 **Xiaojun Wang*** (xjwang08@vt.edu), 822 Claytor Sq., Blacksburg, VA 24060, and **Michael Renardy**. *On a PDE system that governs the boundary layers system for complex fluids.*

We discuss the well-posedness of a nonlinear PDE system that describes boundary layers in complex (non-Newtonian) fluids. The boundary layer theory for Newtonian fluids, based on Navier-Stokes equations, was developed by Prandtl more than one hundred years ago, addressing the existence of a thin velocity transition layer next to a solid boundary. Boundary layers arise in many applications in aerodynamics and fluid dynamics, but there is still a lack of fundamental understanding of the corresponding boundary layer equations, namely Prandtl's system. Indeed, it has recently been shown that these equations are not necessarily well-posed.

Fluids with complex microstructure, such as polymers, suspensions,and granular materials, abound in biological science, materials sciences as well as in many industrial processes. In the limit of high elasticity (Weissenberg number), a boundary layer problem similar to Prandtl's arises. We derive the system of equations to describe the behavior near the boundary. By taking advantage of the Lagrangian coordinates, we show that the non-Newtonian boundary layer system is actually well-posed. (Received September 21, 2011)

1077-76-1864 **Joseph E Hibdon, Jr*** (jhibdon@gmail.com), 1208 Hull Terrace, Apt#3, Evanston, IL 60202, and **Moshe Matalon**, Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, IL 61801. *Effect of Gravity in Diffusive Thermal Instabilities of Diffusion Flames.*

Non-premixed or diffusion flames are the type of flames observed in multiple systems from a relatively simple candle flame or the complexities of a forest fire. With an increase in populations that are moving into areas prone to forest fires and an increase to have more efficient furnaces, understanding the effect the environment has on diffusion flames is essential. To have a better understanding of how these flames behave we examine the effect of convection and gravity on diffusive thermal instabilities. The configuration adopted is the planar unstrained flame with a bulk flow directed toward the reaction zone from either the fuel or the oxidizer sides. The model also allows for the no bulk flow case, where the reactants reach reaction zone purely by diffusion. Diffusive-thermal instabilities were examined for several limiting cases. In the absence of a flow and no gravity the only mode of instability observed are planar oscillations, when convective flow is introduced a general increase in the frequency of the oscillations occurs. The addition of gravity in the absence of a convective flow leads to cellular instabilities where unconditionally stable flames persist otherwise and has a relatively minor effect on diffusive-thermal instabilities with a convective flow. (Received September 21, 2011)

1077-76-1898 **Gregory R Baker*** (baker@math.ohio-state.edu), Dept Mathematics, Ohio State University, 231 W 18th Ave, Columbys, OH 43210, and **Chao Xie**. *Singularities in the complex plane for deep water waves.*

Water waves are perhaps the most notable feature of the planet, and they have occupied the attention of scientists since the birth of civilization. Yet they remain incompletely understood. Despite recent theoretical advances, the generic mathematical behavior of water waves eludes description. I will present a different view of water waves traveling in two-dimensions, a view based on the relationship between the curvature and the arclength. The curvature has simple poles in the complex arclength plane that travel about while retaining their form. They can approach closely to the real axis during wave breaking and are associated with the tip of the plunging breaker. A different view of wave breaking is the presence of a square-root singularity in the surface height as a function of the horizontal coordinate that reaches the real axis in finite time when the slope becomes vertical. Even in the absence of wave breaking, these singularities are present and strongly affect the wave spectra. (Received September 21, 2011)

1077-76-1969 **M Taylan Sengul*** (msengul@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405, and **Henk Dijkstra** and **Shouhong Wang**. *Dynamic Transitions and Hexagonal Patterns in Surface Tension Driven Convection.*

In this talk, we study dynamic transitions and the hexagonal pattern formation in the surface tension driven convection. It is shown that as the Marangoni number crosses the critical threshold, the system always undergoes a dynamic transition, with the types of transition dictated by some computable nondimensional parameters. In addi- tion, the formation and classification of hexagonal patterns are precisely determined by metastable states and their basin of attractions. (Received September 21, 2011)

1077-76-2077 **Antonio Mastroberardino*** (axm62@psu.edu), 4205 College Drive, Erie, PA 16563. *Mixed convection in viscoelastic flow due to a stretching sheet.* Preliminary report.

I will present an analysis of mixed convection boundary layer flow of an incompressible viscoelastic fluid - Walters liquid B - over a continuously stretching surface embedded in a porous medium. The momentum equation includes the effect of the buoyancy force due to free convection. The thermal equation includes the effects of radiation, viscous dissipation and internal heat generation/absorption. I will consider two general types of non-isothermal boundary conditions, namely, prescribed surface temperature and prescribed heat flux. The governing partial differential equations for the fluid flow and temperature are reduced to a nonlinear system of ordinary differential equations which are solved analytically using the homotopy analysis method (HAM). I will discuss the convergence of the HAM solutions and then the effects of various parameters on the skin friction coefficient and wall heat transfer. (Received September 21, 2011)

1077-76-2164 **Joanna A Bieri***, 503 S Center St, Redlands, CA 92373. *Characteristics of Non-symmetric Edge Flames in Narrow Channels.*

Two streams, one containing fuel and the other oxidizer, are flowing into a narrow channel where they mix and support an edge flame at some distance downstream. Our analysis is based on a model that assumes a constant-density flow. Both steady and time dependent solutions are found numerically. When the mixture strength is not equal to one, the flame is non-symmetric, the premixed edge is located away from the center of the channel, and the diffusion flame is curved along the stoichiometric surface. In some cases the flame is located very close to the channel wall and the trailing diffusion flame curves toward the wall. This could act as a possible source of heating for extinction re-ignition patterns seen in experiment. We consider the effects of underlying flow rates and heat losses to the channel walls. (Received September 21, 2011)

1077-76-2301 **Xuesong Wu*** (x.wu@ic.ac.uk), Department of Mechanics, School of Mechanical Engineering, Tianjin University, Tianjin, 300072, Peoples Rep of China. *Some Integro-differential Equations Describing Nonlinear Evolution of Instability Waves on Shear Flows.*

Transition of a laminar shear flow to a turbulent state is a complex nonlinear phenomenon. Crutical to its understanding and prediction is the nonlinear evolution of initially small-ampltude perturbations, or the so-called instability modes. In the past two decades, some interesting integro-differential equations were derived from the Navier-Stokes equations by using sophisticated asymptotic analysis. A common novel feature is that they all consist of history dependent nonlinear terms. The physical context of these equations and their main mathematical properties will be reviewed with a call for more attention to these equations from applied analysists. The focus will be on a set of equations which describe the ineteraction and coupling of the small- and large-scale motions. Numerical solutions will be presented to demonstrate that they are able to capture spectral broadening and randomization of free shear layers as observed in experiments. (Received September 22, 2011)

1077-76-2481 **Hyunsun Lee*** (hlee9@fsu.edu), **Ali Uzun** and **M. Yousuff Hussaini**. *Identifying jet noise source based on high-fidelity numerical simulations of round and chevron jet flows.*

An acoustic analogy using decomposition of the Lighthill source term to ten sub-terms is discussed based on two simulations of round jet and Chevron jet configurations, at Mach number 0.9 and Reynolds number 1×10^5. These sub-terms consist of density, velocity, vorticity and dilatation fields, presenting their mutual non-linear interactions.To understand aerodynamic noise generation mechanism, intrinsic links between turbulence and emitted sound waves, such as cross-correlation function, are necessary. This causality method is directly adopted to the LES data to identify fundamental noise sources by calculating the cross-correlation between each spatial sub-term in near field and acoustic pressure fluctuation at a far field position, showing its contribution on the noise generation. Three principal noise production terms, related to Laplacian of turbulence kinetic energy and divergence of Lamb vector, are witnessed and interpreted, showing encouraging agreement with previous predictions. The comparison of profiles between round and Chevron jet configurations potentially shed light on accessing better understanding on the mechanism of control devices. (Received September 22, 2011)

1077-76-2796 **Michael I Weinstein*** (miw2103@columbia.edu), 212 SW Mudd Building, Columbia University, New York, NY 10027. *Radiative decay of bubble oscillations in a compressible fluid.*

We consider the dynamics of a gas bubble in an unbounded, inviscid and compressible fluid with surface tension. Kinematic and dynamic boundary conditions couple the dynamics of bubble surface deformations to the dynamics of waves in the fluid. This system has a spherical equilibrium state, resulting from the balance of pressure at infinity and the gas pressure within the bubble. We study the linear decay estimates near this state. The analysis makes use of a general result on the Neumann to Dirichlet map for the wave equation, exterior to the sphere. Local energy decay is exponential in time, exp(-Gamma t). The rate is determined by scattering resonances, solutions to a non-selfadjoint spectral problem. The scattering resonances which limit the time-decay rate are of a high order multipole character, whose decay rate, Gamma, is exponentially small in the Mach number, epsilon, as epsilon tends to zero. In contrast the decay rate for spherically symmetric solutions is linear in epsilon, for epsilon small. This is joint work with A.M. Shapiro. (Received September 22, 2011)

78 ► Optics, electromagnetic theory

1077-78-343 **Justin Droba*** (drobajus@msu.edu). *Second Harmonic Generation at Metal/Dielectric Interfaces via Density Functional Theory.* Preliminary report.

Second harmonic generation (SHG), in which a material converts electromagnetic radiation at frequency ω to that at 2ω, is perhaps the simplest yet most widely studied nonlinear optical phenomenon. Following the convention used for dielectrics, the nonlinear behavior is traditionally expressed mathematically by introduction of a polarization term $\mathbf{P}^{\mathrm{NL}}$ into Maxwell's equations. Bloembergen *et al.* derived a simple expression for $\mathbf{P}^{\mathrm{NL}}$ using the hydrodynamic model for electrons, but this model leaves much to be desired mathematically and physically. Thus, instead of using this classical model, we compute the electron density using density functional theory (DFT) and use that to calculate the current within macroscopic Maxwell Equations. In this presentation, I will present the basic theory of this approach as well as some preliminary results for 1D current in a 2D Maxwell system. (Received August 24, 2011)

1077-78-1311 **John C Schotland*** (schotland@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Acousto-Optic Tomography and Related Inverse Problems.*

A method to reconstruct the optical properties of a highly-scattering medium from incoherent acousto-optic measurements is proposed. The method is based on the solution to an inverse problem for the diffusion equation and makes use of the principle of interior control of boundary measurements by an external wave field. Related inverse source problems are also considered. (Received September 19, 2011)

1077-78-2252 **J E Pina*** (jep.xyz@gmail.com). *Optimizing Plasmonic Effects for a More Efficient Nanoscale Biophotovoltaic Device.*

Biophotovoltaics utilize biological components from photosynthetic systems for the normal charge separation process in a photovoltaic device. The promise of such devices is great, as they are highly efficient in their biological environment at converting photons into free charge. However when utilized in artificial photovoltaic devices, their efficiency is quite low, even when compared with conventional solar cells. One way to increase their efficiency is to use plasmonic effects to augment the intensity of incident light in the charge separation area. Plasmonic effects occur when electromagnetic waves at a conductor-dielectric interface cause the oscillation of free elections relative to the atomic lattice, allowing the electrons to act as a plasma. In our current computational study, we are investigating the use of plasmonic effects with silver and gold to optimize the delivery of light to a film of bacterial photosynthetic reaction centers in an attempt to increase the efficiency of a biophotovoltaic nanodevice. (Received September 21, 2011)

80 ► Classical thermodynamics, heat transfer

1077-80-2766 **B S Tilley*** (tilley@wpi.edu), Dept. Mathematical Sciences, 100 Institute Rd, Worcester, MA 01609. *Mathematical Problems in Residential Geothermal Heating Systems.*

Although the promise of environmentally friendly, low-cost energy harvesting for heating and cooling of residential properties has been known for nearly 30 years, the adoption of the technology has been slow in the United States. These geothermal systems, known as ground-source heat pumps (GSHP), consist of a field of vertical boreholes in the ground with pipes carrying a heat transfer fluid into the earth to gain access to the stable year-round temperatures underground. However, a significant portion of the cost of these systems is in the installation of the pipes, with a return on investment on the order of 8-10 years. The main cost in the installation is the depth of the boreholes. We focus on this talk on systems with a concentric geometry. Fluid from the residence flows down the center tube, and returns in the annular region between the inner and outer tubes. In the case of an uniform annular spacing, spectral methods give a characteristic value that determines the length-scale over which thermal exchange takes place. This length is optimized when the gap thickness of the annulus is minimized. Preliminary results on variable annular thicknesses is also presented. This work is done in collaboration with the New England Geothermal Professionals Association (NEGPA). (Received September 22, 2011)

81 ► Quantum theory

1077-81-19 **Quan-Fang Wang*** (quanfangwang@yahoo.co.jp), Mechanical and Automation Engineering, The Chinese University of Hong Kong, Shatin, N. T., Hong Kong, Hong Kong. *High dimension control for quantum system.*

It is interesting for us to consider the approach of controlling quantum system in high dimension(2D,3D). This presentation is try to deal with quantum optimal control theory for the poly-particles system described by nonlinear Schrodinger equation. Especially, the computational approximate for simulation of controlling process will be executed in high dimension spatial cases.

The illustration of quantum control theory by the efficient numerical demonstration is shown for quantum systems with different physical parameters.

Hope wide application would be utilized to control quantum systems in real laboratory experiments. (Received May 29, 2011)

1077-81-646 **Richard H Warren***, Lockheed Martin Corporation, Bldg 100, Room U1238, P.O. Box 8048, Philadelphia, PA 19101. *Optimization Algorithms on a Quantum Computer.* Preliminary report.

Lockheed Martin Corporation has purchased a quantum computer. Quantum algorithms is one of the research areas that the Corporation is engaged in. This report is about initial progress. (Received September 09, 2011)

1077-81-745 **Faisal Shah Khan*** (faisal.khan@kustar.ac.ae), PO Box 127788, Abu Dhabi, United Arab Emirates, and **Simon J. D. Phoenix** (simon.phoenix@kustar.ac.ae), PO Box 127788, Abu Dhabi, United Arab Emirates. *Quantum Circuits at Nash Equilibrium.*

A multi-player, normal form game G is defined by a collection consisting of a function $\mathcal{G}$ together with its domain $\mathcal{D}$ and range $\mathcal{R}$, and sets $\mathcal{P}_i$ of the players non-identical preferences over the elements of $\mathcal{R}$. Players seek an"optimal outcome", that is, an element of $\mathcal{R}$ that best satisfies the constraints of their non-identical preferences. When an optimal outcomes exists, then an element of $\mathcal{D}$ that $\mathcal{G}$ maps into the optimal outcome is called a *Nash equilibrium.* Here, in the context of optimal control of a quantum system under given constraints, the quantum circuit model for quantum computing is cast in the preceding game-theoretic setting, and a notion of Nash equilibrium is defined with respect to which a quantum circuit is constructed. (Received September 12, 2011)

1077-81-785 **Eric Akkermans*** (eric@physics.technion.ac.il), Physics Department, Technion Israel Institute, Haifa, Israel. *Statistical mechanics and quantum field theory on fractal structures.*

Fractals define a new and interesting realm for a discussion of basic phenomena in Quantum Electrodynamics and Statistical Mechanics. This interest results from specific properties of fractals, e.g., their dilatation symmetry and the corresponding absence of Fourier mode decomposition. Moreover, the existence of a set of distinct dimensions characterizing the physical properties (spatial or spectral) of fractals make them a useful testing ground for dimensionality dependent physical problems.

We shall start by noting that the absence of Fourier transform on a fractal implies necessarily different notions of volume in direct and reciprocal spaces and thus the need to modify the Heisenberg uncertainty principle. Implications for field quantization and the definition of the notion of photon on a fractal will be further addressed.

We shall address specific problems including the behavior of the heat kernel and zeta functions on fractals and their importance in the expression of spectral properties in quantum field theory. Finally, we shall apply these results to specific problems such as thermodynamics of radiation by a fractal blackbody and a conjecture regarding the behavior of the non diagonal heat kernel. (Received September 12, 2011)

1077-81-870 **Viswanath Ramakrishna*** (vish@utdallas.edu), FO 35, 800 W. Campbell Rd, Richardson, TX 75080. *Remarks on Computing the Williamson Normal Form.*

The Williamson normal form is a canonical form for positive definite matrices, under conjugation by symplectic matrices. It plays an important role in classical and quantum mechanics, as well as in quantum optics and quantum information theory of continuous mode systems.

In this talk we will discuss an algorithmic approach to computing the Williamson normal form (in particular, to the the calculation of the symplectic matrix which achieves the form). The method is based on combining the so-called Schur- Constantinescu parametrization of positive matrices together with a quaternion based approach to the Schur canonical form of anti-symmetric matrices. Simplifications which occur, when the positive definite matrix has additional structure (e.g., Toeplitz) will also be presented. (Received September 13, 2011)

1077-81-984 **Istvan Heckenberger*** (heckenberger@mathematik.uni-marburg.de). *On an equivalence of categories of relative Yetter-Drinfeld modules.*

The structure theory and the classification of pointed Hopf algebras is greatly influenced by the Weyl groupoid action on categories of semisimple Yetter-Drinfeld modules. The Weyl groupoid was introduced first in a joint paper of Andruskiewitsch, Schneider and the presenter. In this talk a very general equivalence between categories of Yetter-Drinfeld modules is presented which explains the existence of the Weyl groupoid. The talk is based on joint work with H.-J. Schneider. (Received September 15, 2011)

1077-81-1273 **Sheng Xiong*** (sheng@temple.edu), Deaprtment of Math & Science, 1658 Kings Road, Jacksonville, FL 32209, and **Shimao Fan**, **Zhiyong Feng** and **Wei-Shih Yang**. *Convergence of quantum random walks with decoherence.*

In this paper, we study the discrete-time quantum random walks on a line subject to decoherence. The convergence of the rescaled position probability distribution $p(x,t)$ depends mainly on the spectrum of the superoperator $\mathcal{L}_{kk}$. We show that if 1 is an eigenvalue of the superoperator with multiplicity one and there is no other eigenvalue whose modulus equals 1, then $\hat{P}(\frac{\nu}{\sqrt{t}},t)$ converges to a convex combination of normal distributions. We give an necessary and sufficient condition for a $U(2)$ decoherent quantum walk that satisfies the eigenvalue conditions. We also give a complete description of the behavior of quantum walks whose eigenvalues do not satisfy these assumptions. Specific examples such as the Hadamard walk, walks under real and complex rotations are illustrated. For the $O(2)$ quantum random walks, an explicit formula is provided for the scaling limit of $p(x,t)$ and their moments. We also obtain exact critical exponents for their moments at the critical point and show universality classes with respect to these critical exponents. (Received September 18, 2011)

1077-81-1511 **Herschel Rabitz*** (hrabitz@princeton.edu), Frick Chemistry Laboratory, Princeton, NJ 08544. *Are traps lurking on quantum control landscapes to impede reaching the objective?*

Seeking an optimal control for manipulating a quantum system entails searching over a landscape, which is specified by the physical objective as a function of the controls. Local suboptimal maxima acting as traps could halt a search algorithm at an undesirable objective value. The quantum control landscape critical point topology may be assessed with the conclusion that traps are not expected to exist upon satisfaction of some key physical assumptions. The validity of this conclusion is confirmed with high quality numerical calculations, and the consequences of the conclusion will be discussed. (Received September 20, 2011)

1077-81-1512 **Ugo Boscain*** (ugo.boscain@polytechnique.edu), CMAP, Ecole Polytechnique, route de Saclay, 91128 palaiseau cedex, France, and **Mario Sigalotti**, **Paolo Mason** and **Francesca Chittaro**. *Adiabatic control of the Schroedinger equation via conical intersections of the eigenvalues.*

We present a constructive method to control the bilinear Schro edinger equation via two controls. The method is based on adiabatic techniques and works if the spectrum of the Hamiltonian admits eigenvalue intersections, and if the latter are conical (as it happens generically). In this framework, we are able to spread on several levels connected by conical intersections a state initially concentrated in a single energy level. We provide sharp estimates on the dependence of the error with respect to the controllability time. Moreover, we identify some special curves in the space of controls that improve the precision of the adiabatic approximation, when passing through conical intersections, with respect to classical adiabatic theory. (Received September 20, 2011)

1077-81-1550 **Sebastian Marius Burciu*** (sebastian.burciu@imar.ro). *On some fusion subcategories of the modular category of representations of a semisimple Drinfeld double.*

This talk is concerned with the study of the category of representations of a semisimple Drinfeld double. All the normal Hopf subalgebras of a semisimple Drinfeld double are completely described. In turn this gives a description of all the normal fusion subcategories of the category of the representations of a semisimple Drinfeld double. The Müger's centralizers of these normal fusion subcategories are also studied. (Received September 20, 2011)

1077-81-1634 **Josiah E. Thornton*** (jthornto@uoregon.edu), Department of Mathematics, University of Oregon, Eugene, OR 97403. *Classification of braided near-group categories.*

A near-group category is a semisimple, rigid tensor category with finitely many simple objects (up to isomorphism) such that all but one of the simple objects is invertible. In other words it is a fusion category with one non-invertible simple object. If a near-group category admits a braiding, then we call it a braided near-group category. I will discuss the classification of braided near-group categories, completing the work done by J. Siehler. There are two families of braided near-group categories, Tambara-Yamagami (due to Siehler) and symmetric, and seven exceptional categories. (Received September 20, 2011)

1077-81-1817 **Umesh Vazirani***, Computer Science Division, U. C. Berkeley, Berkeley, CA 94720. *How does quantum mechanics scale?*

The quantum description of a system of n spins requires 2^n complex numbers. For n = 500 this dwarves estimates for the number of particles in the Universe. This simple observation lies at the heart of the extravagant computing power of quantum computers. It also presents a fundamental obstacle to simulating or "solving" general quantum many body system.

Is this exponential scaling real? Can it be experimentally tested? And to what extent is the scientific method valid for many body quantum systems if we cannot even calculate the predictions of the theory? This talk is about a computational approach to these questions.

No prior knowledge of quantum computation or quantum mechanics will be assumed. (Received September 21, 2011)

1077-81-1963 **Robert Kesler** and **Benjamin Steinhurst*** (steinhurst@math.cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853. *Casimir effect on higher dimensional Laakso spaces.* Preliminary report.

We define three dimensional Laakso spaces as the uncountably many unit cubes that have been identified so as to be able to cross from one cube to another, from one 'universe' to another. On these spaces we construct a Laplacian and derive a spectral zeta function from which can be calculated the strength of a Casimir effect. (Received September 21, 2011)

1077-81-2281 **William H Sulis*** (sulisw@mcmaster.ca), 255 Townline Rd E, RR5, Cayuga, Ontario N0A 1E0, Canada. *The Reality Game: A Process Theory Approach to Quantum Foundations.*

Causal tapestries, an innovative complex systems-process theory approach to quantum foundations, address several foundational problems including the measurement problem, nonlocality, and entanglement. Causal tapestries admit a Lorentz invariant dynamic corresponding to a succession of transient "nows" as required by process theory. A causal tapestry I is a 4-tuple $(L, K, \mathcal{M}, I_p)$ where K is an index set of cardinality κ, $\mathcal{M}$ a causal space, I_p a causal tapestry and L a set of informons such that each informon in L has the form $[n] < \alpha > \{G\}$ with $n \in K$, $\alpha \in \mathcal{M}$ and G an acyclic directed graph whose vertex set is a subset of L_p, b) The union of all such G forms an acyclic directed graph, c) The mapping $i : [n] < \alpha > \{G\} \rightarrow \alpha$ is a causal embedding. There are ancillary conditions to preserve causal consistency across informons. The reality game is a two player multilayer combinatorial game involving two coupled tapestries, E (event) and P (process), evolving new tapestries through techniques of forcing and E-F games. A graph duality between the spaces of symmetry operators on E and P is shown conditionally to reduce to the classical state-momentum space duality of quantum mechanics. (Received September 22, 2011)

1077-81-2525 **Dylan Charles Rupel*** (drupel@uoregon.edu), Department of Mathematics, University of Oregon, Eugene, OR 97403. *Quantum Caldero-Chapoton Type Cluster Characters.*

Let $(Q, \mathbf{d})$ be an acyclic valued quiver with n vertices and let Λ be a compatible skew-symmetric $n \times n$ matrix. We will consider the skew-symmetrizable quantum cluster algebra $\mathcal{A}_q(Q, \Lambda) \subset \mathcal{T}_{\Lambda,q}$ inside the n-dimensional quantum torus associated to Λ. In our first work, "On a Quantum Analogue of the Caldero-Chapoton Formula," we propose a quantum Caldero-Chapoton type cluster character for skew-symmetrizable quantum cluster algebras, assigning to each valued representation of Q an element of the quantum torus $\mathcal{T}_{\Lambda,q}$. Our main conjecture states that exceptional objects are actually sent to cluster variables inside $\mathcal{A}_q(Q, \Lambda)$. We show that the mutation of the initial cluster in a sink or source direction exactly gives the action of the corresponding Dlab-Ringel reflection functor on valued representations, thus establishing the conjecture for those representations which can be obtained in this way. Later Qin established the conjecture for quivers where the valuations on the vertices are all equal. In this talk we will discuss the history of this problem and settle this conjecture using the Ringel-Hall algebra approach of Hubery. (Received September 22, 2011)

1077-81-2783 **Zhenwei Cao*** (zhenwei@vt.edu), 407J Mcbryde Hall Virginia Tech, Blacksburg, VA 24061, and **Alexander Elgart**. *On efficiency of Hamiltonian–based quantum computation for low–rank matrices.*

We present an extension of Adiabatic Quantum Computing (AQC) algorithm for the unstructured search to the case when the number of marked items is unknown. The algorithm maintains the optimal Grover speedup and includes a small Hamiltonian based counting subroutine.

We also demonstrate that quantum speedup for the unstructured search using AQC type algorithms may only be achieved under very rigid control precision requirements. Namely, $O(\frac{1}{\sqrt{N}})$ control precision is necessary. (Received September 22, 2011)

82 ► Statistical mechanics, structure of matter

1077-82-708 **Joe P Chen*** (joe.p.chen@cornell.edu), Cornell University, Ithaca, NY 14853. *Spectral zeta function and quantum statistical mechanics on Sierpinski carpets.*

Generalized Sierpinski carpets (GSCs) are a class of infinitely ramified fractals which include the canonical Sierpinski carpet (in 2D) and the Menger sponge (in 3D). Much progress has been made on showing the uniqueness of Brownian motion on GSC and a sharp estimate of the heat kernel trace. As a result, we can now compute the zeta function associated with the Laplacian on GSC, whose poles give the "complex dimensions" of the various spectral volumes; and show that the zeta function can be meromorphically continued to the left half plane. This allows us to compute the grand canonical partition function for any ideal gas confined to a GSC. One implication I will explain is the onset of Bose-Einstein condensation in unbounded GSC, which depends sensitively on the spectral dimension. If time permits I will also discuss the role of vacuum fluctuations (Casimir effect) in GSC. (Received September 10, 2011)

1077-82-837 **Timothy D Andersen*** (tim@va.wagner.com), Hampton, VA 23666. *Exact solution to the 1d one component Coulomb gas at fixed energy.*

The one dimensional one component plasma has applications to one dimensional particle systems with logarithmic interactions such as charges in a single channel wire or vortex filaments in a fluid convection stream. The exact integral of this plasma in the canonical ensemble with a gaussian confining potential has already been computed. In this talk, I derive the exact volume of the phase space of the plasma of N particles at fixed energy without a confining potential using a microcanonical ensemble and show that, as in the two-dimensional case, it has negative temperature states, suggesting that one dimensional turbulence can occur from vortex/electron clustering. (Received September 13, 2011)

1077-82-1752 **Grethe Hystad*** (ghystad@math.arizona.edu), Department of Mathematics, The University of Arizona, 617 N. Santa Rita Ave. P.O. Box 210089, Tucson, AZ 85719. *Periodic Ising model and Ising Correlations.*

The Ising model, which is one of the most studied models in modern physics, has had great success in shedding light on the existence of phase transitions at a finite temperature (critical temperature). The simplicity of the model made it possible to obtain exact mathematical results in the thermodynamic limit of statistical mechanics. In this talk we will compute the spin correlation functions for the finite 2-D periodic Ising model. We will show how this problem can be reduced to a representation theoretic problem associated with the orthogonal group. The correlation functions on the cylinder and the torus can be evaluated in terms of spin matrix elements in an orthonormal basis of eigenvectors for the transfer matrix. The representation of the spin matrix elements is obtained by considering the spin operator as an intertwining map. (Received September 20, 2011)

1077-82-2306 **Claudio Chamon*** (chamon@bu.edu), Physics Dept., Boston University, Boston, MA MA 02215. *Fractional topological states in electronic flattened bands with non-zero Chern number.*

Topology finds many applications in physics, and recently there has been a surge of activity in the study of phases of matter whose properties cannot be described by local order parameters, and instead are topological in nature. Recently discovered topological insulators and topological superconductors are examples of such systems. Even more recently, attention has turned to fractional topological states in lattice models which occur when interacting electrons propagate on flattened Bloch bands with non-zero Chern number. Here I shall discuss some of the features of the topologically ordered many-particle states that can emerge when these bands are partially filled, including a possible realization of the fractional quantum Hall effect without external magnetic fields. I shall also discuss an effective description of certain fractional topological insulators by considering the time-reversal symmetric pendant to the topological quantum field theories that encode the Abelian fractional quantum Hall liquids. (Received September 22, 2011)

1077-82-2454 **Valerio Lucarini*** (valerio.lucarini@zmaw.de), Klimacampus, University of Hamburg, Grindelberg 5, 20144 Hamburg, Hamburg, Germany. *Stochastic perturbations to dynamical systems: a response theory approach.*

We study the impact of stochastic perturbations to deterministic dynamical systems using the formalism of the Ruelle response theory. We find the expression for the change in the expectation value of a general observable when a white noise forcing is introduced in the system. The difference between the expectation value of the power spectrum of an observable in the stochastically perturbed case and of the same observable in the unperturbed case is equal to the variance of the noise times the square of the modulus of the corresponding susceptibility.

We then extend our results to rather general patterns of random forcing, up to the case of a space-time random field. As a general result, we find, using an argument of positive-definiteness, that the power spectrum of the stochastically perturbed system is larger at all frequencies than the power spectrum of the unperturbed system. We provide a example of application of our results by considering the Lorenz 96 model. These results clarify the property of stochastic stability of SRB measures in Axiom A flows, provide tools for analysing stochastic parameterisations and related closure ansatz to be implemented in modelling studies. (Received September 22, 2011)

85 ► Astronomy and astrophysics

1077-85-2083 **Nicholas P Robbins*** (nrobbins@gettysburg.edu), Gettysburg College, 300 North Washington St., Gettysburg College, PA 17325. *Scalar Field Dark Matter and Spiral Structures of Galaxies: Higher Order Effects and Gravitational Lensing.* Preliminary report.

H. Bray recently suggested that density waves in scalar field dark matter caused by their wave nature is the source of spiral structures in disk galaxies using just the zeroth and second order spherical harmonic. We examine the contribution of fourth order spherical harmonics to the spiral structure.

We also determine the gravitational lensing properties of these models of galaxy scale dark matter. (Received September 21, 2011)

86 ► Geophysics

1077-86-254 **Lioudmila Bourchtein*** (ludmila.bourchtein@gmail.com), Rua Anchieta 4715, bloco K, ap.402, Pelotas, 96015-420, Brazil, and **Andrei Bourchtein**. *On conformal mappings of spherical domains.*

Generation of conformal mappings of spherical domains is the important problem of mathematical cartography and geophysical fluid dynamics. For large-scale atmosphere/ocean processes, formulation of the governing equations in spherical geometry is imperative, which causes the problems of accuracy and stability in numerical solution over considered spherical domain. It can be shown that the condition of the minimum distortion of mapping is an important characteristic for efficiency of numerical schemes employed in atmosphere/ocean simulation.

Since general homeomorphic mappings of sphere are not usually applied because of complex form of the governing equations in such general coordinates, the most frequent choice is conformal mapping from a sphere onto a plane. Such projections maintain a simpler form of the governing equations and assure local isotropy and smoothness of the variation of physical mesh size on computational grid. In this study the problem of generation of the conformal mappings with the most possible uniformity is considered. The construction of conformal mappings for spherical domains of different forms and extensions is performed and their properties are compared to those of orthogonal projections. (Received August 16, 2011)

1077-86-1504 **Peiliang Xu*** (pxu@rcep.dpri.kyoto-u.ac.jp), Disaster Prevention Research Institute, Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan. *Mathematical challenges arising from earth-space observation: mixed integer linear model, measurement-based perturbation theory and data assimilation for ill-posed problems.*

Earth-space observation has not only revolutionized the way we observe the Earth but also presented a unique opportunity for mathematical challenges. We focus on three of such challenges. The first is about mixed integer linear models, which arise from precise GNSS positioning. The unknowns are real-valued and integer. We review approximate and exact numerical solutions, the representation of the integer least squares estimator, probabilistic bounds and two hypothesis testings on integers. The second is to precisely recover the Earth's gravity field from continuous and high precision space data. Conventional perturbation is based on a reference orbit to linearize measurements and has to divide a long arc into small pieces. Thus one cannot recover small gravity signals from space measurements. We develop a measurement-based perturbation theory for recovering the Earth's gravity field, which is valid for an orbit of any length. The new model is able to recover small gravity signals from continuous and unprecedented precise measurements. Finally, we solve inverse ill-posed problems from many different sources of data. Assuming no prior weights, we let data speak for themselves and develop a biased-corrected variance component estimator to determine the weights of data. (Received September 20, 2011)

1077-86-1986 **Martin J. Fengler*** (martin.fengler@gmail.com). *Modern Meteorology: An Overview over the Methods used in Numerical Weather Prediction and its Application to Hurricane Irene.*

This talk gives a short overview on techniques used in modern numerical weather prediction (NWP): It sketches the mathematical formulation of the underlying physical problem, its numerical treatment and gives finally an outlook on statistical weather forecasting (MOS). Special emphasis is given to Hurricane Irene in order to demonstrate the application and limits of the different methods. (Received September 21, 2011)

1077-86-2173 **Paul P. B. Eggermont*** (eggermon@udel.edu), Food and Resource Economics, University of Delaware, Newark, DE 19716. *Maximum likelihood regularization of some inverse problems.* Preliminary report.

We consider some inverse problems in geophysics when the data is contaminated by random noise. We show that one may treat the noise as deterministic but highly oscillatory, but that it is too pessimistic to describe it solely in terms of its average power. (Received September 21, 2011)

1077-86-2435 **A A Abokhodair*** (akwahab@kfupm.edu.sa), KFUPM, Box 448, ESD, Dhahran, EP 31261, Saudi Arabia. *Differentiation Tools in Geoscience Computation.*

The need for numerical differentiation arises in a wide range of geosciences applications. We distinguish here between two types of differentiation problems: the first is the differentiation of functions available in closed form without determining their derivatives explicitly; this type of problem is referred to here as derivative approximation. The second problem is that of estimating the gradients of digital data or digital differentiation. In this paper, we describe two methods for these two different types of differentiation problems, semiautomatic differentiation (SD) and least square digital differentiation filters (LSDD). SD is based on complex calculus and provides an effective way of approximating derivatives of analytic functions similar to automatic differentiation. The SD method is shown to be superior to finite difference (FD) schemes in accuracy, robustness and ease of implementation. Unlike FD-based filters, LSDD filters are low-pass, maximally linear near the DC frequency and have a low noise reduction ratio. Based on theoretical arguments, direct comparisons with ideal low-pass filters and results of numerical experiments we show that these digital differentiators are optimum in robustness, noise reduction and moment preservation of input signal. (Received September 22, 2011)

1077-86-2488 **Susan E. Minkoff*** (sminkoff@umbc.edu), Department of Mathematics and Statistics, University of Maryland, Baltimore County, 1000 Hilltop Circle, Baltimore, MD 21250. *Multiscale methods for seismic imaging.*

Scientists and engineers who wish to understand the earth's subsurface are faced with a daunting challenge. Features of interest range from the microscale (centimeters) to the macroscale (hundreds of kilometers). It is unlikely that computational power limitations will ever allow routine modeling of this level of detail. Numerical upscaling is one technique intended to reduce this computational burden. I will discuss a two-scale algorithm for solution of the wave equation. The upscaling technique relies on decomposing the solution space into coarse and fine components. Step one involves solving for fine-grid features internal to coarse blocks. In step two we augment the coarse-scale problem via this internal subgrid information. I will discuss convergence of the forward algorithm for acoustics. I will conclude with a discussion of how one might efficiently calculate the adjoint for the upscaling algorithm so that it can be used as a forward model for inversion. (Received September 22, 2011)

1077-86-2657 **Laurent Demanet*** (demanet@gmail.com), MIT 2-392, 77 Massachusetts Ave, Cambridge, MA 02139. *Do high frequencies contain information about low frequencies?*

Data usually come in a high frequency band in wave-based imaging, yet one often wishes to determine large-scale features of the model that predicted them. When is this possible? Both the specifics of wave propagation and signal structure matter in trying to deal with this multifaceted question. I report on some progress we recently made with Paul Hand and Hyoungsu Baek. The answers are not always pretty. (Received September 22, 2011)

1077-86-2741 **Matthew J Hoffman*** (mjhsma@rit.edu), 85 Lomb Memorial Dr., School of Mathematical Sciences, Rochester, NY 14623-5602. *Correcting flow estimates in Chesapeake Bay using data assimilation.*

An ensemble Kalman filter data assimilation system has been applied to a model of the Chesapeake Bay for the purpose of regional ocean prediction. Observation simulation experiments have shown that the LETKF improves the state estimate of the system using a realistic simulated observation system. Errors in forcing in the Bay dominate the chaotic grown of initial condition errors. Model errors, most importantly over-mixing that leads to reduced stratification, are also important. Experiments show that the assimilation improves the state using an ensemble of forcing fields as well as adaptive inflation techniques to counteract forcing and model errors. We evaluate improvements made for a reanalysis of the year 2003 and the changes made to the geophysical flow. (Received September 22, 2011)

1077-86-2871 **M. Zuhair Nashed*** (zuhair.nashed@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Inverse and Moment Problems in Geosciences - Revisited.*

The geoscieces gave rise to some of the most interesting classical inverse problems. The early roots of generalized inverses, particularly the inner inverse, reside in geodesical studies. In this talk,I'll revisit moment problems and related inverse problems in the geosciences, and discuss new variants of the Backus-Gilbert method for reconstruction of a function from its moments. Some connections with sampling expansions will also be briefly considered. (Received September 22, 2011)

1077-86-2929 **Shouhong Wang*** (showang@indiana.edu), Department of Mathematics, Bloomington, IN 47405. *Dynamic Transition Theory for Thermohaline Circulation.*

The main objective of this study is to derive a mathematical theory associated with the thermohaline circulations (THC). The results derived provides a general transition and stability theory for the Boussinesq system, governing the motion and states of the large-scale ocean circulation. First, it is shown that the first transition is either to multiple steady states or to oscillations (periodic solutions), determined by the sign of a nondimensional parameter K, depending on the geometry of the physical domain and the thermal and saline Rayleigh numbers. Second, for both the multiple equilibria and periodic solutions transitions, both Type-I (continuous) and Type-II (jump) transitions can occur, and precise criteria are derived in terms of two computable nondimensional parameters b1 and b2. Third, a convection scale law is introduced, leading to an introduction of proper friction terms in the model in order to derive the correct circulation length scale. In particular, the dynamic transitions of the model with the derived friction terms suggest that the THC favors the continuous transitions to stable multiple equilibria. This is joint with Tian Ma (Received September 23, 2011)

90 ► Operations research, mathematical programming

1077-90-16 **Liang Hong*** (lhong@bradley.edu), Department of Mathematics, Bradley University, 1501 W Bradley Avenue, Peoria, IL 61625, and **Jyotirmoy Sarkar** and **Bruno Bieth**. *An Innovative Approach to Limiting Availibility Using Extended Semi-Markov Processes.*

We are interested in a one-unit system supported by an identical spare unit. It is perfectly repaired by an in-house person, if doable within a random or deterministic patience time, or else by a visiting expert. We generalize the previous results in the case of the exponential distribution to the case of arbitrary continuous life and repair time distributions. Our technique involves extending the limiting probability theorem of semi-Markov processes to that of extended semi-Markov processes. We will explain the shortcomings of the traditional Laplace transformation technique by demonstrating that our approach is superior to the Laplace transformation approach. Finally, we introduce the line digraph approach which methodically converts the continuous time stochastic process (CTSP) into an SMP (albeit on a different state space). Thereafter, standard limiting theorems for an SMP yield the steady state probabilities, which can be related back to those of the original CTSP. The line digraph approach is applicable to many other stochastic models. (Received April 30, 2011)

1077-90-179 **Elena Constantin*** (constane@pitt.edu), University of Pittsburgh-Johnstown, Mathematics Department, 450 Schoolhouse Road, Johnstown, PA 15904. *First and Second Order Tangent Cones and Their Applications in Set Constrained Optimization.*

Our goal is to characterize Pavel and Ursescu's second-order tangent cones to the null-set $G^{-1}(0)$ of a Fréchet differentiable map G between two linear normed spaces at a point $x \in G^{-1}(0)$, in the degenerate case where the derivative of G at x is identically zero. We use Ursescu first-order tangent cone to formulate sufficient optimality conditions for a locally Lipschitz functional on a convex subset of a finite dimensional normed space. We employ the first and the second-order tangent cones to give necessary conditions of extremum for a locally Lipschitz functional on an arbitrary subset of a Banach space. We analyze some examples to illustrate the applicability of our results. (Received August 08, 2011)

1077-90-623 **Ram U Verma*** (verma99@msn.com), Texas A&M University, Kingsville, TX 78363. *The Weak Optimality Conditions for Multiple Objective Fractional Programming Based on Generalized Invexity of Higher Order.*

A general framework for a class of generalized invexity of higher order is developed and then applied to establish some results on weakly efficient solutions to a class of multiple objective fractional subset programming problems.

The investigated results generalize and unify a wide range of results on fractional programming available in literature. (Received September 08, 2011)

1077-90-721 **Natali Hritonenko*** (nahritonenko@pvamu.edu), P.O. Box 519, Prairie View, TX 77446, and **Yuri Yatsenko** (yyatsenko@hbu.edu), 7502 Fondren, Houston, TX 77074.
Time-and-age distributed controls in economic and management applications.

The talk surveys recent developments in the optimal capital replacement under technical progress and provides a qualitative analysis of arising integral and differential models with two-dimensional time-and-age distributed controls. The major applied technique for such models is the balanced growth analysis, which mathematically means finding steady-state (time-independent) solutions of these models. The authors obtain and analyze an exact analytic steady-state solution for the optimal control of an economy with the limited substitution among capital assets of various ages. This analysis leads to new results in the optimal control and new policy implications on when and how much the firms should optimally invest into capital assets of different ages. (Received September 11, 2011)

1077-90-735 **Nahid Jafari***, Mathematical and Geospatial Sciences, RMIT University, Melbourne, Australia, and **John Hearne**, Mathematical and Geospatial Sciences, RMIT University, Melbourne, Australia. *Selecting Sites for a Fully Connected Reserve Network.*

The aim of this work is to design a network of sites for conservation purposes. The problem considers the selection of sites that maximize biodiversity values (species richness, rarity, etc) subject to various constraints. These constraints comprise a budget limitation and connectivity that is usually desirable in reserve design recently. In the biological conservation networks, connectivity is important to allow species to move freely without leaving the protected area. The spatial attributes have been addressed in several studies but these techniques either did not guarantee full connectivity or did not guarantee an optimal solution.

In this study we proposed an integer program that selects a subset of sites which are fully connected and which maximizes the bio-diversity value given a limited budget. Our method approaches the reserve design problem as a transshipment problem. (Received September 11, 2011)

1077-90-1204 **Mihai Anitescu*** (anitescu@mcs.anl.gov), Mathematics and Computer Science Division, 9700 S Cass Avenue, Argonne, IL 60439, and **Cosmin Petra**, **Miles Lubin** and **Victor Zavala**. *Scalable Stochastic Programming for Optimization Under Uncertainty of Energy Systems.*

Optimal design, planning and management of nationally critical complex energy systems such as the power electric grid require the optimization of large-scale interconnected sub-systems in the presence of multiple sources of uncertainty. For complex energy systems, the source of uncertainty can be incomplete information or reductive modeling of weather conditions, consumer demand, market prices, etc. In this work we investigate scalable approaches for one framework for decision-making under uncertainty: stochastic programming (SP) with recourse. Our methodology relies on approximating the underlying uncertainty of the stochastic problem via sampling, and solving the corresponding sample average approximation (SAA) problem using an interior-point method with a specialized linear algebra layer, based on a Schur complement approach. The approach is demonstrated to scale well for problems of up to a few billion variables on 130 thousand cores of Argonne BG/L supercomputer. We discuss how to eliminate expected scalability bottlenecks on future architectures, by use of stochastic preconditioning and resampling approaches, for which both theoretical and computational demonstrations will be presented. (Received September 17, 2011)

1077-90-1418 **Warren P Adams** and **Frank M Muldoon*** (fmuldoo@clemson.edu). *Modeling Special Ordered Set Restrictions and Other Disjunctions using Base-2 Expansions.* Preliminary report.

In an effort to reduce the number of discrete variables present within specially-structured mixed-integer programs, various authors have posed strategies for equivalently replacing binary variables with continuous. Such replacements require the defining of logarithmic numbers of new binary variables, together with linear constraints that equate the new binary variables to the old. Example instances include functions having discrete domains, products of such functions, and SOS-1 and SOS-2 type restrictions. This paper gives a novel interpretation of such base-2 expansions in terms of the convex hull of extreme points to the unit hypercube. This interpretation promotes representations that require fewer numbers of auxiliary constraints, while preserving the strengths of the linear programming relaxations. Computational experiments on piecewise linear functions demonstrate the merits of this approach. (Received September 20, 2011)

1077-90-1507 **Miguel Sama*** (msama@ind.uned.es), Calle Juan del Rosal, 12, 28040 Madrid, Madrid, Spain, **Bienvenido Jimenez** (vnovo@ind.uned.es), Calle Juan del Rosal, 12, 28040 Madrid, Madrid, Spain, and **Vicente Novo** (bjimenez@ind.uned.es), Calle Juan del Rosal, 12, 28040 Madrid, Madrid, Spain. *KKT conditions for a nonconvex vector optimization problem.*

In this talk we deal with a nonconvex constrained vector optimization problem. Our aim is to obtain KKT conditions in terms of a half-space decoupling of the constraint cone. Following this purpose we introduce a new constraint qualification in vector optimization extending the usual Basic Constraint Qualification of convex programming. We give some examples showing the relationship with other results in the literature. (Received September 21, 2011)

1077-90-1715 **Mau Nam Nguyen*** (nguyenmn@utpa.edu), Department of Mathematics, University of Texas-Pan American, 1201 W. University Drive, Edinburg, TX 78539, and **Cristina Villalobos** (mcvilla@utpa.edu), Department of Mathematics, University of Texas-Pan American, 1201 W. University Drive, Edinburg, TX 78539. *The Smallest Intersecting Ball Problem and the Smallest Enclosing Ball Problem: Theoretical Analysis.*

The smallest enclosing circle problem asks for the circle of smallest radius enclosing a given set of finite points on the plane. This problem was introduced in the 19th century by James Joseph Sylvester (1814–1897). After more than a century, extended work on the problem remains very active. In this talk we present new results on the following two problems: *the smallest enclosing ball problem* and *the smallest intersecting ball problem*. The smallest enclosing ball problem states that given a finite number of nonempty closed subsets of a Banach space, find a ball with the smallest radius that encloses all of the sets. Similarly, the smallest intersecting ball problem finds a ball with the smallest radius that intersects all of the sets. We will focus on the existence and uniqueness of optimal solutions, as well as, necessary and sufficient optimality conditions for the problems. This work is a continuation of our effort in shedding new light to classical geometry problems using advanced tools of variational analysis and optimization. (Received September 22, 2011)

1077-90-1718 **Mau Nam Nguyen*** (nguyenmn@utpa.edu), Department of Mathematics, University of Texas-Pan American, 1201 W. University Drive, Edinburg, TX 78541, and **Cristina Villalobos** (mcvilla@utpa.edu), Department of Mathematics, University of Texas-Pan American, 1201 W. University Drive, Edinburg, TX 78539. *The Smallest Intersecting Ball Problem and the Smallest Enclosing Ball Problem: Numerical Implementation.*

The smallest enclosing circle problem asks for the circle of smallest radius enclosing a given set of finite points on the plane. This problem was introduced in the 19th century by James Joseph Sylvester (1814–1897). After more than a century, extended work on the problem remains very active. In this talk we present new results on the following two problems: *the smallest enclosing ball problem* and *the smallest intersecting ball problem*. The smallest enclosing ball problem states that given a finite number of nonempty closed subsets of a Banach space, find a ball with the smallest radius that encloses all of the sets. Similarly, the smallest intersecting ball problem finds a ball with the smallest radius that intersects all of the sets. We will focus on algorithms and numerical implementation to solve the problems. This work is a continuation of our effort in shedding new light to classical geometry problems using advanced tools of variational analysis and optimization. (Received September 22, 2011)

1077-90-1809 **Jesus A. De Loera**, **Amitabh Basu** and **Mark Junod*** (mjunod@math.ucdavis.edu). *Numerical Experiments on New Relaxation-Type Algorithms for LPs.*

In early 2011, Sergei Chubanov introduced a new algorithm for linear programming. The algorithm, based on the famous relaxation method first introduced by Motzkin and Schoenberg, and Agmon in 1951, either determines a feasible point of the system or correctly decides no integer solutions exist. Based on this Chubanov gave a new polynomial time algorithm for general LPs. Our paper discusses computer implementations of (1) a simplified version of Chubanov's new algorithm, and (2) his original version, and also runs a series of numerical experiments in order to determine if this algorithm provides us with a new, practically efficient methods of solving linear programs. Our simplified version is a pure feasibility algorithm, i.e. either a point is found or the system is determined to be infeasible, and nothing about integer solutions is determined. We then look at applications to integer programming. (Received September 21, 2011)

1077-90-1978 **Gwen Spencer*** (gwnspencer@gmail.com), 116 Oak Ave, Ithaca, NY 14850, and **David Shmoys**. *Optimally Fragmenting Graphs Against Stochastically-located Threats: Balancing Preventative and Real-time Actions in Wildfire Containment.*

Motivated by issues in allocating limited preventative resources to protect a landscape against the spread of a wildfire from a stochastic ignition point, we give approximation algorithms for a new family of stochastic optimization problems. We study several models in which we are given a graph with edge costs and node values, a budget, and a probabilistic distribution over ignition nodes: the goal is to find a budget-limited set of edges whose removal protects the largest expected value from being reachable from a stochastic ignition node. In particular, 2-stage stochastic models capture the tradeoffs between preventative treatment and real-time response. The resulting stochastic cut problems are interesting in their own right, and capture a number of related interdiction problems including other topics in sustainability.

We discuss a hierarchy of efficient techniques for successively more general variants. Some special cases can be solved to arbitrary precision via dynamic programming. In more general cases efficient provably-good bicriteria results are obtained by carefully rounding the solution of a natural LP relaxation (this exploits the special form of the linked Knapsack-type budget constraints). The techniques extend to 2-stage Maximum Coverage problems. (Received September 21, 2011)

1077-90-2070 **Birgit Rudloff*** (brudloff@princeton.edu), ORFE, Princeton University, Princeton, NJ 08544, and **Andreas Loehne**, Martin-Luther-University Halle-Wittenberg, Department of Mathematics, 06099 Halle, Germany. *A set-valued approach to superhedging in markets with transaction costs.*

In this talk, we will show how to calculate the set of initial endowments that allow to superhedge a European option in markets with transaction costs as well as a method to calculate superheding strategies. This leads to a sequence of linear vector optimization problems solved by Benson's algorithm. We will show that the problem to calculate the scalar superhedging price is related to the set-valued problem by geometric duality. (Received September 21, 2011)

1077-90-2182 **Charles N Glover*** (cnglover@umd.edu), 3117 A. V. Williams, University of Maryland, College Park, MD 20742, and **Michael O Ball** (mball@rhsmith.umd.edu), Robert H. Smith School of Business, 4471 Van Munching Hall, College Park, MD 20742. *Computationally Tractable Stochastic Integer Programming Models for Air Traffic Flow Management.*

Weather is a major contributor to air traffic delays. There is much uncertainty associated with weather predictions so stochastic models are necessary to effectively assign ground delay and route adjustments to flights. We describe a two-stage stochastic integer program for this problem and provide proof that the Linear Programming Relaxation of this model always yields integer results. (Received September 21, 2011)

1077-90-2299 **Andrew D Hedman*** (adhedman@eagle.fgcu.edu) and **Thomas W Hair**. *Spatial dispersion of interstellar civilizations: a site percolation model in three dimensions.*

A site percolation model is presented that simulates the dispersion of an emergent civilization into a uniform distribution of stellar systems. This process is modeled as a three-dimensional network of vertices within which an algorithm is run defining both the number of daughter colonies the original seed vertex and all subsequent connected vertices may have and the probability of a connection between any two vertices. This algorithm is then run over a wide set of these parameters and for iterations that represent up to 250 million years within the model's assumptions. (Received September 22, 2011)

1077-90-2357 **Sven Leyffer*** (leyffer@mcs.anl.gov), 9700 South Cass Avenue, Argonne, IL 60439, and **Ashutosh Mahajan** (mahajan@mcs.anl.gov), 9700 South Cass, Argonne, IL 60439. *MINOTAUR: A New Toolkit for Mixed-Integer and Nonlinear Optimization.*

Scientists and engineers are increasingly turning from the simulation of complex processes to the optimization and design of complex systems. Many important design problems involve not only continuous variables with nonlinear relationships but also discrete decisions, giving rise to mixed-integer nonlinear programming problems (MINLPs). MINLPs combine the combinatorial complexity of the discrete decisions with the numerical challenges of the nonlinear functions.

We present a new toolkit for solving mixed-integer nonlinear optimization problems, called MINOTAUR. The MINOTAUR toolkit is designed to provide a flexible and efficient framework for solving MINLPs. The code s developed in a modular way to enable developers and users to efficiently combine the knowledge of problem structure with algorithmic insights. We will survey recent developments in MINLP and present the underlying algorithmic ideas of MINOTAUR. Our talk will focus on the integration of nonlinear solvers into the

MINOTAUR's branch-and-cut framework, and highlight challenges and opportunities for nonlinear optimization. (Received September 22, 2011)

1077-90-2502 **Bradley J. Paynter*** (paynter@clemson.edu), Department of Mathematical Sciences, Clemson University, Box 340975, Clemson, SC 29634, and **Douglas R. Shier** (shierd@clemson.edu), Department of Mathematical Sciences, Clemson University, Box 340975, Clemson, SC 29634. *On a Geometric Packing Problem.* Preliminary report.

We investigate a geometric packing problem (derived from an industrial setting) that involves fitting patterns of regularly spaced disks without overlap. We derive conditions for achieving the feasible placement of a given set of patterns and discuss certain related optimization problems (e.g., fitting the maximum number of patterns). In addition, a variety of heuristics are developed for solving large-scale instances of this provably difficult problem. (Received September 22, 2011)

1077-90-2907 **Ahlam E.H. Tannouri***, Mathematics Department, Morgan State University, 1700 E.Cold Spring, Baltimore, MD 21251, and **Sam F. Tannouri** and **Belinda Kauffman**. *Strategies to Deploy Temporary Ambulatory Medical Services in Response of a Catastrophic Event.* Preliminary report.

In case of a catastrophic event, two major problems arise, traffic congestion to reach a medical facility and the wait time for service. In order to alleviate the congestion, primary emergency medical services can be deployed temporary in strategic locations in such a way that the average wait time is minimized. The local analysis of the queuing system arising at each medical station is collected and the feedback is used to reassign traffic in order to divert patients to a less congested station when the wait time goes beyond a preset tolerance. We propose an algorithm to dynamically assign the best temporary location of primary medical services in function of distance and users density in different location of a metropolitan area. Visual Analytics tools using confluent graph will be used to help display data and take decision on the fly. The challenges would be to test the algorithm using reel data associated with a specific geographic location. We will simulate preliminary results using primary Data collected from a study supported in part by the U.S. Department of Homeland Security through a grant awarded to the National Center for study of Preparedness and Critical Event Response at Johns Hopkins University. In this study, data was collected for a year from a local hospital (Received September 22, 2011)

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1077-91-75 **Katherine A Baldiga*** (kbaldiga@fas.harvard.edu). *A Failure of Representative Democracy.*

Collective decision-making may be done by either direct or representative democracy. In a direct democracy, the population votes over alternatives as choice problems arrive. In a representative democracy, the population instead votes over candidates, where a candidate is an ordering of alternatives that serves as a binding, contingent plan of action for future choice problems. While direct democracy is normatively appealing, representative democracy has practical advantages and, as a result, is the far more common institution. The key question then is whether representative democracy can successfully implement the choices that would be made under direct democracy. We address this question from a theoretical standpoint. We show that for small numbers of alternatives, representative democracy selects an ordering that ranks highly those alternatives that are selected under direct democracy. However, this result does not hold in the general case. In fact, we show that in settings where the majority preferences over alternatives are consistent with an ordering, this ordering may not be selected as a winner under representative democracy. (Received July 18, 2011)

1077-91-126 **Sinan Aksoy**, University of Chicago, Chicago, IL, **Adam Azzam**, University of Nebraska Lincoln, Lincoln, NE, **Chaya Coppersmith**, Bryn Mawr College, Bryn Mawr, PA, **Julie Glass**, California State University East Bay, Hayward, CA, **Gizem Karaali***, Pomona College, Claremont, CA, **Xueying Zhao**, Mount Holyoke College, South Hadley, MA , and **Xinjing Zhu**, Mount Holyoke College, South Hadley, MA. *Coalitions and Cliques in the School Choice Problem.*

The school choice mechanism design problem focuses on assignment mechanisms matching students to public schools in a given school district. The well-known Gale-Shapley Student Optimal Stable Matching Mechanism (SOSM) is the most efficient stable mechanism proposed so far as a solution to this problem. However its inefficiency is well-documented. In this note we describe two adjustments to SOSM in order to address this inefficiency. In one we create possibly artificial coalitions among students where some students modify their preference profiles in order to improve the outcome for some other students. Our second approach involves trading cliques among students where those involved improve their assignments by waiving some of their priorities. We also discuss the practical implications and limitations of both approaches. (Received July 28, 2011)

1077-91-133 **Marcus J Pivato*** (marcuspivato@gmail.com), Department of Mathematics, Trent University, 1600 West Bank Drive, Peterborough, Ontario K9J 7B8, Canada.
Variable-population voting rules.

Let X be a set of social alternatives. Let V be a set of 'signals'. A *variable population voting rule* F takes any number of anonymous votes drawn from V as input, and produces a nonempty subset of X as output. For example, let R be a linearly ordered abelian group (e.g. $\mathbb{R}$). In an *R-valued scoring rule*, each vote in V assigns an R-valued 'score' to each alternative in X. We add up the scores of each alternative over all votes in the profile, and select the alternative(s) with the highest aggregate score. An *R-valued balance rule* is similar, but now an R-valued scoring rule is used to decide each two-way race; we select the alternative(s) which beat or tie every other alternative. F satisfies *reinforcement* if, whenever two disjoint sets of voters each select some subset $Y \subseteq X$, the union of these two sets will also select Y. We show that F satisfies reinforcement iff F is a balance rule. If F satisfies a form of neutrality, then F is satisfies reinforcement iff F is a scoring rule; this generalizes a result of Myerson (1995). We discuss the uniqueness of these representations. Finally, we axiomatically characterize two scoring rules: *formally utilitarian* voting and *range voting*. (Received July 28, 2011)

1077-91-194 **Nakisa Nassersharif***, Mathematics Department, 215 Carnegie Building, Syracuse University, Syracuse, NY 13244-1150, and **Megan Sinton**, Department of Mathematics, Bucknell University, Lewisburg, PA 17837. *Generating Dynamic Adjustable Weighted Social Networks.*

The DAWN algorithm (Dynamic Adjustable Weighted Network algorithm) randomly generates realistic, dynamic, and weighted artificial social networks. The artificial social networks demonstrate degree distributions that obey a power law, as well as realistic clustering coefficients and average path lengths. The networks are dynamic in that people leave and enter the network, and edges can be created, removed, or re-weighted in each iteration. The edges of the network are asymmetrically weighted in terms of frenergy, a metric that measures the effort put into maintaining a friendship. Due to the dynamic nature of the DAWN algorithm, the network reaches a steady state in the overall network metrics, which include size, clustering coefficient, path length, and degree distribution. However, nodes and edges follow agent based rules, and therefore the network continues to change locally. Locally, friendships form and are strengthened; people join neighborhoods, and some friends leave or become merely acquaintances. These realistic artificial social networks will be invaluable in other mathematical sociology research endeavors and their numeric experiments. (Received August 10, 2011)

1077-91-297 **Zhengyuan Gao*** (z.gao@uva.nl). *Computational Manifold Equilibrium in Dynamical Economic Models.*

In economics, computing general equilibria bases on the validity assumption of Arrow-Debreu models and Kakutani fixed point theorem. The algorithm is optimize a (lower semi-)continuous function from a compact, convex set. When the model is a dynamic system, the (lower semi-)continuous function has to been replaced by an Euler equation. The Euler equation methods generally work well for simple cases, but it is very likely unfeasible if applied to models with heterogeneous agents, multiple goods, multiple factors, and other features often present in general equilibrium problems. We introduce the manifold concept to dynamic equilibrium models. Dynamical equilibria will be representation as the potential solutions of a dual variational problem. Discrete and differential geometric analysis have been conducted to study the properties of the manifold equilibria. A numerical example is presented in a simulated economic system. (Received August 18, 2011)

1077-91-326 **Keith R Criddle*** (Keith.Criddle@alaska.edu), UAF Fisheries Division, 17101 Pt. Lena Loop Rd, Juneau, AK 99801, and **James Strong**. *Dysfunction by Design: Consequences of Limitations on Transferability of Catch Shares in the Alaska Pollock Fishery.*

The American Fisheries Act of 1998 (AFA) granted permanent shares of the Eastern Bering Sea pollock Total Allowable Catch (TAC) to four fishery sectors and to western Alaska Community Development Quota entities (CDQs). The AFA cooperatives and CDQs have prospered. Product recovery rates have increased by 150%, the mix of products has shifted from high throughput product forms such as fillets and mince to higher per-unit value product forms such as fillets. In addition, the development of markets for fillets and surimi in the U.S. and Europe has reduced dependency on Japanese demand for surimi. However, legal barriers to short-term and

long-term intersectoral transfers of harvest allocations reduces total revenues and, in 2007, resulted in a 10% under-harvest of the inshore sector B-season allocation. Stochastic simulations based on empirical models of international trade in pollock products are used to estimate the opportunity costs associated with barriers to intersectoral transfers. (Received August 22, 2011)

1077-91-358 **Allan M Cordish*** (freestarpr@aol.com), 2562 Sprague Rd, Bethel, OH 45106. *(Me) vs (Them) with the Help of Mr. Lincoln.*

Two payment schedules for a loan with the same: number of payments, principal, Annual Percentage Rate (APR) and monthly payments except the principal to interst ratios are different, differ on completion of the number of payment. One schedule shows deficiency in the amount of principal paid balanced by the excess interest paid. The other has the principal paid and any further interest to be zero. Then combining the two schedules, the principal is now overpaid on one by one cent less than the inteest owed on the other. This result is achieved linearly, leaving the question as to how to compute the initial assumption of overpaid interest from the two schedules? To this end a nonlinear function is derived whose properties over a large range appear linear. Now the exact overpayment of interest is computed from the two schedules. From this, we conclude either both schedules are correct which cannot be or both are incorrect which shows that in any case, the principal is not owed. (Received August 25, 2011)

1077-91-459 **Michael G. Neubert*** (mneubert@whoi.edu), Biology Department, MS 34, Woods Hole Oceanographic Institution, Woods Hole, MA 02543-1049, and **Holly V. Moeller** and **Guillermo E. Herrera**. *Models for the Spatial Management of Transboundary and Straddling Stocks and their Bioeconomic Implications for Marine Protected Areas.* Preliminary report.

Marine protected areas (MPAs) can be established for either conservation or fisheries management purposes. The mathematical models that are currently used to design MPAs, and to understand their economic costs and benefits, assume that the stock is either under the exclusive control of a single owner, or that it can be exploited by anyone. However, the distributions of actual stocks often straddle the exclusive economic zones (EEZs) of a small number of states as well as the high seas. In this talk, we will demonstrate how to construct spatially-explicit bioeconomic models for transboundary and straddling stocks. Using a two-state model, we will: (1) show how to analyze such models using game-theoretic methods, (2) show the ecological and economic conditions under which closed areas are optimal, and (3) show how the economic and conservation costs of noncooperation between states depend on biological and economic conditions. (Received September 02, 2011)

1077-91-574 **Ha T Nguyen*** (nguyenht@lafayette.edu), 111 Quad Drive, Box 8054, Easton, PA 18042, and **Ryan A Warrier**, **Miranda I. Teboh-Ewungkem** and **Thomas Yuster**. *Optimization of P. falciparum gametocyte sex ratios via competitive and non-competitive strategies: the evolutionary implications.*

We analyze two distinct fitness optimization strategies for sex ratio determination for P. falciparum with varying fecundity. Initial results indicate that no polymorphic population containing both strategies is stable. The pure strategy that is the final evolutionary state depends heavily on the composition of the initial polymorphic population. (Received September 07, 2011)

1077-91-580 **Nicolas Houy** and **William S. Zwicker*** (zwickerw@union.edu), Department of Mathematics, Union College, Schenectady, NY 12308. *The geometry of influence: weighted voting and hyper-ellipsoids.*

We provide three new characterizations of weighted voting, each based on the intuition that for weighted rules, winning coalitions are close to one another. The "small spread" and "tightly packed" characterizations use a Hamming metric, as modified by a vector B of Hamming weights. In "Ellipsoidal separability", which employs the Euclidean metric, the separating hyper-ellipsoid E contains all winning coalitions, omits all losing ones, and is centered at the barycenter of all winning coalitions. The proportions of E are determined by this same vector B, which bears a surprising relationship to the vector of voting weights; the i^{th} Hamming weight b_i is given by the ratio $\frac{w_i}{\eta_i}$ of player i's voting weight w_i to her Penrose-Banzhaf voting power η_i. The ellipsoid's geometry thus reflects the relationship between weight and influence. For example, the spherically separable rules are precisely those weighted rules for which the players' Penrose-Banzhaf voting powers can serve as their voting weights. (Received September 07, 2011)

1077-91-651 **Jonathan K. Hodge*** (hodgejo@gvsu.edu). *The Separability Problem in Referendum Elections: Some Recent Developments.*

In referendum elections, voters are often required to register simultaneous votes on multiple proposals. The separability problem, first identified in the late 1990s, occurs when a voter's preferences on one or more proposals depend on the known or predicted outcomes of other proposals. Here we survey several recent developments pertaining to the separability problem, including: (1) structural properties of interdependent preferences; (2) the impact of separability on election outcomes; (3) causes and models of nonseparability; and (4) the potential of iterative voting to solve the separability problem. All of these results involve contributions from undergraduates, some of whom will be in attendance at the session. (Received September 09, 2011)

1077-91-1182 **Steven J. Brams**, **Todd R. Kaplan** and **D. Marc Kilgour*** (mkilgour@wlu.ca), Department of Mathematics, Wilfrid Laurier University, 75 University Avenue, Waterloo, ON N2L3C5, Canada. *A Simple Bargaining Mechanism That Elicits Truthful Reservation Prices.*

We describe a simple 2-stage mechanism that induces two bargainers to be truthful in reporting their reservation prices in a 1^{st} stage. If these prices criss-cross, the referee reports that they overlap, and the bargainers proceed to make offers in a 2^{nd} stage. The average of the 2^{nd}-stage offers becomes the settlement if both offers fall into the overlap interval; if only one offer falls into this interval, it is the settlement, but is implemented with probability $\frac{1}{2}$; if neither offer falls into the interval, there is no settlement. Thus, if the bargainers reach the 2^{nd} stage, they know their reservation prices overlap even if they fail to reach a settlement, possibly motivating them to try again. (Received September 17, 2011)

1077-91-1261 **Steven J. Brams*** (steven.brams@nyu.edu), Dept. of Politics, New York University, 19 West 4th St., 2nd Fl., New York, NY 10012, and **Michael A. Jones** and **Christian Klamler**. *N-Person Cake-Cutting: There May Be No Perfect Division.* Preliminary report.

A cake is a metaphor for a heterogeneous, divisible good. A perfect division of a cake is efficient (Pareto-optimal), envy-free, and equitable. We give an example of a cake in which it is impossible to divide it among three players such that these three properties are all satisfied, however many cuts are made. By contrast, If there are only two players, not only is there a perfect division, but there is also an algorithm for determining where and now many cuts must be made. (Received September 18, 2011)

1077-91-1338 **Uma V Ravat*** (ravat1@illinois.edu) and **Uday V Shanbhag**. *On the characterization of solution sets of smooth and nonsmooth stochastic Nash games.*

Variational analysis provides an avenue for characterizing solution sets of deterministic Nash games over continuous strategy sets. A direct application of deterministic results to settings when player objectives are stochastic is challenging since the expectation operation generally leads to a far less tractable nonlinear function. We present a framework for the tractable verification of existence of equilibria of stochastic Nash games; importantly, this avenue does not necessitate the evaluation of an expectation or its derivatives. Extensions to nonsmooth regimes are also presented. We provide some illustrative examples from risk-averse Nash-Cournot games. We have also extended the above framework to stochastic generalized Nash games in smooth and nonsmooth regimes. (Received September 22, 2011)

1077-91-1350 **Josep Freixas*** (josep.freixas@upc.edu), Av. Bases de Manresa 61-73, 08242 Manresa, Spain, Manresa, Spain, and **Cameron Parker** (cparker@sandiego.edu), Department of Mathematics and Computer S., 5998 Alcala Park, San Diego, CA 92110, San Diego, CA. *On the possibility of manipulation in voting rules with several levels of approval.* Preliminary report.

We analyze the possibility of manipulation in (j,k) voting rules, i.e. the individual voters have a finite and naturally ordered set of voting options to choose from and the body as a whole has a finite and natural ordered set of outcomes.

In principle, these voting systems have in common that the system is set up under the assumption that each individual is not motivated by hoping for an outcome but rather voting in a way that is their best assessment of what the best option is and trust the voting system to produce the best outcome.

However, if the voter is more interested in the final outcome than the honesty of his or her actual vote, then the voter may not have a vote that will correspond to giving the best chance that his or her top preference will be the final outcome and instead must guess or investigate how others will vote in order to decide on his or her vote. The notion of Nash equilibrium and its existence makes sense in this context. (Received September 19, 2011)

1077-91-1398 **Michael A. Jones** and **Jennifer Wilson*** (wilsonj@newschool.edu). *Two-Step Coaliton Values for Multichoice Games.*

We introduce and compare several coalition values for multichoice games. Following the approach of Owen and Winter for cooperative games, we introduce a set of nested or two-step coalition values on multichoice games which measure the value of each coalition and then divide this among the players in the coalition using either a Shapley or Banzhaf value at each step. We show that when a Shapley value is used in both steps, the resulting coalition value coincides with one introduced by Albizuri. We axiomatize the three new coalition values and show that each set of axioms is independent. Finally we show how the multilinear extension can be used to compute the coalition values. (Received September 19, 2011)

1077-91-1410 **Karl-Dieter Crisman*** (karl.crisman@gordon.edu). *Symmetry in Voting Theory: The Borda-Kemeny Spectrum and Beyond.* Preliminary report.

One natural criterion for fairness in the theory of voting and choice is 'reversal symmetry' – the idea that if all voters reverse their rankings completely, the outcome ranking should likewise be reversed. This makes particular sense in the context of so-called *social preference functions*, whose output is one or more complete rankings of candidates.

Just as the symmetric group naturally encodes permutational symmetry, adding reversal symmetry can be represented by the symmetries of the *permutahedron* (and its representation theory). The Borda Count and Kemeny Rule both have reversal symmetry, and using the permutahedron, one can show that the one-parameter family of choice procedures they determine is maximally symmetric in several nice ways.

In this talk, we will explain the results leading to this Borda-Kemeny family in some detail, and will give some interesting examples that show why this family is useful to study. We also will give simple examples of how to extend these methods to choice situations with other symmetries – for instance, ways of seating people at at table using the *cyclic-order* graph. (Received September 19, 2011)

1077-91-1480 **Michael A. Jones*** (maj@ams.org), Mathematical Reviews, 416 Fourth Street, Ann Arbor, MI 48103, and **Jennifer M. Wilson** (wilsonj@newschool.edu), Department of Natural Science and Mathematics, Eugene Lang College, New School for Liberal Arts, New York, NY 10011. *Dynamics of Consistent Bankruptcy Rules.* Preliminary report.

The allocation of consistent bankruptcy rules between n players is viewed as a fixed point of an iterative dynamic process that averages allocations under the rule over subsets of players. For certain subsets of players (e.g., when all pairs of players are considered), the fixed point is unique and is attractive for the proportional rule, Talmud rule, and Rif's rule. (Received September 19, 2011)

1077-91-1563 **Esther F Jackson*** (ejacksoh@masonlive.gmu.edu). *Modern Portfolio Theory Enhanced by Manifold Learning.* Preliminary report.

In the realm of investment theory, Modern Portfolio Theory (MPT) remains the most important and influential mathematical model. Modern Portfolio Theory attempts to maximize portfolio expected return for a given amount of portfolio risk, or equivalently minimize risk for a given level of expected return, by carefully choosing the proportions of various assets. The theory has been widely used in the financial industry. We examine the assumptions underlying MPT, and investigate replacing some of the underlying linearity assumptions with nonlinear approaches from manifold learning theory. (Received September 20, 2011)

1077-91-1728 **Maxim Bichuch** and **Stephan Sturm*** (ssturm@princeton.edu), 116 Sherrerd Hall, Princeton University, Princeton, NJ 08544. *Portfolio Optimization under Convex Incentive Schemes.*

We consider the utility maximization problem of terminal wealth from the point of view of a portfolio manager paid by an incentive scheme given as a convex function g of the terminal wealth. The manager's own utility function U is assumed to be smooth and strictly concave, however the resulting utility function $U \circ g$ fails to be concave. As a consequence, this problem does not fit into the classical portfolio optimization theory. Using duality theory, we prove wealth-independent existence and uniqueness of the optimal wealth in general (incomplete) semimartingale markets as long as the unique optimizer of the dual problem has no atom with respect to the Lebesgue measure. In many cases, this fact is independent of the incentive scheme and depends only on the structure of the set of equivalent local martingale measures. As example we discuss stochastic volatility models and show that existence and uniqueness of an optimizer are guaranteed as long as the market price of risk satisfies a certain (Malliavin-)smoothness condition. We provide also a detailed analysis of the case when this criterium fails, leading to optimization problems whose solvability by duality methods depends on the initial wealth of the investor. (Received September 21, 2011)

1077-91-1830 **Karen Saxe*** (saxe@macalester.edu), Mathematics, Statistics, and Computer Science, Macalester College, 1600 Grand Avenue, St. Paul, MN 55105. *Redistricting: from theory to practice.* Preliminary report.

We will begin this talk with an overview of congressional redistricting and the role that mathematics can play in the process, with particular attention to measures of compactness. This will be followed by an account of my experience working on Minnesota's Citizens' Redistricting Commission. (Received September 21, 2011)

1077-91-1832 **Aniket Anil Panjwani*** (apanjwa1@masonlive.gmu.edu), 4450 Rivanna Lane, PMB 4580, Fairfax, VA 22030. *Searching for the Implied Market Utility Function.*

Modern portfolio theory tells us how to choose the optimal portfolio given the returns and variances of assets. We choose to modify modern portfolio theory, as created by Merton (1972), by introducing a stochastic element to the standard model. Then, after making an assumption on agents' valuation functions, an assumption on agents' pricing functions, and a 'no arbitrage' assumption on prices, we use parametric and nonparametric methods to estimate a 'market utility function'. This market utility function allows us to see how the market differentiates between portfolios of identical means and variances, but different higher moments and distributions. (Received September 21, 2011)

1077-91-2023 **Tselil Schramm*** (tschramm@hmc.edu), 340 E. Foothill Blvd, Claremont, CA 91711, and **Emily Carlson** (ec9467@bard.edu), 39 Ridgeview Ave, West Orange, NJ 07052. *Sequences for Solving Puzzles and Touring Graphs.*

We examine Generalized Towers of Hanoi, Generalized Spin-Out, and the Combination Puzzle, and continue to describe the puzzles and their properties. We introduce Finite State Transducers (FSTs) that compute the shortest sequence of winning moves for each of these puzzles for all dimensions, and show that the solution sequence for Spin-Out is not finite-state computable when going from configuration $11\dots1$ to configuration $00\dots0$. We also examine the graphs of these puzzles, the class of graphs known as iterated complete graphs. We show that Hamiltonian paths and circuits exist but are not unique for iterated complete graphs of dimension greater than 3. We then introduce FSTs which produce Hamiltonian paths on K_d^n for every $d \in \mathbb{N}$, and prove the transducers' minimality for d odd – these FSTs define a d-ary Gray code. Finally, we create FSTs that produce a Hamiltonian circuit on K_d^n for all d. (Received September 21, 2011)

1077-91-2238 **James F. Booker*** (jbooker@siena.edu), Economics Department, Siena College, 515 Loudon Road, Loudonville, NY 12211, and **Richard E. Howitt** (howitt@primal.ucdavis.edu), **Ari M. Michelsen** (amichelsen@ag.tamu.edu) and **Robert A. Young** (ryoung@lamar.colostate.edu). *Modeling the Economics of Water: Progress and Challenges.*

Building upon well-established principles and applications, economic policy models have advanced in scope and methods over the last 25 years. Approaches to address an ever growing list of water resources challenges are identified, including new and evolving methods for estimating consumer and producer demand for water use, valuation of public goods related demands, treatment of risk, and strategies for capturing system-wide impacts by improving hydrologic and institutional descriptions and integrating ground and surface water modeling. Future economic modeling of water resources is likely to expand in depth and breadth, and continuing and emerging approaches, from the parsimonious to complex interdisciplinary hydroeconomic modeling systems, are considered. (Received September 21, 2011)

1077-91-2303 **Laurent E Calvet*** (calvet@hec.fr), 1 rue de la Liberation, 78350 Jouy en Josas, France. *Extreme risk and fractal regularity in finance.*

As the current crisis reminds us, extreme movements in the level and volatility of asset prices are key features of financial markets. These phenomena are difficult to explain using traditional models in which extreme risk is specified as a rare event that is difficult to measure. Multifractal analysis, whose use in finance has considerably expanded over the past fifteen years, reveals that price series observed at different time horizons exhibit several forms of scale-invariance. Building on these observations, researchers have developed a new class of multifractal processes that generate reliable forecasts of the value at risk (VaR) and volatility of a portfolio of assets. The new models provide a structured framework for studying the likely size and price impact of events that are more extreme than the ones historically observed. (Received September 22, 2011)

1077-91-2382 **Barbara A Bennie*** (bbennie@uwlax.edu). *Strategic market games with random endowments.*

Monetary models are often used to gain a better understanding of the interplay between interest rates, spending, and inflation. Here we use stochastic game theory to model an infinite horizon, cash-in-advance market economy. We derive a Nash equilibrium set of spending strategies for agents in the economy and then investigate the relationship between the nominal interest rate and inflation assuming that agents act according to their equilibrium strategies. What makes this monetary model novel is that the amount of good endowed to the agents in the economy at each stage is assumed to be a random variable from a known distribution that changes over time. That is, the endowment distribution may be different from one stage to the next. We show that while the classical Fisher equation for relating interest to inflation does not hold in this context, a limiting harmonic Fisher equation applies. (Received September 22, 2011)

1077-91-2426 **Nicholas S Chaung*** (nschaung7@gmail.com). *Effects of Non-Independent Behavior on a Macroeconomic Model.*

The standard macroeconomic models in use today are Dynamic Stochastic General Equilibrium (DSGE) models. DSGE models attempt to calculate macroeconomic variables based on microeconomic principles. These variables are determined at each time step (dynamically) by calculating the equilibrium solution to a system of equations, that represents the behaviors and expectations of the involved agents. By assumption, these agents behave independently and rationally to maximize a given function. Taking for example inflation, the DSGE model studied here predicts that changes in inflation over time converge to a normal distribution.

However in real economies, very large fluctuations occur much more frequently than a normal distribution would predict; i.e., frequency distributions of macroeconomic variables show 'fat tails'. An explanation for these fat tails is that agents do not always act independently and rationally, but can instead exhibit non-independent and sometimes perverse behavior. One such non-independent behavior agents have been known to exhibit is 'herding', where agents mimic the behavior of other agents. We will investigate the sensitivity of such DSGE models to herding behavior. (Received September 22, 2011)

1077-91-2483 **Yingyun Shen*** (yshen@math.fsu.edu), 208 Love Building, 1017 Academic Way, Tallahassee, FL 32306-4510, and **Mike Mesterton-Gibbons**. *Game theory in vaccination and its application.* Preliminary report.

Under any voluntary vaccination scheme, the level of coverage within a population depends on several factors, which include fear of side-effects from the vaccine, the "free-rider" effect (relying on others to ensure widespread coverage) and perceptions of risk from the disease. Consequently, individual self-interest may differ from what is best for the population as a whole. I will present a synthesis of game theory and epidemic modeling that analyzes this conflict in the context of an infectious disease, thus facilitating effective vaccination policy. (Received September 22, 2011)

1077-91-2528 **Ajanta Roy*** (ajantaro@mailbox.sc.edu), University of South Carolina - Salk, SC 29488. *A Minimax Distribution Free Approach: Joint Vendor and Buyer Model.*

It has been observed that mutual coordination between vendor and buyer systems is more profitable as compared to their individual system. The buyer's aim is to reduce the lead time, which facilitates the buyer to fulfill the demand on time. Vendor offers trade credit and early payment options as well as discount in purchase price to the buyer. This study shows joint optimization of both the vendor and the buyer's operations. Author has used minimax distribution free approach. The results are demonstrated with the help of numerical examples. This study examines the sensitivity of the resulting cost savings due to the exchange of cost information. (Received September 22, 2011)

1077-91-2946 **Lek-Heng Lim*** (lekheng@galton.uchicago.edu), University of Chicago, Department of Statistics, Chicago, IL 60637. *Hodge Theory and the Netflix Problem.*

Suppose a large number of voters have each rated or compared a small subset of a large number of alternatives, how could we rank the alternatives based on these data? The rank aggregation problem is fraught with famous difficulties — Arrow's impossibility, Saari's chaos, NP-hardness of Kemeny optima. To complicate matters further, let's say the ratings do not come all at once but trickles in on a daily basis and we would like to regularly update our rankings. Let's say we also want a measure of reliability or quality of our rankings. We shall disucss a method based on Hodge decomposition that meets all these requirements. (Received September 23, 2011)

92 ► Biology and other natural sciences

1077-92-36 **Anne Shiu** and **Bernd Sturmfels*** (bernd@math.berkeley.edu), Department of Mathematics, University of California, Berkeley, CA 94720. *Siphons in Chemical Reaction Networks.*

Siphons in a chemical reaction system are subsets of the species that have the potential of being absent in a steady state. We present a characterization of minimal siphons in terms of primary decomposition of binomial ideals, we explore the underlying geometry, and we demonstrate the effective computation of siphons using computer algebra software. This enables us to determine whether given initial concentrations allow for various boundary steady states. (Received June 21, 2011)

1077-92-84 **Bonni J Kealy*** (bkealy@math.wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113, and **David J Wollkind** (dwollkind@wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113. *Vegetative Turing Pattern Formation: A Historical Perspective.*

An interaction-diffusion plant-surface water model system for the development of spontaneous stationary vegetative patterns in an arid flat environment is investigated by means of a weakly nonlinear diffusive instability analysis originally applied to a particular set of chemical reaction-diffusion equations. The main results of this analysis can be represented by closed-form plots in the rate of precipitation versus the specific rate of plant density loss parameter space. From these plots, regions corresponding to bare ground and vegetative patterns consisting of tiger bush, labyrinth-like mazes, pearled bush, irregular mosaics, and homogeneous distributions of vegetation, respectively, may be identified in this parameter space. Then those predictions are compared with both relevant observational evidence and the existing chemical pattern formation results from that particular set of reaction-diffusion equation as well as placed int eh context of Alan Turing's seminal 1952 diffusive instability mechanism employed historically as a paradigm for morphogenesis. (Received July 22, 2011)

1077-92-88 **Jin Wang*** (j3wang@odu.edu), Department of Mathematics, Old Dominion University, Norfolk, VA 23529. *Analyzing Cholera Dynamics and Controls.* Preliminary report.

In this talk, we will present a new mathematical model to explore the complex dynamics of cholera, a severe water-borne infectious disease, and discuss effective control strategies against cholera outbreak. The model incorporates both human population and environmental components, representing the multiple transmission pathways of cholera. We will conduct both epidemic and endemic analysis, and use optimal control theory to seek a cost-effective balance of different intervention methods. We will validate the analytical predictions by numerical simulation and realistic case studies. (Received July 24, 2011)

1077-92-145 **Michael Malisoff*** (malisoff@lsu.edu), Department of Mathematics, 303 Lockett Hall, Louisiana State University, Baton Rouge, LA 70803-4918. *Stability and Stabilization for Chemostat Models: A Survey.*

The chemostat is a bioreactor in which fresh medium is continuously added and culture liquid is continuously removed, so the culture volume remains constant. It has industrial applications, including the commercial production of genetically altered organisms. Chemostat models are used in bioengineering and population biology, e.g., for experimentally reproducing and understanding the behaviors of interacting organisms in lakes and waste-water treatment plants. I will summarize my work with Frederic Mazenc on nonlinear control methods for ensuring coexistence in chemostats with multiple species and one or more limiting substrates. Our work uses Lyapunov functions and feedback controller design and can capture the effects of actuator errors, feedback delays, and model uncertainty. (Received September 22, 2011)

1077-92-146 **Bonni J Kealy*** (bkealy@math.wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113, and **David J Wollkind** (dwollkind@wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113. *A Vegetative Pattern Formation Aridity Classification Scheme Along a Rainfall Gradient: An Example of Desertification Control.*

A classification scheme for stationary vegetative patterned states along a rainfall gradient in an arid flat environment is developed by applying a weakly nonlinear diffusive instability analysis to an interaction-diffusion plant-surface water model system. The main results of this analysis can be represented by closed=form plots in the rate of precipitation versus the specific rate of plant loss parameter space. Form these plots regions corresponding to bare ground and vegetative patterns consisting of tiger bush, labyrinth-like mazes, pearled bush, irregular mosaics, and homogeneous distributions of vegetation, respectively, may be identified in this parameter space. Then that predicted sequence of stable states along a rainfall gradient is both compared with observational evidence and used to motivate an aridity classification scheme which sheds new light on desertification phenomena, while suggesting potential recovery operations by human intervention due to its intrinsic hysteric behavior where bistability occurs. (Received August 01, 2011)

1077-92-189 **Patrick Thomas Davis*** (davis1pt@cmich.edu), 2363 Geoffry, Warren, MI 48092, and **Andrew M. Ross** (andrew.ross@emich.edu). *Modeling the Spread of a Ug99-Type Wheat Pathogen in the United States of America.*

Stem rust of wheat (*Puccinia grammis tritici*) is certainly not a new fungal pathogen; however, in 1999 a new variety of the disease (which became known as Ug99) was discovered in eastern Africa. This new strain of wheat rust has become epidemic in this area of the world and has now spread to parts of Asia and the Middle East, resulting in significant crop loss. Moreover, Ug99 has shown an ability to overcome resistance genes bred into wheat cultivars intended to fend off stem rust. In this paper, we explore techniques to model the path of a hypothetical outbreak of a Ug99-variety stem rust in the United States of America and its effect on wheat production through a discrete deterministic model run via computer simulation. The model adapts a standard SEIR model for a single region of wheat and then extends it to consider the interactions between multiple regions, and finally throughout the entire country. The effects of distance and wind patterns are accounted for. We conclude with a discussion of the effectiveness of various proposed prescriptive measures regarding control procedures if the fungus were to reach U.S. soil. (Received August 28, 2011)

1077-92-196 **Tucker Gilman**, **Tony Jhwueng** and **Dana Botesteanu*** (botes20d@mtholyoke.edu), 1154 Blanchard Campus Center, 50 College Street, South Hadley, MA 01075, and **Frances Goglio** and **Yicong Yong**. *How does the effort a mother bird expends on her offspring depend on the attractiveness of her mate?* Preliminary report.

The Differential Allocation Hypothesis (DAH) proposes that selection would favor individuals in a population that invest more resources in their current reproductive attempt when paired with a high-quality mate, at the expense of future reproductive attempts. Additionally, it is argued that DAH should take place to a greater extent in polygamous species since they are more likely to engage in extra-pair copulations. A two-fold approach was used to investigate the circumstances in which DAH would occur: firstly, a mathematical model was developed to illustrate the relationship between male attractiveness and female fitness. The model provides a theoretical framework for determining whether DAH depends on extra-pair paternity levels (EPP), assuming that male attractiveness only signals indirect fitness benefits. Secondly, meta-analytical techniques with correction for phylogeny were used to examine data from 31 empirical studies of 20 species of birds, using egg size and egg androgen content as response variables. A multiple regression model was formed using data collected from literature to determine the correlation between the male's attractiveness and EPP in the context of DAH. The goal was to verify the predictions of the theoretical model with empirical evidence. (Received August 11, 2011)

1077-92-203 **Franziska Hinkelmann***, Mathematical Biosciences Institute, The Ohio State University, Jennings Hall 3rd Floor, 1735 Neil Ave, Columbus, OH 43210, and **Reinhard Laubenbacher**. *Algebraic theory for discrete models in systems biology.*

Systems biology aims to explain how a biological system functions by investigating the interactions of its individual components from a systems perspective. Modeling is a vital tool as it helps to elucidate the underlying mechanisms of the system. Many discrete model types can be translated into the framework of polynomial dynamical systems (PDS), that is, time- and state-discrete dynamical systems over a finite field where the transition function for each variable is given as a polynomial. This allows for using a range of theoretical and computational tools from computer algebra, which results in a powerful computational engine for model construction, parameter estimation, and analysis methods. (Received August 11, 2011)

1077-92-233 **Necibe Tuncer** (tuncer@ufl.edu), Tulsa, OK 74104, and **Maia Martcheva*** (maia@ufl.edu), 358 Little Hall, Gainesville, FL 32611. *Seasonality in Avian Influenza H5N1.*

Avian influenza H5N1 has been infecting poultry and humans in many countries since 2003. The cases follow a seasonal pattern with peaks in the winter months. This pattern is puzzling as most of the human cases occur in equatorial countries where even the seasonal human influenza occurs with different pattern. We hypothesize three different mechanisms that may be responsible for the seasonality in H5N1 cases: (1) seasonality in direct transmission in domestic birds; (2) seasonality introduced by migratory patterns in wild birds; (3) seasonality introduced by environmental transmission of H5N1. We incorporate all these types of seasonality one by one or in combination in 7 different models. We fit each of the models to the cumulative number of human cases reported by the World Health Organization for the period January 2005-December 2009. We compare the models based on their Akaike Information Criterion (AIC) score. We find that model that incorporates seasonality in the direct transmission in domestic birds best explains the data. Furthermore, we use the best fitted model to project the cumulative number of human cases of H5N1 through 2011 and compare it with the incoming data. The best fitted model shows good agreement with future data. (Received August 15, 2011)

1077-92-241 **Lauren M Childs*** (lauren.childs@biology.gatech.edu), **Nicole Held**, **Mark J Young**, **Rachel J Whitaker** and **Joshua S Weitz**. *Multi-scale Model of CRISPR-induced Coevolutionary Dynamics: Diversification at the Interface of Lamarck and Darwin.* Preliminary report.

The CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) system is a recently discovered immune defense in bacteria and archaea (hosts) that functions via directed incorporation of viral DNA into host genomes. Here, we introduce a multi-scale model of dynamic coevolution between hosts and viruses in an ecological context that incorporates CRISPR immunity principles. We analyze the model to test whether and how CRISPR immunity induces host and viral diversifi cation and maintenance of coexisting strains. We show that hosts and viruses coevolve to form highly diverse communities through punctuated replacement of extant strains. The populations have low similarity over long time scales. However over short time scales, we observe evolutionary dynamics consistent with incomplete selective sweeps, recurrence of previously rare strains, and sweeps of coalitions of dominant host strains with identical phenotypes but different genotypes. Our explicit eco-evolutionary model of CRISPR immunity can help guide efforts to understand the drivers of diversity seen in microbial communities where CRISPR systems are active. Understanding the role of the CRISPR system in bacterial survival has important consequences in environmental cleanup, probiotics, and agriculture management. (Received August 16, 2011)

1077-92-245 **Abra Brisbin*** (brisbin.abra@mayo.edu), Mayo Clinic, 200 First St SW, Rochester, MN 55905, and **Brooke L. Fridley**. *Association testing in sequencing studies: Accommodating risk and protective variants.*

Many existing methods address the question of identifying associations between a phenotype and a set of rare variants. However, the majority of these methods implicitly assume that the direction of effect is the same for all rare variants, and are subject to loss of power in the presence of both risk and protective rare alleles. We developed a new method for analysis of rare variants, the Difference in Minor Allele Frequency (D-MAF), which allows combined analysis of common and rare variants, and makes no assumptions about the direction of effects. We tested our method and 9 other methods on simulated genomic regions with varying mutation and recombination rates, and a variety of phenotypic models. We found that several methods, including D-MAF, performed well when all rare variants were either risk alleles or neutral; however, D-MAF and two other methods, C-alpha and CMC, outperformed the others when protective variants were present. D-MAF can also be extended to the analysis of pooled sequencing data, for which many collapsing methods are not applicable. (Received August 16, 2011)

1077-92-251 **Yanthe E Pearson*** (yanthe.pearson@gmail.com), 38 Maryland Ave, Rockville, MD 20850, and **William Fagan**, **Elise Larsen**, **Emma Goldberg**, **Heather Lynch**, **Hillary Staver** and **Jessica Turner**. *Estimating population growth rates for mammalian species.*

The per capita rate of population growth, r, is a central measure of population biology that is crucial for understanding the dynamics and extinction risks of real species. However, researchers can only calculate this metric for the small subset of species for which adequate time series, life tables, and similar datasets are available. Here we introduce a phylogenetic approach for predicting r for poorly known species by viewing r as a synthetic life history trait that varies among species within a clade. Combining stochastic macroevolutionary models, molecular phylogenies, and life history trait data, we predict the potential for population growth for mammals of the Caniformia and Cervidae. Cross-validation analyses demonstrate that, even with sparse life history data across species, these phylogenetic methods are capable of estimating to within a factor of 2 routinely, and often do much better. (Received August 16, 2011)

1077-92-268 **Anne Elizabeth Yust*** (aeyust@gmail.com), Birmingham-Southern College, 900 Arkadelphia Rd, Box 549032, Birmingham, AL 35254, and **Shlomo Ta'asan**. *A Data-Driven Approach to Modeling the Effect of Disease on the Immune System.* Preliminary report.

If we can determine the effect of a disease on the immune system, then we have the potential to develop interventions that could counter the ill-effects and return the system to a healthy state. Thus, the creation of

models that can predict these effects on the immune system has become a current focus of scientists. Traditional models rely on underlying biological assumptions resulting from the current understanding of the interactions between a specific infectious disease and the immune system. Though often producing an effective model, this approach is limited to diseases that are widely understood. In my talk, I will introduce and discuss the advantages and disadvantages of a more general approach to modeling the effect of disease on the immune system. I will also include results produced by modeling specific diseases such as influenza A and lipopolysaccharide (LPS) with both traditional models and my general, agnostic model. (Received August 17, 2011)

1077-92-322 **John Nardini*** (jtnardin@ncsu.edu), 263 Main Street, Chichester, NH 03258, and **Kahmya McAlpin**, **Leslie Myint** and **Shernita Lee**. *A discrete model of iron metabolism in lung epithelial cells with fungal challenge.* Preliminary report.

Iron is essential for the growth and survival of the cells in our body as well as the pathogens attacking them. As such, cells have developed complex mechanisms of both regulating their iron stores and withholding iron from microbial invaders. In particular, lung epithelial cells are a target for fungal infection because of constant exposure to airborne pathogens. Upon fungal infection in the airway, an innate immune response is initiated to combat the pathogen. The ensuing struggle is a battle for iron, with the host triumphing if it can deprive the fungus of enough iron and the fungus winning if it can overcome the iron deficiency induced by the host's immune proteins. We present a logical model of iron metabolism in lung epithelial cells exposed to proinflammatory cytokines and the fungi *Aspergillus fumigatus* and *Alternaria alternata*. It makes predictions about the way in which lung epithelial cells sequester excess extracellular iron, along with how internal iron is stored and released from the cell. Additionally, it allows for the testing of conditions that are experimentally intractable, a process beneficial to many fields, as novel interactions and relationships can be explored without laboratory experimentation. (Received August 21, 2011)

1077-92-332 **M T Malik*** (tufail@asu.edu), Department of Mathematics, University of Manitoba, Winnipeg, Manitoba R3T2N2, Canada, and **J Reimer**, **A B Gumel**, **E H Elbasha** and **S M Mahmud**. *Qualitative Assessment of the Roles of an Imperfect Vaccine and Pap Cytology Screening on the Transmission Dynamics of Human Papillomavirus.*

The talk will address the problem of the transmission dynamics of human papillomavirus in a population. A new sex-structured model, which takes into account the associated multiple cervical intraepithelial neoplasia stages, will be used to assess the combined impact of Pap cytology screening and a vaccine on the disease dynamics and the associated dysplasia. Rigorous qualitative analysis will be presented. Simulation results, using a realistic set of parameter values, will also be discussed. (Received August 22, 2011)

1077-92-335 **Qing Nie***, Department of Mathematics, University of California, Irvine, Irvine, CA 92617. *Noise Attenuation in Biological Systems.*

In this talk, we will first introduce a new quantity defined as Signed Activation Time (SAT), which is found to be critical in determining noise attenuation capability of a feedback system. We will next study how noise amplification rates of several biological examples may depend on SAT and investigate strategies for noise attenuation in systems involving both extra-cellular and intra-cellular components. In particular, we will study boundary sharpening during zebrafish embryonic development. (Received August 23, 2011)

1077-92-338 **Yue Fan**, **Shinuk Kim**, **Mark A Kon** and **Louise A Raphael*** (Lraphael@howard.edu), Department of Mathematics, Howard University, Washington, DC 20059, and **Charles DeLisi**. *Cancer Classification of Microarray Data by Denoising Methods on Graphs.* Preliminary report.

We prove results for two denoising methods, local averaging and kernel regression on graphs, adapted from denoising methods for functions in Euclidean space and applied to functions on graphs. These approaches are illustrated in computational biology in the regularization of gene expression feature vectors derived from (typically noisy) cancer microarrays. The microarray feature vectors are viewed as functions on the set of genes, which have the structure of a graph (network) based on gene-gene connections derived from a protein-protein interaction network. A particular property of Euclidean denoising which carries over to these cases is that the accuracy of the denoised function increases to a maximum as a function of the denoising parameter t, and then decreases. (Received August 23, 2011)

1077-92-348 **Corinne Alexandra Wentworth*** (cawentworth@smcm.edu), Campus Center #2354, 16800 Point Lookout Rd., St. Mary's City, MD 20686, and **Jay Walton** (jwalton@math.tamu.edu) and **Masami Fujiwara** (fujiwara@tamu.edu). *Optimal Harvesting Models for Fishery Populations.* Preliminary report.

Fishery management is the consideration of the ecological effects of harvesting. Fisherman work to provide fish for a growing human population but because of this some fish populations have been dangerously declining. It is important to balance ecological and economic needs. In this talk, we investigate various deterministic models of fishery populations. A simple logistic model, a skewed logistic model with a quadratic term, and a model that demonstrates the Allee effect have all been considered with a constant harvest rate as well as time dependent harvesting. Optimization and numerical calculations were used to determine the harvest rate that produces maximum yield under different population density scenarios. (Received September 21, 2011)

1077-92-353 **Mike Martin*** (michael.e.martin@gmail.com), 6319 Sherwood Lane, Merriam, KS 66203. *Bringing Biological Applications to the High School Mathematics Curriculum.*

The recently published text, BioMath in the Schools (vol 76 in the DIMACS-AMS series), is directed specifically for the incorporation of biological models and specific mathematical tools into the high school and early undergraduate mathematics courses. This talk will lay out the rationale for change in the curriculum, the training and materials for educators in this area, specific tools and course directions, and the evaluation of the integration of these approaches. The presenter of this talk is one of the contributors to this text and actively involved with high school educators who are involved in these areas. (Received August 25, 2011)

1077-92-356 **Katie Storey*** (storeyk@carleton.edu), **May Boggess** and **Jay Walton**. *Eradicating Invasive Species through Sex Reversal.* Preliminary report.

An invasive species causes harm to the habitat in which it resides, and the Trojan Y Chromosome Model is a potential method for eradicating invasive species of fish. Feminized YY Supermales of the targeted invasive species are added to an ecosystem, causing the female XX fish to decrease in population until they reach a specified level. If the level of female fish is low enough when the addition of feminized supermales stops, the species will die out. An ordinary differential equation model, a stochastic model, and a spatial model were used to determine the level of female fish necessary to ensure the eradication of the species. (Received August 25, 2011)

1077-92-361 **David Murrugarra*** (davidmur@vt.edu), 830 Claytor Sq, Blacksburg, VA 24060. *The Number of Multistate Nested Canalyzing Functions.*

Nested canalyzing functions, a class of biologically meaningful functions, have shown to have very nice dynamical properties. This talk addresses the very important question of knowing how restrictive this class of functions is, for instance for the purpose of network reverse-engineering. This talk will present a formula for the number of nested canalyzing functions and a comparison to the class of all functions. In particular, it will be shown that, as the number of variables become large, the ratio of the number of nested canalyzing functions to the number of all functions converge to zero. This shows that the class of nested canalyzing function is indeed very restrictive. The main tool used for this research is a description of these functions as polynomials over finite fields and a parametrization of the class of all such polynomials in terms of relations on their coefficients. (Received August 25, 2011)

1077-92-362 **Sara Anne Krueger***, 700 Luther Drive, Mankato, MN 56001, and **May Boggess** and **Jay Walton**. *A Reservoir Model of Chagas Disease.*

More than 1 billion people all over the world are infected with neglected tropical diseases, such as Chagas disease in Latin and South America. Like malaria, this disease is passed between infected animals and people by an insect, the reduviid bug. In this paper, an ordinary differential equations model was developed that accounts for the existance of a disease reservoir in mammals, such as domestic livestock. Our results show that the disease free state is not a stable equilibrium, meaning that the introduction of even a small number of insects will lead to an epidemic. (Received August 25, 2011)

1077-92-402 **L. J. S. Allen*** (linda.j.allen@ttu.edu), **V. L. Brown**, **C. B. Jonsson**, **S. L. Klein**, **S. M. Laverty**, **K. Magwedere**, **J. C. Owen** and **P. van den Driessche**. *Mathematical Modeling of Viral Zoonoses in Wildlife.*

Zoonoses are a worldwide public health concern, accounting for approximately 75% of human infectious diseases. In addition, zoonoses adversely affect agricultural production and wildlife. We review some mathematical models developed for the study of viral zoonoses in wildlife and identify areas where further modeling efforts are needed. (Received August 29, 2011)

1077-92-411 **Roland H Lamberson*** (rhl1@humboldt.edu), Math Dept, Humboldt State University, Arcata, CA 95521. *On the Complexity of Competition.*

Spatial and temporal variation in the environment can have profound effects on both interspecific and intraspecific competition. We have used an individual-based stream fish model to study competition in various settings. We will look at the impact of intraspecific competition between hatchery and wild fish on the spatial distribution of wild fish and their feeding habits. We will look at the ways traditional habitat selection studies can be misled by competitive dynamics. Finally, we will look at cases where the dominance in the competition between two species can switch as a result of rather modest temporal changes in stream flow. (Received August 29, 2011)

1077-92-431 **Bonni J Kealy*** (bkealy@math.wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113, and **David J Wollkind** (dwollkind@wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113. *Stripes Versus Spots in Reaction-Diffusion Systems: Comparison of Vegetative and Chemical Turing Pattern Formation.*

Turing pattern formation results are deduced for reaction-diffusion partial differential equations relevant to describing plant-surface water and iodide-chlorite interactions on an arid flat environment and in a gel chemical reactor, respectively, by means of a hexagonal planform weakly nonlinear diffusive instability analysis applied to those model systems. These biological and chemical physical results are plotted in a rainfall-plant loss parameter space and for one involving pool species, respectively. Then the predicted leopard, tiger, and pearled bush vegetative patterns and the spot, stripe, and honeycomb chemical ones are compared with appropriate observational and experimental evidence, respectively, as well as with each other. (Received August 31, 2011)

1077-92-484 **Eduardo Sontag*** (sontag@math.rutgers.edu). *Theory and experiments in molecular systems biology.*

We will discuss a few selected vignettes in "systems biology" that combine mathematical analysis with molecular biology experimentation. (Received September 04, 2011)

1077-92-497 **Yuan Lou*** (lou@math.ohio-state.edu), Department of Mathematics, Ohio State University, Columbus, OH 43210. *Dispersal in heterogeneous landscape.*

A general question in the study of the evolution of dispersal is what kind of dispersal strategies can convey competitive advantages and thus will evolve. We will mainly focus on a reaction-diffusion-advection model for two competing species, in which the species are assumed to have the same population dynamics but different dispersal strategies. We find a conditional dispersal strategy which results in the ideal free distribution of species, and we investigate whether such dispersal strategy is evolutionarily stable. Discrete and nonlocal dispersal models will also be discussed. The talk is mainly based upon joint works with Isabel Averill, Steve Cantrell, Chris Cosner, Dan Munther and Dan Ryan. (Received September 05, 2011)

1077-92-581 **Yifan Mo*** (jasonmo2006@gmail.com), **Will Liao**, **Haipeng Xing** and **Michael Zhang**. *A Novel Baysian Change-Point (BCP) Model for Better ChIP-seq Data Analyses.* Preliminary report.

The Chromatin Immunoprecipitation followed by high throughput massively parallel next-generation sequencing technology has being widely used to analyze the interaction between protein and chromatin DNA interaction, as a result, large amounts of ChIP sequencing (ChIP-seq) data consisting of tens of millions short reads become the focus of intense interest in studies of various transcription factor binding sites (TFBSs) and/or histone modification sites.

To meet such challenge, we present a novel stochastic Bayesian BCP segmentation model and the related estimation procedure to analyze different types of ChIP-seq data by taking the advantage of using explicit analytical formula to calculate the posterior means in our model.

For transcription factor binding site (TFBS) analysis, it can find more accurate localization with less false positives and higher functional motif enrichment. When applied to the more diffused data as some histone modification (HM) profiles, it will generate more robust and accurate segmentations than using arbitrary ad hoc windows to do the clustering in many popular methods.

We chose CTCF and STAT1 for the TFBS study and H3k27me3, H3k36me3 and H3k27ac for the HM analysis to demonstrate the superiority of our method than other similar methods. (Received September 07, 2011)

1077-92-585 **Heather Johnston*** (hjohnston09@wou.edu), **Dr. May Boggess** and **Dr. Jay Walton**. *Oregon Blackberry Invasion Analyzed by Spatial Stochastic Modeling.*

Nonnative species are disruptive to natural ecosystems. The Himalayan Blackberry in Western Oregon is of particular concern due to the massive barriers the plant creates and its stubbornness of eradication. A spatially stochastic model is used to predict the spread of the blackberry in Oregon, taking into account factors such as elevation, annual rainfall, temperature, urban sprawl and black bear ranges. This presentation covers individual research in mathematical ecology done at the Texas A&M Math REU 2011. (Received September 07, 2011)

1077-92-608 **Natali Hritonenko*** (nahritonenko@pvamu.edu), Box 4189, Department of Mathematics, Prairie View A&M University, Prairie View, TX 77446, and **yuri yatsenko** and **Renan Goetz**. *The environmental impact on sustainable forest management.* Preliminary report.

Forest is an important natural, economic, and recreation resource. The development of reliable models for the rational exploitation of forests belongs to significant open issues of the natural resource modeling. The suggested model of forest dynamics is described by a system of PDEs and integral equations and is flexible enough to consider benefits from carbon sequestration and revenue from timber production and, on the other side, to reflect changes in the environment and different climate scenarios. One of the research goals is to understand how fluctuations in the environment impact natural / biological processes of the forest growth and carbon sequestration and economic regimes of forest management. The results of a collaborative research with Spanish environmental economists are presented. The outcomes of the model investigation are approbated on real data on forestry in Spain and can be implemented in corresponding long-term policies and regulations. (Received September 08, 2011)

1077-92-629 **Frank H Lynch*** (flynch@oxy.edu) and **Thomas Jemielita**. *Mathematical Modeling of Competitive Binding on a Microarray.*

Microarray analysis can be used to detect single nucleotide polymorphisms (SNPs) in DNA samples. Since SNPs are markers of pathology, ability to detect SNPs can advance treatment protocols. We present an ODE model of such analysis in a competitive (two-species) environment. Our analysis determines the unknown concentration of SNP in a sample. Comparison to experimental data is also shown. (Received September 08, 2011)

1077-92-673 **Charles (Chip) E Lawrence*** (Charles_Lawrence@brown.edu), 182 George Street, Providence, RI 02912, and **Donglai Wei** and **Lauren Alpert** (Lauren_Alpert@brown.edu), 182 George Street, Box M, Providence, RI 02912. *RNAG: A New Gibbs Sampler for Predicting RNA Secondary Structural Ensembles of Unaligned Sequences.*

RNA secondary structures play an important role in the function of many RNAs, and structural features are often crucial to their interaction with other cellular components. We present a new algorithm, RNAG, to predict consensus secondary structures for unaligned sequences using the blocked Gibbs sampler, which has theoretical advantage in convergence time (Liu JASA, 1994). This algorithm iteratively samples from the conditional probability distributions P(Structure — Alignment) and P(Alignment — Structure) using efficient recursive sampling algorithms for each of these conditional distributions. We used hierarchical clustering to characterize the expected complex posterior space of these structural ensembles, gamma-centroid estimator to generate predictions, and credibility limits to characterize their uncertainty. An analysis of 17 RNA families shows substantially improved structural prediction based on PPV-SEN curves comparisons, compactness of sampled structures around their ensemble centroids, and at least eleven families with well separated clusters. (Received September 09, 2011)

1077-92-690 **Matthew H Holden*** (mhh88@cornell.edu), 657 Frank T. Rhodes Hall, Cornell University, Ithaca, NY 14853, and **Stephen P Ellner**, **Doo-Hyung Lee**, **Jan P Nyrop** and **John P Sanderson**. *Mathematical modeling for the improvement of sustainable pest management: a trap cropping example.*

Trap cropping, the use of alternative host plants to reduce damage to a focal cash crop or other managed area, can be a sustainable strategy for pest control, but in practice often fails to reach management goals. In order to explain past failures and suggest guidelines for future improvements, we developed a simple model to understand how a trap plant's spatial configuration within a field, its attractiveness, and its ability to retain pests affects pest density on a target cash crop. The model predicts that when trap crop retention is low, small differences in retention have little effect on pest populations in the cash crop, but when retention is high, these differences have a large effect. The opposite is true for attraction. Compared to uniformly located trap plants, clumping trap plants close together, while most often deleterious to trap cropping, can potentially reduce pest densities for frequently moving insects. These results suggest that trap cropping must be supplemented with complimentary management tactics in order for it to successfully control pest populations. (Received September 10, 2011)

1077-92-719 **Jason M Graham*** (jason-graham@uiowa.edu), 115 Hawkeye Court, Iowa City, IA 52246. *Reaction-Diffusion-Delay Model for Chondrocyte/Cytokine Interactions During Typical Injury Response in Articular Cartilage.* Preliminary report.

Mechanical or chemical stress to articular cartilage kills chondrocytes resulting in the development of lesions on the cartilage surface. The typical injury response often causes collateral damage, which results in the spread of these lesions beyond the region of initial injury. This increases the chances of development of post-traumatic osteoarthritis. A balancing act between pro- and anti- inflammatory cytokines determines the amount of collateral damage that occurs and suggests possible therapies for limiting such damage. The goal of this work is to develop a mathematical representation for the interactions of such cytokines and the resulting effects on the chondrocyte population, that may be used to investigate the spread or abatement of post-injury cartilage damage. (Received September 11, 2011)

1077-92-773 **Necibe Tuncer*** (necibe-tuncer@utulsa.edu), necibe-tuncer@utulsa.edu. *Applications Of Reaction Diffusion Systems Defined On Evolving Surfaces.*

Reaction diffusion systems defined on evolving surfaces has many application in mathematical biology. Examples of such applications include tumor growth, pattern formation on seashells, butterfly wing pigmentation patterns and animal coat markings. We develop and analyze a finite element method to approximate solutions of reaction diffusion systems defined on evolving surfaces. The method we propose is based on *radially projected finite elements* (Received September 21, 2011)

1077-92-829 **Artem S Novozhilov*** (anovozhilov@gmail.com), **Vladimir P Posvyanskii** and **Alexander S Bratus**. *Reaction-diffusion replicator equation: Stability and asymptotic behavior.*

The replicator equation is known to provide a general modeling framework for several distinct areas in mathematical biology. There are several different approaches to add space to the replicator equation. As a counterpart of the local model we consider the model

$$\frac{\partial u_i}{\partial t} = u_i \left[(Au)_i - f^{sp}(t)\right] + d_i \Delta u_i, \quad i = 1, \ldots, n, \tag{1}$$

where now $u = u(x,t)$, $x \in \Omega \subset \mathbb{R}^k$, $k = 1, 2, 3$, $d_i > 0$ are diffusion coefficients, and the mean integral fitness is given by $f^{sp}(t) = \int_\Omega \langle Au, u\rangle \, dx$. This approach allows analytical investigation of (1): the tool which was mainly missing in the analysis of replicator equations with explicit space. In our work, we show that for some values of the diffusion coefficients spatially heterogeneous solutions appear. Using a definition for the stability in the mean integral sense we prove that these heterogeneous solutions can be attracting; in particular this is the case for Eigen's hypercycle. Defining in some natural way evolutionary stable states for the distributed system (1), we provide the conditions for this distributed state to be an asymptotically stable stationary solution to (1).
(Received September 13, 2011)

1077-92-835 **Noah M. Daniels**, Department of Computer Science, Tufts University, Medford, MA 02155, **Raghavendra Hosur**, CSAIL, Massachusetts Institute of Technology, Cambridge, MA 02139, **Lenore J. Cowen*** (lenore.cowen@tufts.edu), Department of Computer Science and, Department of Mathematics, Tufts University, Medford, MA 02155, and **Bonnie Berger** (bab@mit.edu), Department of Mathematics and, CSAIL, Massachusetts Institute of Technology, Cambridge, MA 02139. *Combining simplified Markov random fields with simulated evolution improves remote homology detection for beta-structural proteins into the twilight zone.* Preliminary report.

One of the most successful methods to date for recognizing protein sequences that are evolutionarily related has been profile Hidden Markov Models (HMMs). However, these models do not capture pairwise statistical preferences of residues that are hydrogen bonded in beta sheets. These dependencies can be partially captured in the HMM setting by simulated evolution in the training phase, and can be fully captured by Markov Random Fields (MRFs). However, the MRFs can be computationally prohibitive when beta strands are interleaved in complex topologies.

We introduce SMURFLite, a method that combines both simplified Markov Random Fields and simulated evolution to substantially improve remote homology detection for beta structures. Unlike previous MRF-based methods, SMURFLIte is computationally feasible on any beta-structural motif. We show a median 24 percent improvement in AUC for beta-structural motif recognition as compared to HMMer (a well-known HMM method), a median 16 percent improvement in AUC as compared to Raptor (a well-known threading method) and even a median 9 percent improvement in AUC as compared to HHpred, despite its use of additional training data, in a stringent cross-validation experiment. (Received September 13, 2011)

1077-92-851 **Lester Caudill*** (lcaudill@richmond.edu), Dept. of Mathematics and Computer Science, 28 Westhampton Way, Univ. of Richmond, VA 23173. *A Low-Dimensional Model of the Innate Immune Response to Bacterial Infection.*

The human immune response to bacterial pathogens is a remarkably complex process, involving many different cell types, chemical signals, and complex lines of communication. Mathematical models of this system have become increasingly complicated, as researchers seek to capture many of the major dynamics. In this talk, the author argues that, in some important instances, preference should be given to low-dimensional models of immune response, as opposed to their high-dimensional counterparts. One such model is analyzed and shown to reflect many of the key phenomenological properties of the immune response in humans. (Received September 22, 2011)

1077-92-873 **Sara Y Del Valle*** (sdelvall@lanl.gov), P.O. Box 1663, MS C933, Los Alamos, NM 87545. *Impact of Modeling and Simulation on Decision-Making: Infectious Diseases.*

At Los Alamos National Laboratory (LANL), one of the main missions is to develop and apply science, technology, and engineering solutions to reduce global threats. Infectious diseases are a major threat to the population's health and welfare and the U.S. economy. Protecting the nation against natural and man-made emerging and re-emerging infectious diseases can mitigate the potential impacts of these events.

Basic research at LANL has led to a deeper understanding of how infectious diseases spread from person to person, how to prevent disease transmission, and how to better treat these diseases. Modeling efforts can help improve the effectiveness of public health intervention measures and minimize the population and economic impacts of an epidemic. In this talk, I will discuss different mathematical and computational models used to simulate the spread of infectious diseases and how they provide decision support during an outbreak. (Received September 13, 2011)

1077-92-895 **Michele L. Joyner*** (joynerm@etsu.edu). *Modeling the Differences in the Development of a New Antibiotic Class versus the Development of a Next Generation Antibiotic to Combat Antimicrobial Resistance in a Hospital Setting.*

The increase in antimicrobial resistance continues to pose a major public health risk leading to a more intense focus on ways to limit and even reduce this threat. One such effort is the push for twenty new classes of antibiotics by the year 2020. Most of the current antibiotics used today are derivations of antibiotics first introduced forty to fifty years ago. In this talk, mathematical model are used to simulate the difference between implementing a next generation antibiotic versus a new class antibiotic within a hospital setting. We simulate both the short term and long term effects of using the new antibiotic to combat existing levels of antimicrobial resistance. In addition to analyzing the difference in antibiotic classes, we also analyze the effects of the method of administration of the new antibiotic. Simulations suggest a need in the long term for the development of new classes of antibiotics administered in a very structured, targeted manner. (Received September 14, 2011)

1077-92-905 **Nicholas S Luke*** (luke@ncat.ed), **Reeder Sams II**, **Michael J Devito**, **Rory B Conolly** and **Hisham A. El-Masri**. *Development of a Quantitative Model Incorporating Key Events in a Hepatotoxic Mode of Action to Predict Tumor Incidence.*

Biologically based dose-response (BBDR) modeling of environmental pollutants can be utilized to inform the mode of action(MOA) by which compounds elicit adverse health effects. Chemicals that produce tumors are typically labeled as either genotoxic or nongenotoxic. One commonly proposed MOA for nongenotoxic carcinogens is characterized by the key events cytotoxicity and regenerative proliferation. The increased division rate associated with such proliferation can cause an increase in the probability of mutations, which may result in tumor formation. We included these steps in a generalized computational pharmacodynamic (PD) model incorporating cytotoxicity as a MOA for three carcinogens (chloroform, CHCl3; carbon tetrachloride,CCL4; and N,N-dimethylformamide, DMF). For each compound, the BBDR model is composed of a chemical-specific physiologically based pharmacokinetic model linked to a PD model of cytotoxicity and cellular proliferation. The rate of proliferation is then linked to a clonal growth model to predict tumor incidences. Optimization of model parameters to tumor data are presented and compared for all three chemicals. (Received September 14, 2011)

1077-92-911 **Pauline van den Driessche*** (pvdd@math.uvic.ca). *Global Dynamics of a Cholera Model that Includes Direct and Indirect Transmission.*

The World Health Organization estimates that there are 3m-5m cholera cases per year with 100,000 deaths spread over 40-50 countries. Recent mathematical models of cholera have considered the importance of two pathways of transmission to humans, namely directly from person-to-person and indirectly via the environment (mainly contaminated water). An ordinary differential equation model for cholera dynamics is formulated that

includes these two pathways with general incidence, as well as stages of infection and infectivity states of the pathogen. Lyapunov functions are used in the model analysis to show that a basic reproduction number gives a sharp threshold determining whether cholera dies out or becomes endemic. In the absence of recruitment and death, the model is used to determine a final size equation or inequality and simulations illustrate how assumptions on cholera transmission affect the final size of the epidemic.
Joint work with Zhisheng Shuai (Received September 14, 2011)

1077-92-918 **Andrew M. Oster*** (ostera@wlu.edu), **Philippe Faure** and **Boris S. Gutkin**.
Mechanisms for multiple activity modes of midbrain DA neurons.

Midbrain dopamine (DA) neurons send numerous projections to cortical and subcortical areas and, in a manner dependent upon their activities, diffusely release DA to their targets. Recent experimental studies have shown that DAergic neuronal bursting is associated with a significantly greater degree of DA release than an equivalent tonic activity pattern. Past computational models for DA cell activity relied upon somatodendritic mechanisms in order to generate DA cell bursting. However, recent experimental studies indicate that burst firing can be generated somatically with the dendrites silenced. These bursts have characteristics consistent with normal bursting, suggesting that a single-compartmental model should be sufficient for generating the observed DA neuronal dynamics. In this talk, we introduce such a model for DA neuronal dynamics and compare the simulated activities to data. In our approach, the interplay between the L-type calcium and the calcium-dependent SK potassium channel provides a scaffold for the underlying oscillation for the pacemaker-like firing patterns. We observe that a reduction of the SK conductance may induce DA bursting. Moreover, our model captures burst firing elicited via a stimulus driven event, manifested by rises in the amount of NMDA. (Received September 14, 2011)

1077-92-948 **Jeong-Mi Yoon*** (yoonj@uhd.edu), One Main Street, Houston, TX 77002, **Volodymyr Hrynkiv** (hrynkivV@uhd.edu), One Main Street, Houston, TX 77002, **Lisa Morano** (moranoL@uhd.edu), One Main Street, Houston, TX 77002, **Sara Wilder** (sarawilder08@yahoo.com), One Main Street, Houston, TX 77002, **Anh Tuan Nguyen** (nguyena48@gator.uhd.edu), One Main Street, Houston, TX 77002, and **Forrest Michell** (FMitchel@ag.tamu.edu), Texas Agricultural Experiment Station, 1229 North US Highway 281, Stephenville, TX 76401. *Parameter Optimization of Glassy-winged Sharpshooter Population Model.* Preliminary report.

Pierce's Disease (PD) is a bacterial disease of grapevines, which is transmitted by xylem feeding insects. To understand the role of insect ecology on PD epidemiology, we analyze Dr. Forrest Mitchell's (Texas A & M University) insect data. Among the insects monitored, Glassy-winged sharpshooter (GWSS) is the most abundant insect. The first goal of our research is modeling the temporal change of GWSS population in the central Texas. This research has been funded by a NSF grant: The Interdisciplinary Training for Undergraduates in Biology and Mathematical Sciences. We develop a time delayed logistic model with harvesting and immigration terms which could include the environmental factors such as insecticide use, information campaigns and weeds cleaning, etc. The experimental data shows periodically decaying behaviors. To obtain a local minimum error between the experimental and theoretical values we work on the optimazatin algorithm using software, MATLAB based on the least square method. In the recent model we use a linear harvesting and a constant immigration. In the next step, we will apply various types of harvesting and immigration terms to improve the fitting. I believe that this research will help to predict future PD risk and determine the optimal management protocols. (Received September 14, 2011)

1077-92-1009 **Joseph Rusinko*** (rusinkoj@winthrop.edu), 142 Bancroft Hall, Rock Hill, SC 29732.
Invariant Based Quartet Puzzling for Phylogentic Reconstruciton. Preliminary report.

We will introduce a variation on the quartet puzzling model of reconstructing evolutionary trees from DNA sequence data. Instead of using maximum likelihood methods to infer the best four taxa tree, we examine the use of phylogenetic invariants in this key step. This model is a step toward using invariants to construct trees for data samples involving a large number of taxa. We will describe the results of preliminary investigations into the accuracy of this model. (Received September 15, 2011)

1077-92-1051 **Martha J. Garlick*** (marti.garlick@aggiemail.usu.edu), **James A. Powell**, **Mevin B. Hooten** and **Leslie R. McFarlane**. *Homogenization of Large-Scale Movement Models in Ecology.*

A difficulty in using diffusion models to predict large scale animal population dispersal is that individuals move differently based on local information (as opposed to gradients) in differing habitat types. This can be accommodated by using ecological diffusion. However, real environments are often spatially complex, limiting application of a direct approach. Homogenization for partial differential equations has long been applied to Fickian diffusion (in which average individual movement is organized along gradients of habitat and population density). We derive a homogenization procedure for ecological diffusion and apply it to a simple model for chronic wasting disease in mule deer. Homogenization allows us to determine the impact of small scale (10-100 m) habitat variability on large scale (10-100 km) movement. The procedure generates asymptotic equations for solutions on the large scale with parameters defined by small-scale variation. The simplicity of this homogenization procedure is striking when compared to the multi-dimensional homogenization procedure for Fickian diffusion, and the method will be equally straightforward for more complex models. (Received September 15, 2011)

1077-92-1067 **Rongsong Liu** and **Junping Shi*** (jxshix@wm.edu), Jones Hall 122, Department of Mathematics, College of William and Mary, Williamsburg, VA 23187, and **Carlos Martinez del Rio** and **Chuncheng Wang**. *Spatiotemporal Mutualistic Model of Mistletoes and Birds.*

A mathematical model which incorporates the spatial dispersal and interaction dynamics of mistletoes and birds is derived and studied to gain insights of the spatial heterogeneity in abundance of mistletoes. Fickian diffusion and chemotaxis are used to model the random movement of birds and the aggregation of birds due to the attraction of mistletoes respectively. The spread of mistletoes by birds is expressed by a convolution integral with a dispersal kernel. Two different types of kernel functions are used to study the model, one is Dirac delta function which reflects one extreme case that the spread behavior is local, and the other one is a general non-negative symmetric function which describes the nonlocal spread of mistletoes. When the kernel function is taken as the Dirac delta function, the threshold condition for the existence of mistletoes is given and explored in term of parameters. For the general non-negative symmetric kernel case, we prove the existence and stability of non-constant equilibrium solutions. Numerical simulations are conducted by taking specific forms of kernel functions. Our study shows that the spatial heterogeneous patterns of the mistletoes are related to the specific dispersal pattern of the birds which carry mistletoe seeds. (Received September 15, 2011)

1077-92-1152 **Erik J Nelson*** (enelson2@bowdoin.edu), Department of Economics, Bowdoin College, 9700 College Station, Brunswick, ME 04011. *The math and algorithms of mapping and valuing ecosystem services.* Preliminary report.

Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) is a family of GIS modules that can be used to map and value the goods and services from nature produced on landscapes and coastal zones. If properly managed, ecosystems yield a flow of services that are vital to humanity, including the production of goods, life support processes, and life fulfilling conditions, and the conservation of options. Despite its importance, this natural capital is poorly understood, scarcely monitored, and, in many cases, undergoing rapid degradation and depletion. InVEST enables decision-makers to assess the tradeoffs associated with alternative choices and to identify areas where investment in natural capital can enhance human development and conservation in terrestrial, freshwater, and marine ecosystems. I will use my session to demonstrate the math and algorithms behind the modules, including recently added algorithms for mapping and measuring service provision and value uncertainty. I will also demonstrate how InVEST modules are being linked with the Google Earth engine. This partnership will allow the user to draw land-use changes on the computer screen and then receive immediate information on the expected impact of this change on service provision and value. (Received September 16, 2011)

1077-92-1257 **Lih-Ing Wu Roeger*** (lih-ing.roeger@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, MS 41042, Lubbock, TX 79409, and **Sze-Bi Hsu** (sbhsu@math.nthu.edu.tw), Department of Mathematics, Hsinchu, Taiwan. *A Refuge-mediated Apparent Competition Model.*

We analyze a competition model of two plant species for a single-limited resource while the competition is apparent: an indirect interaction where the invading plants provide a refuge for a shared consumer, subsequently increasing the consumer pressure on the resident plant species. When there is no refuge effect, the resident species is a superior species. As the refuge effect increases, the coexistence state appears as a saddle point with a two-dimensional stable manifold while the two extinction equilibria are locally stable. Thus the refuge-mediated apparent competition creates an Allee effect for both the invading and the resident species. A Lyapunov function is found to show the global stability of the equilibrium in which only the resident species survives. (Received September 18, 2011)

1077-92-1269 **Azmy S. Ackleh*** (ackleh@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504-1010, and **Paul Salceanu** (salceanu@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504-1010. *Persistence and Competitive Exclusion for a Nonautonomous Multi-Strain SIR Epidemic Model with Nonlinear Host Mortality.* Preliminary report.

We study a nonautonomous version of the SIR multi-strain epidemic model developed by Ackleh and Allen (2003). We give sufficient conditions for the persistence of the total population, as well as of the susceptible and infected subpopulations. We also discuss the competitive exclusion among the n infection strains, namely when a single infection strain survives and all the others go extinct. Numerical examples that demonstrate coexistence between different strains are also presented. (Received September 18, 2011)

1077-92-1320 **Worku T. Bitew*** (biteww@farmingdale.edu), 2350 Broadhollow Rd, MATHEMATICS, Farmingdale, NY 11735, and **Wisdom Akpalu** (akpaluw@farmingdale.edu), 2350 Broadhollow Rd, Economics, Farmingdale, NY 11735. *Species Diversity, Fishing Induced Change In Carrying Capacity And Sustainable Fisheries Management.*

It is well established in the fisheries management literature that marine ecosystems are complex and marine species depend on one another. As a result, it is important to account for species diversity to ensure sustainable management. In addition, recent research published in the marine sciences literature has provided unequivocal evidence that fishing activities destroy habitats and inhibit production of planktons. This paper illustrates that if a conventional bio-economic model is employed, an optimum effort policy as opposed to quota appears to result in sustainable management even if fishing impacts carrying capacity. However, the so-called optimum effort may collapse the stock if species diversity is not accounted for. Conversely, if species diversity and the impact of fishing on carrying capacity are considered, neither the equilibrium quota nor effort may guarantee sustainable yield.

Keywords: fishing impact on carrying capacity, fishing policy, phenotypic diversity, stock collapse (Received September 19, 2011)

1077-92-1324 **Myrielle N Allen-Prince*** (myrielle.aprince@ymail.com), 608 Province Spring Circle apt# 4B, Greensboro, PA 27403, and **Jay Walton**. *Finger Motion Modeling for Bionic Fingers.* Preliminary report.

The use of bionic hands is becoming a reality for those who have suffered amputation. Mathematical models are necessary to calculate the forces needed on each tendon to mimic the motion of human fingers. We modeled the motion of the human finger and thumb as it bends in and out using Newton's second law of motion. A system of partial differential equations was developed to describe the relationship of the forces needed to move the finger to a specified position, incorporating a feedback mechanism. Our work shows that this type of model can be used to accurately control the motion of a human finger. (Received September 19, 2011)

1077-92-1349 **Brianna G Payne*** (brianna@andrews.edu), **James L Hayward**, **Shandelle M Henson**, **Libby C Megna** and **Susana del Rocio Velastegui Chavez**. *Model of Marine Iguana Haulout on Fernandina, Galapagos.* Preliminary report.

We use ordinary differential equation models, connected rigorously to field data, to measure the degree to which behavioral dynamics are a function of the abiotic environment. Specifically, we model the haulout dynamics of Galapagos marine iguanas (Amblyrhynchus cristatus cristatus) at Cabo Douglas on the Island of Fernandina in the Galapagos Archigelago. The study outlines a methodology potentially useful as a management tool and provides a nuanced understanding of marine iguana behavior and niche characteristics. (Received September 19, 2011)

1077-92-1450 **David E Hiebeler***, Dept of Mathematics & Statistics, 236 Neville Hall, Orono, ME 04469. *Biological dispersal strategies of Internet worms.*

For the past decade, Internet worms (a type of malicious software similar to a virus) spreading through networks have been using biological strategies, such as hierarchical dispersal and adaptive strategies, to spread more efficiently among susceptible computers. There is a direct analogy between susceptible computers on the Internet and susceptible hosts in community-structured populations. Our measurements show that the Internet is an incredibly clustered heterogeneous environment when measured in a natural way inspired by the dispersal strategy used by worms. We have used these measurements to build an epidemiological simulation model of the entire Internet (4.29 billion hosts) efficient enough to run on an ordinary desktop computer. A worm which would have a basic reproduction ratio far less than one and therefore be quite unsuccessful at spreading using simple random dispersal strategies can be very successful by exploiting the large variance or clustering of vulnerable computers

among subnetworks in the Internet. With the new Internet addressing scheme (IPv6) currently being rolled out, these issues will be amplified by many orders of magnitude. (Received September 19, 2011)

1077-92-1451 **Nianpeng Li** and **Abdul-Aziz Yakubu*** (ayakubu@howard.edu), Department of Mathematics, 2441 6th Street NW, Washington, DC 20059. *A Discrete-Time Age-Structured Model Of Exploited Fishery Systems.*

In this talk, we will introduce a juvenile-adult age-structured production exploited fishery model with a very general recruitment function. As case studies, we will use our model results and historical fish population data from Georges Bank to investigate the impact of recent harvesting levels on the sustainability of cod fishery. We will show that a constant harvesting policy with the historical harvesting rates would lead to the recovery and sustainability of Georges Bank cod fishery. (Received September 19, 2011)

1077-92-1452 **Christine E Heitsch*** (heitsch@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *"RNA folding prediction: the continued need for interaction between biologists and mathematicians".*

A 1986 article by M. Zuker with this title, published in an AMS collection, outlined several major questions in the area — many of which are still relevant today. Stating the folding problem is simple; given an RNA sequence, predict the set of (canonical, nested) base pairs found in the native structure. Yet, despite significant advances over the past 25 years, it remains largely unsolved. A fundamental challenge identified by Zuker was, and still is, the "ill-conditioning" of discrete optimization solution approaches. We revisit some of the questions this raises, and present recent advances in considering multiple (sub)optimal structures, in incorporating auxiliary experimental data into the optimization, and in characterizing sequences for which the optimization does give satisfactory results. (Received September 19, 2011)

1077-92-1463 **Fred Brauer*** (brauer@math.ubc.ca), Department of Mathematics, University of British Columbia, 1984 Mathematics Road, Vancouver, BC V6T 1Z2, Canada. *Initial exponential growth rates in compartmental models.*

We give a complete proof of the relation between the basic reproduction number and the initial exponential growth rate of an epidemic given by Diekmann & Heesterbeek (2000) and Wallinga & Lipsitch (2007). As examples we describe a general SEIR model and a quarantine/isolation model. (Received September 21, 2011)

1077-92-1466 **Andrew Nevai*** (anevai@math.ucf.edu), Department of Mathematics, P.O. Box 161364, Orlando, FL 32816, and **Robert Van Gorder** (rav@knights.ucf.edu), Department of Mathematics, P.O. Box 161364, Orlando, FL 32816. *The influence of a resource subsidy on predator-prey interactions.*

We study the influence of a donor-controlled resource subsidy on predator-prey interactions. The prey increases logistically, the subsidy appears arithmetically, and the predator experiences satiation. In one model, the prey and subsidy are found together, and in a second they are spatially separated. Criteria for feasibility and stability of the different equilibrium states are discussed. Implications for a biological system involving arctic foxes (predator), lemmings (prey), and seal carcasses (subsidy) are considered. (Received September 19, 2011)

1077-92-1489 **Wondimu W Teka*** (wteka@math.fsu.edu), 1017 Academic Way, 208 Love Bldg, Tallahassee, FL 32306, **Joel Tabak**, Tallahassee, FL, **Theodore Vo**, Sydney, Australia, **Martin Wechselberger**, Sydney, Australia, and **Richard Bertram**, Tallahassee, FL. *The Dynamics Underlying Pseudo-Plateau Bursting in a Pituitary Cell Model.* Preliminary report.

Pituitary cells of the anterior pituitary gland secrete hormones in response to patterns of electrical activity. Several types of pituitary cells produce short bursts of electrical activity which are more effective than single spikes in evoking hormone release. These bursts, called pseudo-plateau bursts, are unlike bursts studied mathematically in neurons (plateau bursting) and the standard fast-slow analysis used for plateau bursting is of limited use. Using an alternative fast-slow analysis, with one fast and two slow variables, we show that pseudo-plateau bursting is a canard-induced mixed mode oscillation. Using this technique, it is possible to determine the region of parameter space where bursting occurs as well as salient properties of the burst such as the number of spikes in the burst. The information gained from this one-fast/two-slow decomposition complements the information obtained from a two-fast/one-slow decomposition. (Received September 22, 2011)

1077-92-1494 **Bernard Sapoval*** (bernard.sapoval@polytechnique.edu), Route de Saclay, 91128 Palaiseau, France. *Magic fractal distribution trees in living systems: 1-Implication for evolution theory 2-Role of randomness.* Preliminary report.

Arborescent structures are common in living systems and their structure can be described by fractal geometry. In particular, the upper structure of the respiratory system of mammalians, or bronchial tree, is a fluid transportation system made of approximately 15 generations of bifurcations leading to the order of 215= 30.000 bronchioles. We discuss the optimal properties of such structures, energy efficiency, rapidity, and space filling. The ideal system is found to be multi-optimal. This multi-optimality suggests that, in the course of evolution, an organ selected against one criterion could have been later used later for a totally different property.

Real physiological trees are close to this ideal tree but different. For example the human bronchial bifurcations present a systematic branching asymmetry. This could lead to a multifractal distribution of the fluids and create a strongly uneven repartition of fluids with obvious dangerous consequences for life. We discuss how nature has lifted this contradiction in a different manner for airways and arteries. (Received September 20, 2011)

1077-92-1505 **James P Peirce*** (jpeirce@uwlax.edu), Mathematics Department, 1725 State Street, La Crosse, WI 54601, and **Gregory J Sandland** (gsandland@uwlax.edu), Biology Department, 1725 State Street, La Crosse, WI 54601. *Predicting the ecological outcomes of species invasions and parasite transmission in the upper Mississippi River.*

Bithynia tentaculata is an invasive aquatic snail that has recently spread to the upper Mississippi River from the Great Lakes region. In addition to being a threat to native benthos, the snail harbors two parasite species that kill thousands of migrating waterfowl each year. Unfortunately, little is known about the factors underlying snail and parasite persistence, and what the consequences of continued disease outbreaks might be for this interaction in the future. We have undertaken complimentary theoretical and empirical approaches to address these shortcomings. We have developed a system of differential equations that capture the change in infection states of host organisms. Model parameters were estimated from field and experimental assessments of this system. Results from the theoretical model suggest that 1) parasite success in this system is species dependent, and 2) the persistence of each species will depend on particular transmission points in the life cycle. These outcomes will be used to expand our current empirical and theoretical approaches to better understand interactions between invasive species, native species, and disease transmission in the upper Mississippi River. (Received September 20, 2011)

1077-92-1535 **Karen A Yokley*** (kyokley@elon.edu). *Sensory Irritation Response in Rats: Recovery and Dose-Dependence.*

Inhaled irritants can cause respiratory depression by simulating trigeminal nerves in the nasal cavity. This decrease in inhalation rate results in a decrease in the rate of the irritant gases flowing to the stimulated nerves, creating a complex feedback response. Previously, a model was created to describe how the presence of formaldehyde affects respiration in the rat. This ordinary differential equation model incorporated a model of the physiology of the upper respiratory tract of the rat and a model of the neurological control of the respiration rate due to signaling from the stimulated nerves in the nasal cavity. However, an optimal fit to data was not fully established. In the current study, the fit of the previously established model is re-evaluated while incorporating the recovery of the ventilation rate after the end of exposure. Additionally, the dose-dependence of the adaptation time allowed by the previous model is more fully quantified, and the updated model predicts formaldehyde data well. The results of the previous study are improved and the model is more appropriate to translate to other irritants. (Received September 20, 2011)

1077-92-1551 **Ronald E. Mickens*** (rohrs@math.gatech.edu), Clark Atlanta University, Department of Physics, Atlanta, GA 30314. *Analysis of a Predator-Prey Model.*

A predator-prey model is constructed in which the birth and death rates for each population depends on the other population. The fixed-points are calculated and their local stability properties are determined. The possibility that a limit-cycle might exist is also investigated. The model is defined by the following system of ODE's:

$$\frac{dx}{dt} = \frac{a_1 x}{1 + c_1 y} - b_1(1 + c_2 y)x^2 - c_3 xy,$$

$$\frac{dy}{dt} = -\frac{a_2 y}{1 + d_1 x} + d_2 xy.$$

(Received September 20, 2011)

1077-92-1553 **Naveen K. Vaidya*** (nvaidya2@uwo.ca), Dept of Applied Maths, The Univeristy of Western Ontario, 1151 Richmond St. N., London, Ontario N6A 5B7, Canada. *Simple Undergraduate Mathematics to Understand Complex HIV-1 Latent Infection Dynamics.*

Human immunodeficiency virus 1 (HIV-1) infection persists for a lifetime despite successful antiviral therapy. Establishment of latently infected cells (cells in resting state with integrated HIV-1 DNA) during early HIV-1 infection is conceptually the most challenging obstacle to viral eradication. A burning question of whether early treatment can reduce such latently infected cells still remains unanswered. In this talk I will demonstrate how simple undergraduate mathematics can help understand such complex dynamics of HIV-1 latent infection. Our model has excellent agreement with experimental data from 27 HIV-1 infected individuals. Our analysis shows that latently infected cells are largely generated before the initiation of therapy during early infection, and that the density of latently infected cells often decays during initial antiviral therapy. These results suggest that the latent infection can be limited by early ART during acute HIV-1 infection. (Received September 20, 2011)

1077-92-1571 **Stephen P Ellner**, Cornell University, and **Sebastian J Schreiber*** (sschreiber@ucdavis.edu), University of California, Davis. *Temporally variable dispersal and demography can accelerate the spread of invading species.*

Invasive organisms are altering natural communities at an unprecedented rate. Since climate models predict greater temporal variability in environmental conditions in the foreseeable future, future management of invasive species requires understanding the joint effects of temporal fluctuations in demography and dispersal on their rates of spatial spread. To address this issue, our model combines state-structured local demography (specified by an integral or matrix projection model) with general dispersal kernels, and stationary temporal variation in both local demography and dispersal kernels. We derive analytic expressions for the asymptotic spread rate and its sensitivity to parameters. Using these results, we show that random temporal variability in dispersal can accelerate population spread. Demographic variability can further accelerate spread if it is positively correlated with dispersal variability. A simple model for an invasive plant, perennial pepperweed, illustrates these effects and shows that they can have substantial impacts on the predicted speed of an invasion wave. Temporal variability in dispersal has gotten very little attention in both the theoretical and empirical literatures on invasive species spread. Our results suggest that this needs to change. (Received September 21, 2011)

1077-92-1606 **Matthew J Labrum*** (mlabrum@math.wsu.edu), PO Box 643113, Neill 103, Washington State University, Pullman, WA 99164-3113. *Biodiversity dynamics under intransitive competition and habitat destruction.* Preliminary report.

As world population increases, anthropogenic habitat destruction becomes more prevalent and poses an increasing threat to biodiversity. To identify species at risk of extinction, it is important to understand the interplay between species interactions and habitat destruction. While recent modeling efforts have made great strides towards understanding the principal factors causing the extinction of species in response to habitat destruction, a common simplifying assumption made in these models is a hierarchical ranking of competitive abilities among the species occupying a focal habitat. Empirical studies, however, have suggested that this assumption is not always valid. I investigate the ecological consequences of incorporating intransitive competition in a habitat-destruction model. As previous studies have shown that spatial scales affect the outcomes of intransitive competition, both spatial and non-spatial models are analyzed. Model outcomes are contrasted with those resulting for a perfect hierarchical ranking of competitive abilities among species. Of particular interest is the extent to which intransitivity in competitive interactions affects biodiversity dynamics and extinction risks, and how the frequency and spatial extent of habitat destruction alter these results. (Received September 20, 2011)

1077-92-1624 **John E. Franke*** (franke@math.ncsu.edu), Department of Mathematics, Box 8205, North Carolina State University, Raleigh, NC 27695-8205, and **Matthew A. Morena**. *Attenuant and Resonant 2-Cycles in Discrete-Time 2-Species Population Models.* Preliminary report.

Periodic environments are commonly observed in nature and may either enhance or suppress a population. We study the responses of two competing discretely reproducing populations to periodic fluctuations in six parameters. Two of these parameters are related to a nontrivial equilibrium (carrying capacity), two are related to the carrying capacities of the individual species in the absence of the other species and the remaining two are quite arbitrary but are usually intrinsic growth rates of the individual species. We prove that small, 2-periodic fluctuations in the six parameters support 2-cyclic oscillations of the populations. We then develop signature functions for predicting the responses of the populations to 2-periodic fluctuations in the environment. Periodic environments are favorable for the total biomass and for each species if the corresponding signature function is positive but are deleterious when the corresponding signature function is negative. We compute the signature functions for four classical discrete-time, two species population models, and then determine regions in parameter

space which are either favorable or detrimental to the populations. The four 2-D models studied are Logistic, Ricker, Beverton-Holt and Hassell type models. (Received September 20, 2011)

1077-92-1638 **Suzanne L. Robertson*** (srobertson@mbi.osu.edu). *Modeling the spread of waterborne disease: Incorporating heterogeneity in multiple transmission pathways.*

Heterogeneity is a fundamental issue in mathematical epidemiology. We expect many factors influencing disease transmission to vary across populations and across different spatial scales. Many results exist for how heterogeneity affects the spread of disease for SIR type models, where transmission occurs as a result of direct contact with infected individuals. However, waterborne diseases such as cholera may be spread through contact with a contaminated water source as well as through direct person-person transmission. Cholera dynamics are well described by a modified SIR model that incorporates a W compartment to track the concentration of pathogen in the water. We investigate the effect of heterogeneity in multiple transmission pathways on the value of the basic reproductive number R_0 in multiple patch SIWR models. (Received September 20, 2011)

1077-92-1680 **Azmy S. Ackleh** and **Jeremy J. Thibodeaux*** (thibodea@loyno.edu). *A second-order finite difference approximation for a mathematical model of erythropoiesis.* Preliminary report.

We present a second-order finite difference scheme for approximating solutions of a mathematical model of erythropoiesis (red blood cell production), which consists of two quasi-linear partial differential equations and one nonlinear ordinary differential equation. Through numerical simulations, we compare the method to a previously developed first-order method and numerically show that the method is indeed second-order. (Received September 20, 2011)

1077-92-1697 **Jill P. Mesirov*** (mesirov@broadinstitute.org). *Machine Learning Approaches for Genomic Medicine.*

The sequencing of the human genome and the development of new methods for acquiring biological data have changed the face of biomedical research. The use of mathematical and computational approaches is taking advantage of the availability of these data to develop new methods with the promise of improved understanding and treatment of disease. I will describe some of these approaches as well as our recent work on a Bayesian method for integrating high-level clinical and genomic features to stratify pediatric brain tumor patients into groups with high and low risk of relapse after treatment. The approach provides a more comprehensive, accurate, and biologically interpretable model than the currently used clinical schema, and highlights possible future drug targets. (Received September 20, 2011)

1077-92-1699 **Kray Van Kirk*** (kfvankirk@alaska.edu), 17101 Point Lena Loop Road, Juneau, AK 99801, and **Terrance J. Quinn II** and **Jeremy S. Collie**. *The influence of high trophic-level predators, data scarcity, parameter confounding, and model mis-specification on a multispecies age-structured assessment model for the Gulf of Alaska.*

A multispecies age-structured assessment model (MSASA) for the Gulf of Alaska is expanded from three species (arrowtooth flounder (Atheresthes stomias), Pacific cod (Gadus macrocephalus), and walleye pollock (Theragra chalcogramma)) to include two major high trophic level predators: Pacific halibut (Hippoglossus stenolepis) and Steller sea lion (Eumatopias jubatus). Significant changes to trophic structures and predation links from the core model were observed. Inclusion of the larger predators resulted in increased predation on older prey ages, including those fully recruited into the commercial fishery. Survey selectivity and catchability are confounded with natural mortality in their relationship to determining cohort structure; including predation mortality can potentially reduce this confounding, resulting in improved model fits to catch data and survey indices. Simulation exercises show that model performance degrades more due to model misspecification and data scarcity than assumptions regarding data weighting and variance. The model structure is able to track complex population dynamics using a relatively simple predation framework, but variability in parameter estimates makes clear the need for improved stomach data. (Received September 20, 2011)

1077-92-1716 **Erin N Bodine*** (bodinee@rhodes.edu), 2000 N. Parkway, Mathematics & Computer Science Department, Rhodes College, Memphis, TN 38112, and **Suzanne Lenhart** (lenhart@math.utk.edu), 227 Ayres Hall, 1403 Circle Drive, Mathematics Department, University of Tennessee, Knoxville, TN 37996-1320. *Bang-bang Optimal Control of Continuous Time Species Augmentation.*

Species augmentation is a method of reducing species loss via augmenting declining/threatened populations with individuals from captive-bred or stable, wild populations. We examine a differential equations model and optimal control formulation for continuous time augmentation of a general declining population. Two populations of the same species are modeled: a target/declining population and a reserve population. The objective functional is linear with respect to the optimal control, and we find a characterization for the optimal control utilizing Pontryagin's Maximum Principle and the generalized Legendre-Clebsch condition. Numerical results for scenarios of different illustrative parameter sets show the optimal controls are of bang-bang type. These numerical simulations articulate to natural resource managers the best they can do given certain constraints, and what augmentation strategy will yield that "best" outcome. (Received September 20, 2011)

1077-92-1751 **Kam Dahlquist** (kdahlquist@lmu.edu), Department of Biology, 1 LMU Drive, Los Angeles, CA 90045, and **Ben G Fitzpatrick*** (bfitzpatrick@lmu.edu), Department of Mathematics, 1 LMU Drive, Los Angeles, CA 90045. *Modeling and Estimation in Gene Regulatory Networks.*

Saccharomyces cerevisiae respond to cold shock by altering gene expression, which is controlled by the binding of transcription factors to regulatory sequences. In this talk, we discuss the modeling of the effect of cold shock on a network of transcription factors and their subsequent influence on gene expression. DNA microarrays were used to collect data over time as the yeast cells respond to cold shock. Spatial and intensity biases are present in microarray data, requiring Loess normalization and median absolute deviation scaling on the microarray data. The microarray data is then used to calibrate a differential equation model for transcription factor regulation. The model includes activation and repression relationships (which must be inferred from the data) in a complex network of interactions. We provide numerical results using microarray data from the literature as well as from our lab. (Received September 20, 2011)

1077-92-1758 **Vrushali A. Bokil** and **Margaret-Rose W. Leung*** (leungm@onid.orst.edu). *An Analysis of the Coexistence of Three Competing Species with a Shared Pathogen.*

We consider an SI model of three competing species that are all affected by a single pathogen which is transmitted directly via mass action. The total population sizes of the three species satisfy a three-dimensional Lotka-Volterra competition model. We address the interaction between competition and disease dynamics, and show that infected coexistence in the model is determined by the values of the basic reproduction numbers as well as the relative strengths of intra-specific crowding versus inter-specific competition for all three species. (Received September 20, 2011)

1077-92-1781 **Peng Zhong*** (zhongpeng85@gmail.com) and **Suzanne Lenhart**. *Optimal Control of a Harvesting Problem Modeled by Integrodifference Equations.*

Integrodifference equations are discrete in time and continuous in space, and are used to model the spread of populations that are growing in discrete generations, or at discrete times, and dispersing spatially. We investigate optimal harvesting strategies, in order to maximize the profit and minimize the cost of harvesting. Theoretical results on the existence, uniqueness and characterization, as well as numerical results of optimized harvesting rates are obtained. This problem can be modified into a pest control problem by using a different objective functional. The order of how the three events, growth, dispersal and harvesting, are arranged affects the harvesting behavior. All six possible orders of arranging the three events are discussed. Considering how certain orders can be obtained through transformations to other orders, we show that the six cases can be reduced to analyzing three cases. (Received September 20, 2011)

1077-92-1807 **Marc Allen Harper*** (marcharper@ucla.edu). *Phenotype Sequencing.*

Phenotype sequencing is a mathematical and statistical approach to the identification of mutations and genes causing and contributing to phenotypes resulting from the evolution of organisms subject to natural or artificial mutagenesis, as well as to the detection of rare-variants associated to particular phenotypes, through next-generation high-throughput DNA sequencing. This technique can significantly reduce the cost of identifying such genes in some cases. In this talk I present explicit results from experiments on biofuel-tolerant bacterial strains independently created through random chemical mutagenesis (effectively screening through background mutations and identifying the mutations and genes that confer tolerance), results from an analysis identifying a gene associated to a rare disease in six Korean subjects, other experimental results and information-theoretic evaluation metrics for these methods and experiment designs if time permits. This is joint work with Chris Lee of UCLA. (Received September 21, 2011)

1077-92-1848 **Courtney L Davis*** (cdavis@cscamm.umd.edu). *Toward a Vaccine: Modeling the Immune Response Against Shigella.*

The bacteria Shigella causes roughly 120 million dysentery infections and kills 1.1 million people per year worldwide, with the majority of deaths occurring in children under five in developing countries. Treatment of shigellosis is difficult due to growing antibiotic resistance, and no vaccine exists despite decades of clinical work. A major hurdle in vaccine development is identifying immune mechanisms that are necessary and/or sufficient for protecting against Shigella infections.

We have developed the first mathematical models of the immune response against Shigella. With these models, we are working to identify key immune interactions responsible for conferring immunity against Shigella. Our work focuses primarily on humoral (antibody and B-cell mediated) immune responses, as these can be most readily elicited with vaccines, and we examine the efficacy of antibodies targeting individual antigens as well as multifaceted responses against a variety of bacterial components. The mathematical models consist of systems of delay differential equations that capture the multiple time scales involved in immune activation and activity. Parameterization and validation of the model is being completed in close collaboration with experimentalists and vaccinologists. (Received September 21, 2011)

1077-92-1871 **Petra Klepac*** (pklepac@princeton.edu), 106a Guyot Hall, Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544. *To eradicate or not to eradicate: Economic optima for spatial immunizing infections.*

The vaccination threshold required to interrupt transmission of an immunizing infection like measles is predicted by epidemic theory to depend only on transmission rates. From the economic perspective, a control strategy is effective if its benefits exceed the costs. Considering economic constraints and assuming that vaccination will have to continue after disease elimination to maintain herd immunity, we look for optimal vaccination coverage that minimizes combined infection and vaccination costs. Surprisingly, the optimum for disease control in a single population is determined mainly by relative costs of infection and control, rather than transmission rates. Adding a spatial dimension can reduce or increase optimal vaccination levels depending on the balance of costs and benefits. For weakly coupled populations, local optimal strategies (Nash optima) agree with the global cost-effective strategy; however asymmetries in costs can lead to divergent control optima in more strongly coupled systems. We conclude by delineating when it is locally optimal to share vaccination resources with other populations. (Received September 21, 2011)

1077-92-1876 **Glenn Lahodny Jr.***, glenn.lahodny@ttu.edu, and **Linda J. S. Allen**. *Extinction or Persistence of Disease in Stochastic Multi-Patch Epidemic Models.*

Stochastic multi-patch SIS epidemic models are derived, continuous-time Markov chains and stochastic differential equations. Patch reproduction numbers and the basic reproduction number are defined for the underlying deterministic model. Applying branching process theory, estimates for the probability of disease extinction are defined for the stochastic epidemic models for isolated patches and for the multi-patch system and expressed in terms of the patch and basic reproduction numbers. Numerical examples are given to illustrate cases where the estimates for probability of disease extinction are good approximations. (Received September 21, 2011)

1077-92-1890 **Olga Stulov*** (olga.stulov@gmail.com) and **Xingzhou Yang**. *3D Numerical Simulation of Microscopic Flagellar Movement With Prescribed Motion at Low Reynolds Number.*

Flagellar dynamic has been attractive topics for researchers for many years. Many microorganisms use the flagellum to swim. To understand the dynamics, we build a 3D model based on the centerline of the flagellum where the falgellum is treated as an elastic structure immersed in the incompressible viscous fluid. In this construction, the flagellum is connected by many small triangular "rings" with its center on the centerline. This "ring" is perpendicular to the tangential direction of the centerline. We utilize the Regularized Stokeslet/Rotlet Method, a grid free approach to solve the fluid equations. The related ODE system is solved by the Runge-Kutta method. Numerical simulations with prescribed motions will be presented. (Received September 21, 2011)

1077-92-1912 **Jim M Cushing*** (cushing@math.arizona.edu), Department of Mathematics, 617 N Santa Rita, University of Arizona, Tucson, AZ 85721, and **Shandelle M Henson**. *High dimensional semelparous Leslie models.*

For lower dimensions, the dynamics of semelparous Leslie models as R_0 increases through 1 is now well understood. A dynamic dichotomy between equilibration with overlapping generations and synchronized periodic oscillations with non-overlapping generations results from the transcritical bifurcation that occurs at $R_0 = 1$. However, for higher dimensional semelparous Leslie models (which corresponds to longer maturation periods) less is known. I will give newly derived conditions for the stability and instability of the bifurcating equilibria for models of arbitrary dimension. In addition, I will give some results concerning the synchronized oscillations that also arise at bifurcation. (Received September 21, 2011)

1077-92-1919 **Matthew D Turner*** (turner@math.utk.edu), 1403 Circle Drive, Knoxville, TN 37996-1320. *Modelling effective transmission strategies and control of the world's most successful parasite.*

Toxoplasma gondii is a protozoan responsible for the disease Toxoplasmosis. The parasite is prevalent worldwide and infects all warm-blooded vertebrates, with cats serving as the only definitive host. Transmission occurs via ingestion of tissue cysts in meats, exposure to oocysts shed in the environment by infected cats, and by vertical transmission to offspring. In this work, a system of differential equations are used to model the complete life cycle of *T. gondii*. Analysis is performed to investigate the significance of each transmission route and the effect of controlling harvest and vaccination on the spread of infection. (Received September 21, 2011)

1077-92-1946 **Samantha Monastra*** (rhaas@smith.edu), **Pamela Clark**, **Jessica Grant** and **Ileana Streinu**. *Periodic Rigidity of Protein Crystal Structures.* Preliminary report.

Rigidity of protein structures solved by X-ray crystallography has been analyzed, until now, only for one unit cell, without taking into account the interactions between the periodic cells of a crystal. This project will investigate, through mathematical modeling, how rigidity changes when neighboring crystal cells are aggregated. (Received September 21, 2011)

1077-92-1975 **Bud Mishra***, Courant Institute, 715 Broadway Room 1002, New York, NY 10003. *"Darwin, Development and Dysplasia: Signalling Games that Cells Play".* Preliminary report.

Signaling is a well-studied phenomenon both in evolutionary game theory and in cell biology. In game theory, signaling frameworks have been used to study the evolution of such fundamental phenomena as conventions and cooperation, while in biology, signal transduction has been extensively studied as a basic ingredient to multicellularity, enabling cells to communicate and coordinate. However, approaches that span both fields are scarce.

In this talk, we explore the idea of viewing multicellular organisms as signaling systems in the game-theoretic sense, attempting to unify these two perspectives on signaling. A multicellular organism corresponds to a population of cells in a cooperative state, with a working signaling system in place. We will discuss how the evolution of such a system may be modeled. Then, we will in particular be interested in the breakdown of cooperation, leading to an interpretation of cancer as a disease of multicellularity. (Received September 21, 2011)

1077-92-1985 **Rebecca Segal*** (rasegal@vcu.edu), VCU, PO Box 842014, Richmond, VA 23284-2014. *Nanoparticle Deposition in the Human Nasal Passages.*

Nasal anatomy differs between individuals. These differences lead to significant differences in respiratory airflow patterns and the subsequent dosimetry of inhaled gases and particles in the respiratory tract. This study used computational fluid dynamics (CFD) to study inter-individual differences in particle deposition patterns. Steady-state inspiratory laminar airflow at 15 L/min was calculated using commercial CFD software. Additionally, flow patterns were calculated using the k-w turbulence algorithm. The deposition of nanoparticles was calculated using a user defined function and deposition patterns were compared between flow scenarios. (Received September 21, 2011)

1077-92-1993 **Amie Rollie*** (nahritonenko@pvamu.edu), P.O.Box 519, Prairie View A&M University, Prairie View, TX 77446, and **Ryan Baxter** and **Natali Hritonenko** (nahritonenko@pvamu.edu). *Optimal control in age-dependent models in epidemiology and demography.*

Optimal control of age-structured populations has sparked significant interest during several decades. A brief survey of age-dependent models in epidemiology, demography, and biology will be presented. A special attention will be given to the models described by means of partial differential equations. The corresponding optimal control problems can be interpreted as the optimal drug vaccination in mathematical epidemiology or the optimal population size problem controlled via health expenditures, and so on. It will be shown that age-structured models fit data well and are most commonly applied to describe the spread of childhood diseases. Basic investigation techniques for the optimal control problems will be discussed. (Received September 21, 2011)

1077-92-1995 **Eric Eager**, **Mary Hebert**, **Elise Hellwig*** (echellwig@gmail.com), **Francisco Hernandez-Cruz**, **Richard Rebarber**, **Brigitte Tenhumberg** and **Bryan Wigianto**. *Metapopulation Modeling and Analysis with Demographic Stochasticity.* Preliminary report.

As human expansion claims more land, previously connected habitats become fragmented, converting larger populations into smaller subpopulations connected through migration. Demographic stochasticity has been shown to have a significant effect in small populations. We explore how taking demographic stochasticity into account affects metapopulations which are typically made up of small subpopulations. We develop a density dependent models using Markov matrices to simulate a metapopulation and compare the predictions with those of a deterministic model. We compare the asymptotic population size of the deterministic model with the mean time to extinction and the quasi stationary distributions predicted by the Markov model. We show that there is a significant difference between the two models under certain conditions and that the deterministic model often overestimates metapopulation persistence. (Received September 21, 2011)

1077-92-2079 **Joanna R Wares*** (jwares@richmond.edu), 204 Jepson Hall, 28 Westhampton Way, Richmond, VA 23173, and **Erika M. C. D'Agata**, **Mary Ann Horn**, **Shigui Ruan** and **Glenn F Webb**. *Efficacy of infection control interventions in reducing the spread of multidrug-resistant organisms in the hospital.*

Multidrug-resistant organisms (MDRO) continue to spread in hospitals globally but, the population-level impact of recommended preventive strategies, and the relative benefit of individual strategies, targeting all MDRO in the hospital setting, is unknown. To explore the dynamics of MDRO transmission in the hospital, we develop a model using a system of ordinary differential equations, extending data from clinical, individual-level studies to quantify the impact of hand hygiene, contact precautions, reducing antimicrobial exposure and screening surveillance cultures in decreasing the prevalence of MDRO colonization and infections. We find that most recommended strategies have substantial effect in decreasing the prevalence of MDRO over time. However, screening for asymptomatic MDRO colonization among patients who are not receiving antimicrobials, is of minimal value in reducing the spread of MDRO and therefore, to reduce costs, screening should be limited to patients receiving antimicrobials. (Received September 21, 2011)

1077-92-2128 **Jerry L. Bona*** (bona@math.uic.edu), Dept. Math. Statistics & Computer Science, University of Illinois at Chicago, 851 S. Morgan Street MC 249, Chicago, IL 60607. *A Simple Model for Arterial Blood Flow.* Preliminary report.

We introduce a model for the flow of blood in the arterial system. This model, developed by Cascaval, Hernandez, Hsia and the author, is comprised of a coupled system of nonlinear, partial differential equations posed on a tree-like structure. After introducing analysis leading to the conclusion that the system is well posed, numerical simulations are presented indicating that the model has some macroscopic predictive power. (Received September 21, 2011)

1077-92-2142 **David K Hammond*** (hammond@uoregon.edu), NeuroInformatics Center, 5294 University of Oregon, Eugene, OR 97403, and **Benoit Scherrer**. *Construction of prior models for EEG source estimation with weighted graph descriptions of anatomical brain connectivity.* Preliminary report.

The EEG source estimation problem consists of inferring cortical activation from measurements of electical potential taken on the scalp surface. This is an underdetermined inverse problem, and generally requires some form of regularization to yield a unique solution. Recent advances in diffusion weighted MRI technology allow non-invasive measurement of the brain connectome, a weighted graph indicating connectivity of different brain regions. In this work I will describe two different approaches for using the connectome graph to regularize the EEG source estimation problem. The first constructs a quadratic penalty on the cortical sources by taking the weighted sum of squares of differences across edges in the graph, yielding a linear source estimator we call cortical graph smoothing. In the second approach we use the spectral graph wavelet transform, a general method for defining wavelet transforms on weighted graphs, to construct a frame of "cortical graph wavelets" on the connectome graph. Assuming sparsity of the desired cortical sources in the cortical graph wavelet frame yields a convex ℓ_1-regularized least squares problem for the source coefficients. We demonstrate the improved effectiveness of both estimation approaches relative the standard minimum norm technique. (Received September 21, 2011)

1077-92-2147 **Sebastian Schreiber*** (sschreiber@ucdavis.edu), University of California, Davis, **Reinhard Bürger**, University of Vienna, and **Dan Bolnick**, University of Texas, Austin. *The community level effects of phenotypic variation within a predator population.*

Natural populations are heterogeneous mixtures of individuals differing in physiology, morphology, and behavior. Despite the ubiquity of phenotypic variation within natural populations, its effects on the dynamics of ecological communities are not well understood. Here, we use a quantitative genetics framework to examine how phenotypic variation in a predator affects the outcome of apparent competition between its two prey species. Classical apparent competition theory predicts that prey have reciprocally negative effects on each other. The addition of phenotypic trait variation in predation can marginalize these negative effects, mediate coexistence, or generate positive indirect effects between the prey species. Long-term coexistence or facilitation, however, can be preceded by long transients of extinction risk whenever the heritability of phenotypic variation is low. Greater heritability can circumvent these ecological transients, but also can generate oscillatory and chaotic dynamics. These dramatic changes in ecological outcomes, in the sign of indirect effects, and in stability suggest that studies which ignore intraspecific trait variation may reach fundamentally incorrect conclusions regarding ecological dynamics. (Received September 21, 2011)

1077-92-2159 **Abdul-Aziz Yakubu*** (ayakubu@howard.edu), 2441 6th Street NW, Washington, DC 20059, and **Nianpeng Li**. *Constant Proportion Harvest Policy, Predator Saturation and Mating Limitation Induced Allee Effects In Pacific Halibut and Atlantic Cod Fisheries.*

In this talk, we will examine the interactions between constant proportion harvesting policy, the classic deterministic Beverton-Holt and Ricker stock recruitment model forms, where the Allee effect in the fish population are induced by predator saturation and mating limitation mechanisms. We will show that the classic Beverton-Holt and Ricker models without the depensation are better fit to Gulf of Alaska Pacific halibut and Georges Bank Atlantic cod fisheries data. These models suggest that, under high fishing mortalities, both halibut and cod fisheries are vulnerable to steady decline to zero. (Received September 21, 2011)

1077-92-2189 **Ummugul Bulut*** (gul.bulut@ttu.edu), Texas Tech University, Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409, and **Edward Allen** (edward.allen@ttu.edu), Texas Tech University, Mathematics and Statistics, Broadway and Boston, Lubbock, TX 79409. *Derivation of system of SDEs for simple phylogenetic tree.*

In this investigation, deterministic and stochastic systems of differential equations are derived for a simple phylogenetic tree. The phylogenetic tree studied is a branching process that shows the evolutionary relationships among genera and species based on similarities and differences in their characteristics. In the present investigation, deterministic and stochastic systems of differential equations are derived under two differing underlying assumptions. The differential equation systems for the phylogenetic trees are derived from basic principles by carefully studying the changes in the problem for a short time interval. The deterministic and stochastic systems are then studied and compared to understand the long term dynamic behavior of species and genera. The first set of assumptions are the same as those used by Yule in his probabilistic study of phylogenetic trees. The second set of assumptions differ from Yule's assumptions in how the species originate from genera. (Received September 21, 2011)

1077-92-2194 **Terrance J. Quinn II*** (Terry.Quinn@alaska.edu), Juneau Center, School of Fisheries and Ocean, University of Alaska Fairbanks, 17101 Point Lena Loop Road, Juneau, AK 998201. *Features of biologically realistic fishery models frequently used in fish stock assessment.*

A fisheries stock assessment model is a model of the population dynamics of a harvested fish species that integrates information from the fishery with scientifically collected biological and survey data. At a minimum, there needs to be a historical dataset comprised of total removals, age or size information, and a relative index of population abundance. Model parameters include cohort abundance, natural and fishing mortality, and calibration coefficients. A realistic model contains those biological and human factors that play a major role in population dynamics. Current models currently provide for realistic changes in cohort abundance and fishing mortality over time. Some fishery models have thousands of observations and hundreds of parameters, and a variety of software has been developed to meet the demand for efficient and accurate parameter estimation. Recent advances to increase biological realism include: (1) allowing for stochasticity in early life survival to recruitment, (2) including temporal variations in natural mortality, either through covariates (such as disease and environment) or explicit incorporation of multi-species interactions (such as predator-prey), and (3) reconciling and exposing data conflicts among multiple datasets. (Received September 21, 2011)

1077-92-2201 **Holly V. Moeller*** (hollyvm@stanford.edu) and **Michael G. Neubert**. *Accounting for Habitat Damage Increases the Economic Optimality of Marine Reserves.* Preliminary report.

Marine reserves – areas closed to fishing – are often touted for their conservation benefits (e.g. protection of essential fish habitat, increases in fish population and biomass). However,reserves are frequently viewed as economically costly because closures deny fishermen access to potentially valuable fishing grounds. To address this issue, we explore a spatially-explicit bioeconomic model that accounts for habitat damage from fishing gear. We solve the model for the profit-maximizing distribution and intensity of fishing effort without designating reserves *a priori*, and show the emergence of reserve networks. These results suggest that reserves may in fact be economically beneficial, especially when fishing gear damages habitat. We also explore alternative management schemes in which the regulatory body has varying degrees of spatial knowledge about fishing activities, and find an explicit value for spatial knowledge. (Received September 21, 2011)

1077-92-2218 **Donald Adongo*** (donald.adongo@murraystate.edu), Department of Mathematics & Statistics, Faculty Hall 6C, Murray, KY 42071, and **Renee Fister** and **Holly Gaff**. *Using Optimal Control to minimize Rift Valley Fever Cases.* Preliminary report.

Rift Valley fever (RVF) virus is a mosquito-born pathogen that infects primarily domestic animals. Humans are not immune to it, with sources of infection being both the infected animals and mosquitoes. We use optimal control techniques and numerical simulations to study RVF dynamics. We look at minimizing the total number of vaccinated animals at some prescribed final time. Note that the cost of vaccines can be prohibitive apart from consumers resisting products from non vaccine free animals. (Received September 21, 2011)

1077-92-2283 **Christina S Leslie*** (cleslie@cbio.mskcc.org), 1275 York Ave, Mail Box #460, New York, NY 10065. *Inferring transcriptional and microRNA-mediated regulatory programs in glioblastoma.*

Large-scale cancer genomics projects are profiling hundreds of tumors at multiple molecular layers, including copy number, mRNA and miRNA expression, but the mechanistic relationships between these layers are often excluded from computational models. We developed a sparse regression framework for integrating molecular profiles with regulatory elements to reveal reveal mechanisms of dysregulation of gene expression in cancer, including miRNA-mediated expression changes. We applied our approach to 320 glioblastoma tumors and identified key miRNAs and transcription factors as common or subtype-specific regulators. We confirmed that target gene expression signatures for proneural subtype regulators were consistent with in vivo expression changes in a relevant mouse model. We tested two predicted proneural drivers, miR-124 and miR-132, both underexpressed in proneural tumors, by overexpression in neurospheres and observed a partial reversal of corresponding tumor expression changes. Computationally dissecting the role of miRNAs in cancer may ultimately lead to small RNA therapeutics tailored to subtype or individual. (Received September 22, 2011)

1077-92-2287 **Folashade B Agusto*** (fbagusto@gmail.com), Department of Mathematics and Statistics, Austin Peay State University, 601 College Street, Clarksville, TN 37044, **Sharon Bewick**, Nat'l Inst for Mathematical & Biological Syn., 1534 White Avenue, Knoxville, Knoxville,, TN 37996, and **Rana D Parshad**, Center for Turbulence Research, Stanford Univ, Stanford University, Stanford, CA 94309. *Mosquito Management in the face of Natural Selection.* Preliminary report.

The sterile insect technique (SIT) is an appealing method for managing mosquito populations while avoiding the environmental and social costs associated with more traditional control strategies like insecticide application. Success of SIT, however, hinges on sterile males being able to compete for females. As a result, heavy and/or continued use of SIT could potentially diminish its efficacy if prolonged treatments result in selection for female preference against sterile males. In this paper we extend a general differential equation model of mosquito dynamics to consider the role of female choosiness in determining the long-term usefulness of SIT as a management option. We then apply optimal control theory to our model and show how natural selection for female choosiness fundamentally alters management strategies. (Received September 22, 2011)

1077-92-2316 **David Chan*** (dmchan@vcu.edu), Department of Mathematics, 1015 Floyd Avenue, Richmond, VA 23284, and **Hye Jin Ban**. *Results on a discrete, age-class population model.* Preliminary report.

In this talk we will present some preliminary results on a system of difference equations modeling multiple species with age-classes. (Received September 22, 2011)

1077-92-2339 **Adrian Sanborn**, **Jian Li** and **Erez Lieberman Aiden*** (erez@math.harvard.edu). *Physical Analogues of Peano Curves: from genome folding to new symmetries.*

I will discuss our recent work mapping the three-dimensional architecture of the human genome, emphasizing he role of the fractal globule, a physical analogue of the Peano curve. Next, I will highlight a collaboration with Adrian Sanborn and Jian Li, in which, motivated by the experimental findings described above, we identify a new symmetry property possessed by a broad array of fractal curves. (Received September 22, 2011)

1077-92-2345 **M. Saleet Jafri*** (sjafri@gmu.edu), School of Systems Biology, 10900 University Blvd., MSN 5B3, Manassas, VA 20110, and **Minh Tuan Hoang-Trong**, **George S. B. Williams** and **W. Jonathan Lederer**. *Stochastic Multi-scale Modeling Suggests the Molecular Basis of Calcium-Entrained Cardiac Arrhythmia.*

Heart disease is the leading cause of death worldwide. Defects in cardiac calcium dynamics account for a class of these fatal arrhythmias. Calcium dynamics are governed by the coordinated stochastic action of over one million macromolecules known as calcium channels in an individual cardiac muscle cell. However, the un-coordinated behavior of a number of these calcium channels can trigger a cardiac arrhythmia. Computational modeling has proven to be an essential tool to understand this complex system. We have developed the first model of the cardiac myocyte that captures the biophysically realistic behavior of these channels as well as the myocyte calcium dynamics. In order to do so, we have had to develop our Ultra-fast Monte Carlo Simulation Methods and ported this method to use modern fast GPUs (Graphics Processing Units) to achieve a 15,000-fold increase in computational efficiency. By modeling the detailed behavior of the individual components correctly, higher level cellular function emerges that suggests the molecular basis of calcium-entrained arrhythmia. (Received September 22, 2011)

1077-92-2359 **James F Selgrade*** (selgrade@math.ncsu.edu), Box 8205, North Carolina State University, Raleigh, NC 27695, and **Alison Margolskee**. *Dynamical behavior of a model for hormonal regulation of the menstrual cycle.*

A system of 13 ordinary differential equations with 42 parameters is presented to model hormonal regulation of the menstrual cycle. For an excellent fit to clinical data, the model requires a 36 hour time delay for the effect of inhibin on the synthesis of follicle stimulating hormone. Biological and mathematical reasons for this delay are discussed. Bifurcations with respect to changes in three important parameters are examined. One parameter represents the level of estradiol adequate for significant synthesis of luteinizing hormone. Bifurcation diagrams with respect to this parameter reveal an interval of parameter values for which a unique stable periodic solution exists and this solution represents a menstrual cycle during which ovulation occurs. The second parameter measures mass transfer between the first two stages of ovarian development and is indicative of healthy follicular growth. The third parameter is the time delay. Changes in the second parameter and the time delay affect the size of the uniqueness interval defined with respect to the first parameter. Saddle-node, transcritical and degenerate Hopf bifurcations are illustrated and biological implications are discussed. (Received September 22, 2011)

1077-92-2431 **Matthew K Fox*** (fox07210@stthomas.edu), 2115 Summit Ave, Mail 6197, St Paul, MN 55105, and **Benjamin Dellaria** and **Magdalena Stolarska**. *Modeling Cell Movement using the Level Set Method.* Preliminary report.

Cell movement is an important topic of research since it affects different biological processes including wound healing, immune response, and the spread of cancer. Experimentally, the usual method of viewing motile cells is on a flat, two-dimensional surface, and as a result most mathematical models are formulated with this assumption. In the body, cells move through a three dimensional array of collagen, filaments, and other proteins. With this in mind, we are modeling cell movement through a series of deformable obstacles meant to represent the collagen network. We use the level set method to track the membrane of the cell, the velocity of which depends on membrane surface tension, a force for volume preservation, and protrusive and retractive forces. We borrow concepts from the theory of beams to model the deformable collagen network. In our initial simulations we consider a two dimensional slice of the cell and collagen network, and our goal is to use the simulations to more accurately model the cell environment within the body and to investigate the effects of collagen stiffness and the presence of multiple cells on the movement of each cell. (Received September 22, 2011)

1077-92-2464 **Ying Chen*** (yingc@math.uci.edu), Department of Mathematics, University of California, Irvine, Irvine, CA 92697, and **John S. Lowengrub** (lowengrb@math.uci.edu), Department of Mathematics, University of California, Irvine, Irvine, CA 92697. *Tumor growth in complex, evolving geometries: A diffuse domain approach.*

In this talk, we present a new diffuse domain method for simulating tumor growth in complex, evolving geometries, taking into account homotype adhesion between tumor cells and heterotype adhesion between the cells and the basement membrane (or extracellular matrix). This method allows a straightforward implementation using standard software packages. Here, in order to solve the governing equations efficiently, we develop an adaptive energy-stable nonlinear multigrid finite difference method. Two and three dimensional simulations are performed where the adhesion between tumor cells and a deformable basement membrane (or extracellular matrix) is varied. The resistance of the membrane to bending is also modeled. The results demonstrate the nontrivial dependence of the growing tumor on the adhesion of cells to and flexibility of the basement membrane. This provides a model for ductal carcinoma in situ. (Received September 22, 2011)

1077-92-2494 **Georgiy P Karev*** (karev@ncbi.nlm.nih.gov), National Institutes of Health, Bldg. 38A, Rm, 8600 Rockville Pike, Bethesda, MD 20894. *On non-exponential models of prebiological evolution.*

E.Szathmary and M.Smith (1997) represent the model of prebiological evolution by the equation for the concentration of molecules$\frac{dx}{dt} = kx^p$ (SMS model). Well established examples of non- exponential growth give global demography ($p = 2$) and some molecular replicator systems ($p = \frac{1}{2}$). It is not always clear why non-exponential growth is observed in reality. We show that SMS model can be understood within the frameworks of inhomogeneous population models. *Theorem. 1) Any SMS equation describes the total size of inhomogeneous frequency-dependent model* $\frac{dl(t,a)}{dt} = \frac{kal(t,a)}{N(t)} = kaP(t,a)$ *with Gamma-distributed parameter a at the initial moment ; 2) Additionally, any hyper-exponential equation with* $p > 1$ *describes the total population size of inhomogeneous density-dependent model* $\frac{dl(t,a)}{dt} = kal(t,a)$ *with Gamma–distributed parameter a at the initial moment;* The results can be extended to the model of a community composed of non-exponential populations and (partly) to Lifsons' theory (1999) of prebiological evolution, which deals with competitions of replicators for extrinsic resources. (Received September 22, 2011)

1077-92-2514 **Baldvin Einarsson*** (baldvine@mail.com), University of California, Santa Barbara, South Hall #6523, Santa Barbara, CA 93106, and **David Rodriguez** and **Ana Carpio**. *A Cellular Automata Model for Biofilm Growth with Surface Flow.*

We describe a two dimensional cellular automata model for biofilm growth in a rectangular tube with nonlaminar surface flow. Nutrient levels and structure of the biofilm determine the probability of the following mechanisms: i)Cell division and spreading ii) Cell erosion due to sheer stress iii) Production of EPS (extracellular polymeric substances) iv) Influx of cells which adhere to the surface and biofilm. We describe these mechanisms and the numerical code used to simulate the model. We then show how the model reproduces biofilm development in the form of flat biofilms, ripples, streamers, towers, "mushroom" growth etc. Finally, we briefly describe the effect of rugosity and an extension to three dimensions. (Received September 22, 2011)

1077-92-2515 **Yang Huang*** (huangyan@mail.nih.gov), 8N811I, NCBI/NLM/NIH, Building 38A, 8600 Rockville Pike, Bethesda, MD 20894, and **Teresa M Przytycka** (przytyck@mail.nih.gov), Room 8S812, NCBI/NLM/NIH, Building 38A, 8600 Rockville Pike, Bethesda, MD 20894. *Allele specific compatibility of interactions underlying yeast DNA repair phenotypes.* Preliminary report.

Recent studies suggest that many observed phenotypes, including common diseases, are complex and are likely governed by multiple loci and interaction between them. Uncovering such interactions will be critical to understating of such complex traits. Here, we proposed a method that explores the hypothesis that such interacting loci might co-evolve acquiring allele specific compatibility to maintain their interaction. This allele specific compatibility between two loci might be compromised in meiotic crosses leading to phenotypic changes in progenies which, in turn, can guide the detection of such interaction. Focusing on such cases we developed a computational method, LoCAp (Locus Compatibility Approach) to detect interactions between loci consistent with such a model. We then applied our approach to detect interactions related to yeast DNA repair phenotype. Our method pointed to the locus harboring Rad5 as a locus interaction hub for the response to DNA damaging agent. Our results are consistent with the results obtained by a recently developed Extreme QTL experimental technique. These findings not only indicate the importance of Rad5 but also serve as a proof of principle for exploring allele specific interaction compatibility in predicting interactions between genetic loci. (Received September 22, 2011)

1077-92-2516 **Mark E Ritchie*** (meritchi@syr.edu), Department of Biology, 107 College Place, Syracuse University, Syracuse, NY 13244. *Fractal geometry: a pathway to understanding biodiversity.*

Biologists have devoted much of the past 50 years to understanding how many species can coexist in the same environment when limited by the same resource. Previous theoretical treatments using differential equations to describe dynamical systems of consumers and their resources produced unacceptable predictions of either victory by a single species or coexistence by an infinite number of species. Here, I present the idea that nature, to a first approximation, exhibits fractal geometry, and that the encounter of fractal resources by organisms depends is scale-dependent. Thus a fractal description of nature predicts that species of different body size should consume non-overlapping sets of clusters of "food" containing different concentrations of a common limiting resource. Fractal geometry thus predicts that a finite number of species of different body size can coexist in a particular environment and corollary predictions follow about the size, abundance, membership, and number of species that should coexist. These predictions are strongly supported in many real communities, which suggests that Describing nature with fractal geometry provides long-sought insight to understanding how environmental conditions drive biodiversity. (Received September 22, 2011)

1077-92-2521 **Kamuela E Yong*** (kamuela-yong@uiowa.edu), 14 MacLean Hall, Iowa City, IA 52242, and **Yi Li** (yi.li@wright.edu) and **Stephen D Hendrix** (stephen-hendrix@uiowa.edu). *A numerical approximation and parameter estimation for modeling bee pollination: an application of the Shigesada-Kawasaki-Teramoto model.* Preliminary report.

California's almond industry, valued at $1.9 billion per year depends on successful cross-pollination. Almond growers mainly depend on honey bees, although other insects are being investigated as alternatives due to honey bee declines. Our objective is to model the movements of honey bees to determine if in the presence of other pollinators, honey bees will forage in less favorable areas of a tree and its surroundings. We use the SKT model (1979) which describes the density of two species in a 2D environment of variable favorableness with respect to intrinsic, self, and cross-diffusions. This model is applied to almond pollination by honey bees and other pollinators with environmental favorableness based on empirical data measuring the attractiveness of the canopy for honey and other pollinators. We found cross-diffusion effects of other pollinators on honey bees result in honey bees foraging in less favorable areas of a tree and the area surrounding a tree. We hypothesize that increased honey bees in unfavorable environments will increase the probability of movement to a different variety of tree, thereby increasing successful pollination and fruit production. Using empirical data, we estimate the diffusion parameters using COPASI and compare with the model. (Received September 22, 2011)

1077-92-2522 **Alicia Prieto-Langarica*** (alicia.prietolangarica@mavs.uta.edu), 411 S. Nedderman Drive, 478 Pickard Hall, Arlington, TX 76019, and **Hristo Kojouharov** and **Benito Chen-Charpentier**. *Discrete and Continuous Approaches to Modeling of Cell Movement in the Presence of a Foreign Stimulus.*

Cell movement is a complex process. Cells can move in response to foreign stimulus, in search of nutrients or to escape predation. However, cells do not follow stimulus exclusively but in general admit a random component. Mathematical modeling of cell movement is needed to aid in the deeper understanding of vital processes such as embryogenesis, angiogenesis, tumor metastasis and immune reactions to foreign bodies. In this work we consider cell movement that can be split into two parts: one part is random and another part directed in response to the stimulus. In order to model the random nature of cell movement, an individually based model is created to simulate cells moving in the presence of a heterogenous distribution of stimulus molecules. The model is then upscaled, starting from nalysis of the transition probabilities of individuals at each site, to obtain a continuous partial differential equation model. Finally, the models are compared to each other for different parameter values. (Received September 22, 2011)

1077-92-2562 **Jonathan D Cowles**, **Shandelle M Henson*** (henson@andrews.edu) and **James L Hayward**. *A Mathematical Model of Harbor Seal Haul-out.*

Harbor seals (Phoca vitulina) haul out in response to various environmental factors such as tide, current, time of day, wind, and surf. Mathematical modeling techniques are useful for determining which environmental factors are important and for predicting the number of seals that will haul-out in a given set of environmental circumstances. We counted the number of hauled-out seals hourly for 16 hrs per day over two 14-d tidal cycles at a site in Washington State. We constructed a suite of alternative mathematical models based on different combinations of environmental factors, parameterized each model, and applied information theoretic model selection techniques. The best model contained the environmental factors tide, current, and time of day and explained >45% of the observed variability. The results of this study are site-specific, but the methods used are portable and useful for researchers and wildlife managers interested in monitoring haul-out or population trends over time as mandated by the Marine Mammal Protection Act. (Received September 22, 2011)

1077-92-2576 **Dennis A. Dean II*** (ddean@rics.bwh.harvard.edu), 221 Longwood Ave, Division of Sleep Medicine, Boston, MA 02115. *Mathematics You Won't Sleep on.*

Sleep-wake and circadian (internal time keeping system) states provide direct and indirect control of nearly all body functions, including human performance and hormone pulsatility. There has been a slow adoption of these mathematical models in applied problems (schedule design and individual hormone analysis) due to differences in the underlying problem specification (i.e. different type of schedules) and individual differences in the dynamics of each system (i.e. group models are not appropriate). To overcome these challenges, we integrate problem specification methods used in computer science (formal language theory) with traditional modeling approaches to define new robust and efficient algorithms for incorporating sleep and circadian principles to the study of applied problems where these systems are strong determinants of important outcomes. The integration of formal language theory and mathematical modeling will be motivated by my research in designing crew schedules for NASA and analyzing individual cortisol pulsatility. (Received September 22, 2011)

1077-92-2588 **X Rosalind Wang**, **Jennifer M Miller*** (millerje@math.udel.edu), **Joseph T Lizier**, **Mikhail Prokopenko** and **Louis F Rossi**. *Measuring Information Storage and Transfer in Swarms.*

Collective behavior of aggregations, such as flocks of birds or groups of autonomous robots, emerge without central control. Individuals within the group base their movement decisions on interactions with nearby individuals. Under certain conditions, local interactions drive the entire aggregation into distinct configurations suggesting a cascade of information is moving through the swarm. By applying an information-theoretic framework to a mathematical model of swarming, we can gain insight into how information propagates through the group. The transitions between large-scale dynamics, such as two groups combining, correspond to changes in the overall information transfer and active information storage. These measures can provide us with knowledge about the dynamics within the models that may not be apparent from simply observing the group. From a robotics standpoint, knowledge of information transfer within the group may allow us to temporarily switch off communication between individuals without affecting the overall group behavior. (Received September 22, 2011)

1077-92-2640 **Eric J. Kostelich*** (kostelich@asu.edu), School of Mathematical & Statistical Sciences, Arizona State University, Campus Box 871804, Tempe, AZ 85287. *Forecasting Cancer: Finding the Initial Conditions for Spatiotemporal Dynamical Models.* Preliminary report.

Can cancer be forecast, just as the weather is forecast? Besides the need for a good dynamical model, one also needs to determine the initial conditions accurately to be able to make quantitative predictions. This talk focuses on the latter question. I will outline an approach, called the Local Ensemble Transform Kalman Filter (LETKF), that provides accurate initial conditions (and estimates of their uncertainty) for numerical weather models from noisy and often sparse measurements. The model independence of the LETKF makes it an attractive candidate for many applications. In particular, I will consider how the LETKF might be adapted to make short-term (2-3 month) predictions of the growth and spread of glioblastoma multiforme, a common and aggressive type of brain cancer. (Received September 22, 2011)

1077-92-2663 **Calistus Ngeh Ngonghala*** (cnngonghala@nimbios.org), NIMBioS, 1534 White Ave., Suite 400, University of Tennessee, Knoxville, TN 37996-1527. *Hopf and backward bifurcations in a new model for the dynamics of malaria transmission.*

A model for malaria that incorporates mosquito demography is developed and studied. The model differs from standard models in that the mosquitoes involved in disease transmission; i.e., adult female mosquitoes questing for human blood are identified and accounted for. We showed that the system can be driven to instability via a Hopf bifurcation. The model therefore captures natural oscillations known to exist in malaria prevalence without recourse to external seasonal forcing and/or delays. Besides the basic reproduction number, which is shown to be smaller than that for previous models, we identified a second threshold parameter that is associated with mosquito demography. These two threshold parameters can be used for purposes of disease control. The model also exhibits a backward bifurcation. Hence, simply reducing the basic reproduction number below unity may not be enough for disease eradication. The discovery of oscillatory dynamics and a backward bifurcation presents a novel and plausible framework for developing and implementing control strategies. Thus, accounting for mosquito demography is important in explaining observed patterns in malaria prevalence, as well as in designing and evaluating control strategies, especially strategies that are related to mosquito control. (Received September 22, 2011)

1077-92-2697 **Anna Mummert*** (mummerta@marshall.edu), Marshall Univeristy, Mathematics Department, One John Marshall Drive, Huntington, WV 25755. *Studying the recovery algorithm for the time-dependent transmission rate in epidemic models.* Preliminary report.

Determining the time-dependent transmission function that exactly reproduces disease incidence data can yield useful information about disease outbreaks, including a range potential values for the recovery rate of the disease and offers a method to test the “school year” hypothesis (seasonality) for disease transmission. Recently two algorithms have been developed to recover the time-dependent transmission function for classical disease models given the disease incidence data. We first review the recovery algorithm for the susceptible-infected-recovered (SIR) and susceptible-exposed-infected-recovered (SEIR) models. Second, we explore several technical issues that appear when implementing the algorithm for the SIR model; these are important when generating the time-dependent transmission function for real-world disease data. Finally, we apply the recovery algorithm to data from the 2009 - 2010 influenza season. For this flu season, we find that the transmission rate is not higher during the school year. Also, using the classical SIR model we find the average recovery rate must be less than 7.14 days. (Received September 22, 2011)

1077-92-2701 **Richard Schugart*** (richard.schugart@wku.edu) and **Tennesse Tucker Joyce**. *Using a Mathematical Model to Analyze the Treatment of a Wound Infection with Oxygen Therapy.* Preliminary report.

A mathematical model was developed to treat a wound with a bacterial infection using oxygen therapy. The model describes the relationship among neutrophils, bacteria, oxygen, cytokines, and reactive oxygen species. A quasi-steady-state assumption was introduced to reduce the model down systems of two and three equations. A mathematical analysis on the reduced model and simulation results will be presented in this talk. (Received September 22, 2011)

1077-92-2714 **Calistus Ngeh Ngonghala*** (cnngonghala@nimbios.org), NIMBioS, 1534 White Ave., Suite 400, University of Tennessee, Knoxville, TN 37996-1527. *Health safety nets can break cycles of poverty and disease: a stochastic ecological model.*

The persistence of extreme poverty is increasingly attributed to dynamic interactions between biophysical processes and economics, though there remains a dearth of integrated theoretical frameworks that can inform policy. Here, we present a stochastic model of disease-driven poverty traps. Whereas deterministic models can result in poverty traps that can only be broken by substantial external changes to the initial conditions, in the stochastic model there is always some probability that a population will leave or enter a poverty trap. We show that a “safety net”, defined as an externally enforced minimum level of health or economic conditions, can guarantee ultimate escape from a poverty trap, even if the safety net is set within the basin of attraction of the poverty trap, and even if the safety net is only in the form of a public health measure. Whereas the deterministic model implies that small improvements in initial conditions near the poverty-trap equilibrium are futile, the stochastic model suggests that the impact of changes in the location of the safety net on the rate of development may be strongest near the poverty-trap equilibrium. (Received September 22, 2011)

1077-92-2778 **Frederick A Adkins*** (fadkins@iup.edu), Mathematics Department, Indiana University of Pennsylvania, Indiana, PA 15705. *MicroRNA Target Modeling via Clustering of mRNA Microarray Data.* Preliminary report.

MicroRNA (miRNA) affect gene expression by either blocking translation or cleaving target mRNA resulting in subsequent degradation. This investigation models the role of miRNA in gene expression. Modeling provides a mechanism for possible discovery of new miRNAs and identification of miRNA targets in conjunction with mRNA expression levels. Gene expression mRNA and miRNA data for disease states are clustered to identify genes that are significantly up or down regulated. For significantly down regulated genes, computational methods are used to identify possible common complementary 20-26 nucleotide sequences that are characteristic of microRNA. Based on weighted sequence alignment, free energy at the target site, and other factors characterizing miRNA binding, likelihood models are used to determine possible miRNA and their targets. This method of miRNA target investigation attempts to utilize clustering of gene expression to predict common miRNA targets. Correlation of known miRNA hairpins or computational investigation of possible pri-miRNA hairpins to correspondingly up-regulated mRNA from microarray clustering analysis is used to create models for exploration of regulatory networks reflecting specific cellular activity. (Received September 22, 2011)

1077-92-2794 **Jared A. Hicks*** (jared.hicks@northwestern.edu), Engineering Sciences and Applied Mathematics, Northwestern University, 2145 Sheridan Road, Evanston, IL 60208-3125, and **David L. Chopp**. *A continuum model for the simultaneous growth and deformation of biofilms.*

Bacterial biofilms are aggregates of cells that adhere to solid/fluid interfaces. While many biofilms have harmful effects, including industrial damage and nosocomial infection, certain species are now generating renewable energy in Microbial Fuel Cells (MFCs). In a MFC, bacteria consume organic waste and, as they respire, produce electrons. To do so efficiently, the bacteria must operate at peak metabolic activity, for which they require an ample nutrient supply. But existing MFCs face several nutrient delivery problems, including clogging and downstream depletion.

Ameliorating these problems will require a better understanding of the interplay between structural evolution and the surrounding fluid flow. In addition to delivering nutrients that affect biofilm growth, the fluid exerts stresses that cause erosion and deformation. These structural changes, in turn, affect the flow and alter the nutrient distribution. To capture this feedback, we have developed a novel continuum model that couples the growth and deformation processes. Our model augments an existing growth model with evolution equations derived from morphoelasticity theory. These models track the evolving biofilm surface using a combination of the level-set method and the eXtended Finite Element Method (XFEM). (Received September 22, 2011)

1077-92-2799 **William R Fuller*** (w-fuller@onu.edu), Department of Mathematics and Statistics, Ohio Northern University, 525 S Main St, Ada, OH 45810. *Modeling thermal propagation along vein walls in endovenous laser treatment.*

Laser ablation of the saphenous vein involves using laser-tipped probes to produce photothermal effects in the vein. In this study we consider the effects of laser-induced thermal heating and conduction on the vein wall. We formulate and solve the relevant two-dimensional heat conduction problem. The solution resolves an aspect of a controversy involving the physiological mechanism of the procedure. (Received September 22, 2011)

1077-92-2818 **Mohammed Yahdi*** (myahdi@ursinus.edu), Depart of Math & CS, Ursinus College, Collegeville, PA 19426, and **Michael Dunlea**. *Optimal Control for a VRE Model.* Preliminary report.

Antibiotic resistance Vancomycin Resistant Enterococci (VRE) is one of CDC's top ten health concerns. Optimal Control Theory is used to determine efficient and economically favorable strategies to prevent outbreaks and to control the emergence of VRE in hospital intensive care units. Key controls included combinations of the levels of special preventive care, healthcare workers' compliance rates, and health and economical costs. In particular, it is shown that, rather than constant levels, variable and lower levels of special preventive care are best for controlling VRE and preventing outbreaks. (Received September 22, 2011)

1077-92-2845 **Rosalyn C Rael*** (rrael@umich.edu), **Annette Ostling**, **Trevor Bedford** and **Rafael D'Andrea**. *Species abundance distributions in a stochastic niche model.*

Whether and how patterns of species abundance reflect the dynamic processes involved in the formation and maintenance of communities remains an open question in ecology. Recent studies focus on the relative roles of neutral and niche-based mechanisms in shaping these patterns. Neutral dynamics are based on demographic stochasticity and immigration and niche dynamics are generated by trait differences that affect growth rates of competing populations. We find that the differences in species abundance distributions of these two types of communities are more substantial than shown in a recent study. While this previous study used a model with non-interacting niches, we allow for full interaction between all species. These interactions give rise to the niches, suggesting that mechanisms that produce niches can also influence abundance patterns. We compare the patterns resulting from a stochastic Lotka-Volterra competition model which generates either neutral communities (when competition does not depend on traits), or communities with niches (when competition declines with trait distance). Further, we investigate the importance of within and between-niche competition in determining outcomes, and discuss differences in distributions produced at different scales along the trait axis. (Received September 22, 2011)

1077-92-2945 **Wayne M. Getz*** (wgetz@berkeley.edu), Dept ESPM, UC Berkeley, Berkeley, CA 94720-3114. *A Biomass Flow Approach to Population Models and Food Webs.*

The Lotka and Volterra paradigm for modeling interacting species lacks a trophic-level-independent formulation of population growth, leading to ambiguities in how to treat populations that are simultaneously both prey and predator. Here I present an approach that provides a unified framework for accounting for biomass transformation in food webs that include both live and dead components of all species in the system. This biomass transformation formulation (BTW) allows for a unified treatment of webs that include consumers of both live and dead material and incorporates scavengers, parasites, and other neglected food web consumption categories in a coherent manner. I trace how BTW is an outgrowth of the metaphysiological growth modeling paradigm and I provide a general compact formulation of BTW in terms of a three-variable differential equation formulation for each species in the food web: viz. live biomass, dead biomass, and a food-intake-related measure called deficit-stress. I then illustrate the application of this new paradigm to provide insights into two-species competition in variable environments and discuss application of BTW to food webs that incorporate parasites and pathogens. (Received September 23, 2011)

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1077-93-37 **Thomas Chambrion*** (thomas.chambrion@iecn.u-nancy.fr), Institut de Mathématiques Elie Cartan, B.P. 239, 54506 Vandoeuvre, France. *Weakly coupled bilinear quantum systems.*

In the absence of decoherence, the dynamics of a controlled quantum system is given by a Schrödinger equation, $x' = Ax + u(t)Bx$, where x lies in some infinite dimensional Hilbert space, A is a skew-adjoint operator, B is a skew-symmetric linear operator accounting for the interaction of the environment with the system (e.g., trough a laser) and u is the time variable scalar intensity of the control. We will restrict ourselves to the case where A has a purely discrete spectrum. The energy of the system is the $A^{1/2}$ norm of x.

A bilinear system is *weakly coupled* if $|\Im\langle Ax, Bx\rangle| \leq |\langle Ax, x\rangle|$ for every x. Most of the physical examples have this feature. For weakly-coupled bilinear systems, there exists an a priori bound for the growth of energy of the system in terms of the L^1 norm of the control u. In particular, such systems can be approximated with arbitrary precision by their finite dimensional Galerkyn approximations. This gives a theoretical justification of the approximations usually done in practice and provides constructive control algorithms.

These results have been recently obtained in collaboration with Nabile Boussaid (Besancon, France) and Marco Caponigro (Nancy, France). (Received July 02, 2011)

1077-93-62 **Nasir U Ahmed*** (ahmed@site.uottawa.ca), University of Ottawa, Ottawa, Ontario K1N6N5, Canada. *Stochastic Differential Equations on Banach Spaces and Optimization of Supports of Measures Induced.*

Let X,E be a pair of separable Banach spaces. The system we consider is governed by a semilinear stochastic differential equation on X

$$dx = Axdt + Bx(t)dt + f(x)dt + CdW(t), x(0) = x_0, t \in I \equiv [0,T], \tag{1}$$

where A is the infinitesimal generator of a C_0-semigroup of bounded linear operators $\{S(t), t \geq 0\} \subset \mathcal{L}(X)$, $B \in \Gamma \subset \mathcal{L}(X)$, $f : X \longrightarrow X$ is a continuous map, $C \in \mathcal{L}(E,X)$ and $W(t), t \geq 0$, is an E valued Brownian motion. For $B \in \Gamma$, $t \geq 0$, let $\mu_t^B \in \mathcal{M}_1(X)$ denote the probability measure induced by the solution process $\{x^B(t), t \geq 0\}$. Our objective is to find sufficient conditions on Γ under which, for each $t \geq 0$, the reachable set of measures given by

$$\mathcal{R}(t) \equiv \left\{\mu \in \mathcal{M}_1(X) : \mu = \mu_t^B, \text{for } B \in \Gamma\right\} \tag{2}$$

is tight or weakly relatively compact. In fact we prove that it is weakly compact. Then we use this result to solve several optimal control problems requiring control of supports and other functionals of measures with $B \in \Gamma$ as the linear feedback operator. (Received July 15, 2011)

1077-93-306 **Aleksandra Gruszka*** (olka@math.lsu.edu), **Michael Malisoff** (malisoff@math.lsu.edu) and **Frederic Mazenc** (Frederic.MAZENC@lss.supelec.fr). *Tracking Control and Robustness Analysis for PVTOL Aircraft under Bounded Feedbacks.*

We study feedback tracking problems for the planar vertical takeoff and landing (PVTOL) aircraft dynamics, which is a benchmark model in aerospace engineering. We provide a survey of the literature on the model. Then we construct new feedback stabilizers for the PVTOL tracking dynamics. The novelty of our work is in the boundedness of our feedback controllers and their applicability to cases where the velocity measurements may not be available, coupled with the uniform global asymptotic stability and uniform local exponential stability of the closed loop tracking dynamics, and the input-to-state stable performance of the closed loop tracking dynamics with respect to actuator errors. Our proofs are based on a new bounded backstepping result. We illustrate our work in a tracking problem along a circle. (Received August 19, 2011)

1077-93-325 **S. Sathananthan**, **N. Jordan Jameson*** (njordan.jameson@gmail.com) and **M. J. Knap**. *Hybrid Impulsive Control of Stochastic Systems with Multiplicative Noise under Markovian Switching.*

Motivated by Markovian Switching Rational Expectation Models (MSRE) in economics, a problem of state output feedback stabilization of discrete-time stochastic systems with multiplicative noise under Markovian switching is considered. Under some appropriate assumptions, the stabilization of this system under pure impulsive control is given. Further under impulsive control, the output feedback stabilization problem is investigated. The jump Markovian switching is modeled by a discrete-time Markov chain. The control input is simultaneously applied to both the rate vector and the diffusion term. Sufficient conditions based on linear matrix inequalities (LMI's) for stochastic stability is obtained. The robustness results of such stability concept against all admissible uncertainties are also investigated. The parameter uncertainties we consider here are norm bounded. An example is given to demonstrate the obtained results. (Received August 22, 2011)

1077-93-619 **Francesco Ticozzi*** (ticozzi@dei.unipd.it), Dept. of Information Engineering, University od Padova, via gradenigo 6/B, 30174 Padova, PD, Italy. *Stabilization of stochastic quantum dynamics via open and closed loop control.*

We investigate parametrization-free solutions of the problem of quantum pure state preparation stabilization by means of Hamiltonian control, continuous measurement and quantum feedback, in the presence of a Markovian environment. In particular, we show that whenever suitable dissipative effects are induced by either the unmonitored environment or non Hermitian measurements, there is no need for feedback control to accomplish the task. Constructive necessary and sufficient conditions on the form of the open-loop controller can be provided in this case, by resorting to a deterministic system via the support theorem and building on existing results for quantum dynamical semigroups. When open-loop control is not sufficient, one can employ filtering-based feedback control laws to steer the evolution towards the target pure state. We show that the approach presented by Mirrahimi and van Handel, SIAM Cont. Opt., 2007, can be used to fill the gap, and thus applied to a quite general class of quantum dynamics undergoing continuous observations. (Received September 08, 2011)

1077-93-624 **Domenico D'Alessandro*** (dmdaless@gmail.com), 440 Carver Hall, Ames, IA 50011, and **Raffaele Romano**. *Indirect controllability of quantum systems; General Lie algebraic conditions and some special cases.*

A quantum mechanical system S is controlled indirectly when the control affects an auxiliary system A and the evolution of S is modified through the interaction with A only. A study of indirect controllability has the goal to describe the set of states that can be obtained for S with this scheme. In this talk, we study the indirect controllability of quantum systems in the finite dimensional case. After discussing the relevant definitions and the connection of this problem with quantum entanglement, we give a general necessary condition for controllability in Lie algebraic terms. We discuss this condition further by showing with an example that it is not sufficient, thus identifying an open mathematical problem. The case where both target and auxiliary system are two dimensional is treated in detail. In particular, we characterize the Lie group of all possible evolutions for the total system S+A in all cases and prove that complete controllability of S+A and an appropriate notion of indirect controllability are equivalent properties. (Received September 08, 2011)

1077-93-631 **Bingyu Zhang*** (zhangb@ucmail.uc.edu) and **Ivonne Rivas**. *Boundary Control of the Korteweg-de Vries Equation.*

In this talk, we will consider the following boundary value problem of the Korteweg-de Vries equation posed on the finite interval $0, L)$:

$$\left\{ \begin{array}{l} u_t + u_x + uu_x + u_{xxx} = 0, \quad x \in (0, L), \ t \in (0, T), \\ u(0,t) = h_1(t), \quad u_(L,t) = h_2(t), \quad u_{xx}(L,t) = h_3(t). \end{array} \right.$$

Viewing the boundary value functions $h_j, \ j = 1, 2, 3$ as control inputs, we will discuss both controllability and stabilizability of the system. (Received September 08, 2011)

1077-93-643 **Luc Doyen*** (luc.doyen@orange.fr), CERSP, MNHN, 55 rue buffon, 75005 Paris, France. *Co-viability modelling for the sustainable management of biodiversity.*

A basic issue for a sustainable management of renewable resources is the reconciliation of ecological and economic requirements with an intergenerational equity perspective. The presence of numerous uncertainties in the systems at stake complexifies such a goal. Stochastic and robust viability and more generally viable control under uncertainty is proposed here as a relevant modeling framework to deal with such issues. Such an approach does not strive to determine optimal or steady-state paths for the joint dynamics of resources and exploitations, but rather aims at maintaining the trajectories of systems within satisfying normative bounds that mix ecological, economic and social requirements. Hence the approach offers a multi-criteria perspective and provides ways to analyze and control the risks and vulnerability of bio-economic systems. Conceptual links to Population Viability Analysis (PVA) and maximin or Rawlsian approach are shown. It can also be proved how a dynamic programming structure underlies such a viability approach. Examples inspired by the management of biodiversity in agriculture or fisheries illustrate the general ideas. (Received September 09, 2011)

1077-93-782 **Peng Liu*** (pliu19@jhu.edu) and **Tim Leung**. *Price Discrepancy and Optimal Liquidation of Credit Derivatives.*

This paper studies the optimal timing to liquidate credit derivatives in a general intensity-based default risk model under stochastic interest rate. We incorporate the potential price discrepancy between the market and derivative holder, which is characterized by risk-neutral valuation under different credit risk premia specifications. To quantify the value of optimally timing to sell, we introduce the *delayed liquidation premium* which is closely related to the stochastic bracket between the market price and the state price deflator. We also provide mathematical characterization and financial explanations for the optimal liquidation policy. Furthermore, we examine the optimal buy-and-sell strategy by studying an optimal double-stopping problem. Numerical examples are provided to illustrate the optimal strategies for various credit derivatives. (Received September 12, 2011)

1077-93-1061 **Dimplekumar N Chalishajar*** (dipu17370@yahoo.com), 417 Mallory Hall, Department of Mathematics and Computer Scienc, Virginia Military Institute (VMI), Lexington, VA 24450. *.*

In this paper we have discussed the controllability result for a nonlinear neutral functional differential system with impulses and infinite delay. We have proved the result for finite dimension and infinite dimension with non compactness of the associated semigroup, using fixed point argument. We claim that the phase space considered by other authors for the system involving infinite delay with impulse effect in infinite dimension space is not correct. We have introduced a new phase space and proved the result. An example is given to illustrate the theory. (Received September 15, 2011)

1077-93-1129 **Elizabeth Weaver*** (eaweaver1s@uky.edu) and **Heide Gluesing-Luerssen**. *Trellis Behavior Under Dualization.* Preliminary report.

Codes may be represented by edge-labeled directed graphs called trellises. These trellises are very important in the decoding process using search algorithms, such as the Viterbi algorithm. A trellis for a code can be used to produce a trellis representing the dual code, and there are two known procedures for trellis dualization. The first follows naturally if one uses the tail-biting BCJR-construction for the trellis. The second introduced by Forney is a very general procedure that works for many different types of graphs and is based on dualizing the edge set in a natural way. We call this construction the local dual. While the process of local dualization is very convenient, it may result in a trellis with some undesirable properties. We will examine a certain (reasonably large) class of trellises, for which the local dual is "well-behaved" exactly when it coincides with the BCJR-dual. (Received September 19, 2011)

1077-93-1291 **Shaobai Kan*** (skan@jjay.cuny.edu), Department of Mathematics & Computer Science, John Jay College of Criminal Justice, CUNY, 445 W. 59th St., New York, NY 10019. *Identification of Systems with Structural Uncertainties using Binary Sensors.* Preliminary report.

This work is concerned with system identification for plants that are equipped with only binary-valued sensors. In the meantime, the systems that we investigate are subject to not only measurement noises, but also structural uncertainties such as unmodeled dynamics, sensor nonlinear mismatch, and observation bias. To identify the underlying system parameter, a truncated empirical estimate is constructed in this paper. Asymptotic analysis is developed to evaluate the quality of the proposed estimate. Upper and lower error bounds are established to analyze the dependence of the identification errors on the binary-valued outputs and these structural uncertainties. (Received September 18, 2011)

1077-93-1544 **Lorenza Viola*** (Lorenza.Viola@Dartmouth.edu), Department of Physics and Astronomy, Dartmouth College, Hanover, NH 03755. *Engineering Pointer States in Open Quantum Systems.*

Pointer states have both a long history in fundamental quantum theory and a practical relevance as long-lasting high-fidelity states in open quantum systems. For generic dissipative dynamics, however, pointer states need not exist or, when they do, need not coincide with states of practical interest. I will show how open-loop control procedures may be used to engineer dissipation in such a way that any desired initial pure state can be guaranteed to survive with high minimum fidelity over time and retrieved on demand. Quantitative fidelity bounds and constructive synthesis protocols will be presented, and validated through simulation in paradigmatic single- and two- qubit dissipative scenarios. The relationship to recent dynamical decoupling experiments will also be elucidated. (Received September 20, 2011)

1077-93-1768 **Shanaz Tiwari*** (stiwari1@fau.edu). *Stability Analysis for Delayed Systems with an Application.*

In this work, we develop boundedness and stability results for nonlinear systems with time-delays. Our approach is based on Lyapunov-Razumikhin functions, where the underlying idea involves treating state variables with time-delays as disturbances. The advantage of such an approach is that we can obtain various properties for a system with time-delays by exploring robust stability properties of a system with disturbances instead of invoking Lyapunov-Krasovskii functionals, which can be difficult to construct. We apply our results to a biological model for hematopoiesis (blood cell production process) to improve the previous conclusions drawn when only linear techniques were employed. (Received September 20, 2011)

1077-93-1855 **Aleksandra Gruszka*** (olka@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803-4918, **Michael Malisoff** (malisoff@lsu.edu), Louisiana State University, and **Frederic Mazenc** (Frederic.MAZENC@lss.supelec.fr), Team INRIA DISCO, CNRS-Supelec. *Tracking and Robustness Analysis for UAVs with Bounded Feedbacks.*

We discuss tracking for unmanned air vehicles (UAVs) with input constraints. We design controllers that give global tracking control. Two key features are our controller bounds and our proof that the tracking is input-to-state stable with respect to additive actuator errors on the velocity controller, under a restriction on the perturbation that respects airspeed constraints. Our main assumption on the reference trajectory is a nondegeneracy condition on a weighted sum of the reference velocity and reference acceleration. We illustrate our work in simulations. (Received September 23, 2011)

1077-93-1992 **Philip Owrutsky***, MD 340, 33 Oxford St, Cambridge, MA 02138, and **Navin Khaneja**, MD 340, 33 Oxford St, Cambridge, MA 02138. *Controllability with Periodic Pulsing.*

The talk motivates and develops the concept of controlling quantum systems with pulses applied at periodic intervals. When the strength of applied pulses is limited, showing control over a broad range of frequencies is challenging. The talk develops methods to address this problem. (Received September 21, 2011)

1077-93-2069 **Elsa N Schaefer*** (elsa@marymount.edu), 11813 Larry Road, Fairfax, VA 22030. *Influence of Model Structure on Control of a Cholera Epidemic.* Preliminary report.

Over the past few years, I've created increasingly complicated models in an effort to explain and explore the sometimes contradictory information I find about cholera in the biology literature. My ultimate goal is to use optimal control to suggest what sort of trade-off between sanitation and vaccination might be most appropriate in mitigating the spread of an outbreak. Given the small amount of data and even the lack of clear, mechanistic descriptions of the disease, can I find any justification for one complicated model over another? Do the different choices of model lead to different advice? (Received September 21, 2011)

1077-93-2078 **Gerardo A. Paz-Silva**, **Ali T. Rezakhani**, **Jason M. Dominy*** (jdominy@usc.edu) and **Daniel A. Lidar**. *Encoded weak quantum Zeno effect for quantum computation and control.*

It is well known that the quantum Zeno effect can protect specific quantum states from decoherence by using projective measurements. In this talk, we combine the theory of weak measurements with stabilizer quantum error correction and detection codes. Rigorous performance bounds will be offered which demonstrate that the Zeno effect can be used to protect appropriately encoded arbitrary states to arbitrary accuracy, while at the same time, allowing for universal quantum computation or quantum control. (Received September 21, 2011)

1077-93-2106 **Irena Lasiecka**, **Rich Marchand** and **Tim McDevitt*** (McDevittT@etown.edu). *Boundary control of a beam equation with non-monotone boundary conditions.*

The goal of this talk is to present new control theoretic results for second order (in time) PDE scalar equations with boundary conditions that are non-monotone. Models of the type considered typically arise in the context of modeling long flexible robot arms. The non-monotonicity prohibits the use of standard analyses for well-posedness, such as fixed point methods, inherent to monotone structures. Instead, microlocal analysis on the boundary appears to be the key to showing that the underlying semigroup is of Gevrey's class, and that the associated control problem is well-posed within a standard finite energy space with controls that are not necessarily collocated. Although the methodology presented is applicable to more general multidimensional problems, the talk will focus on a one-dimensional Euler-Bernoulli beam equation. Numerical simulations will demonstrate spectral properties of the operators that complement the theoretical findings. (Received September 21, 2011)

1077-93-2344 **Nutan Kumar Tomar*** (chinidma@gmail.com), School of Basic Sciences, IIT Patna, Patna, Bihar 800013, India, and **Suman Kumar**, School of Basic Sciences, IIT Patna, Patna, Bihar 800013, India. *Controllability of nonlocal semilinear boundary delay control systems.* Preliminary report.

Let $(X, \|\cdot\|)$ be a Banach space and $\mathcal{C}_t = C([-\tau, t]; X), \tau > 0, 0 \le t \le T < \infty$, be a Banach space of all continuous functions from $[-\tau, t]$ into X endowed with the norm $||\phi||_{\mathcal{C}_t} = \sup_{-\tau \le \eta \le t} ||\phi(\eta)||$.

In this paper, the controllability for the class of following abstract semilinear boundary control system is discussed in X:

$$\begin{aligned} \dot{x}(t) &= A_{max}(t)x(t), 0 \le t \le T \\ L(t)x(t) &= f(t, x(t), x(b(t))), 0 \le t \le T \\ h(x) &= \phi \text{ on } [-\tau, 0] \end{aligned}$$

where $\phi \in \mathcal{C}_0$, the operators $A_{max}(t) \in \mathcal{L}(D, X), L(t) \in \mathcal{L}(D, \partial X)$ for $t \in [0, T]$ with D and ∂X being Banach spaces and D is dense in X, $f : [0, T] \times X \times X \to \partial X, b : [0, T] \to [-\tau, T]$ and $h : \mathcal{C}_0 \to \mathcal{C}_0$. (Received September 22, 2011)

1077-93-2360 **Weiwei Hu*** (huweiwei@vt.edu), ICAM / Wright House, West Campus Drive, Blacksburg, VA 24061. *Theoretical and Computational Issues in Control of a Thermal Fluid.*

In this talk, we present theoretical and numerical results for a feedback control problem defined by a thermal fluid. The problem is motivated by recent interest in designing and controlling energy efficient building systems. In particular, we show that it is possible to locally exponentially stabilize the nonlinear Boussinesq Equations by applying Neumann/Robin type boundary control on a bounded and connected domain. The feedback controller is obtained by solving a Linear Quadratic Regulator problem for the linearized Bounssinesq equations. Applying classical results for semilinear equations where the linear term generates an analytic semigroup, we establish that this Riccati-based optimal boundary feedback control provides a local stabilizing controller for the full nonlinear Boussinesq equations. In addition, we present a finite element Galerkin approximations and discuss convergence issues. Finally, we provide numerical results based on standard Taylor-Hood elements to illustrate the theory. (Received September 22, 2011)

1077-93-2730 **Humberto C. Godinez*** (hgodinez@lanl.gov), Los Alamos National Laboratory, Applied Mathematics and Plasma Physics, Mail Stop B284, Los ALamos, NM 87545. *Data Assimilation for Dynamical Systems.*

Data assimilation methods combine information from a model, observational data, and relevant error statistics to produce an improved state of the model. These methodologies are widely used to produce accurate forecast of atmospheric weather, climate, ocean circulation, and space weather models, to name a few. In this talk we present how data assimilation is used for complex dynamical systems and the various considerations for its effectiveness. We discuss the various factors that influence the success of assimilation, such as the quantity and quality of the observations, errors in initial conditions and/or input parameters, and model uncertainty. The Lorenz 40-variable system and the coupled Lorenz 2-scale system, are taken as test models for assimilation. A twin-experiment is preformed where artificial observations are produced from a reference run, and assimilated using an ensemble-based data assimilation method. From the results it is noted that the accurate description of model and observation uncertainty plays a crucial role for the success of the assimilation. Additionally, for the coupled system, it is found that the coupling between variables of different time scales affects the assimilation, where a strong coupling may adversely impact the assimilation. (Received September 22, 2011)

1077-93-2836 **Brian P Kelly*** (bkelly@bryant.edu), 1150 Douglas Pike, Smithfield, RI 02917. *Application of Modified Shannon Entropy.*

Increasing complexity in corporate supply chains creates a need for an objective measure of the waste a given corporate structure implies. This research treats the vector of probabilities as a signal in the context of Information Theory. However, the traditional Shannon's Entropy is not entirely suitable since it is primarily a measure of certainty in the distribution of signals. Our modification seeks to refine the measure to incorporate a measure of the unintended costs generated by specific inventory combinations. This paper will delineate the formal properties of the modified entropy formula. This will include how the entropy relates to lexicographical ordering of probability vectors. Thus we will show how the entropy can be applied to other settings where the vector components have an inherent preference order. (Received September 22, 2011)

1077-93-2922 **Eric B Auld*** (imurme8@yahoo.com), 1214 S Farmer Ave, #B103, Tempe, AZ 85281.
Topological Obstructions to Consensus on $SO(3)$.

In this work we examine the topological obstructions to consensus on Lie Groups, with particular reference to $SO(3)$, the space of orthogonal matrices with determinant equal to 1. In decentralized control on Lie Groups, we encounter topological obstructions to consensus which are instructive in their own right about the topology of the given space. We propose a feedback law and examine its properties by way of simulation. Our animations start with random elements of $SO(3)^n$ and apply to them a feedback law of our own device. We examine the conditions under which it converges, and discuss what topological properties of $SO(3)$ present obstacles to consensus. For example, the fact that $SO(3)$ is not simply connected is a frequent obstacle to consensus. To support our simulations, we present analytic results concerning the stability of points in $SO(3)$ under our algorithm, and examine which conditions may be necessary and/or sufficient to ensure convergence to such points. (Received September 23, 2011)

94 ► Information and communication, circuits

1077-94-225 **Michael Robinson*** (robim@math.upenn.edu), 209 S 33rd Street, Philadelphia, PA 19104.
Sheaf invariants for temporal logic.

A simple invariant of temporal logic gate networks is the truth table. Although easy to compute, a truth table contains no dynamical information about the associated network. On the other hand, a complete dynamical invariant can be obtained by exhaustive event-level simulation. In practical settings, this tends to be too unwieldy, and is subject to difficulties akin to the halting problem. Recently, an intermediate family of algebraic invariants have been discovered that arise from the theory of constructible sheaves on graphs. I will outline the mechanics of this emerging theory and some of its key findings. (Received August 15, 2011)

1077-94-257 **Katherine Morrison*** (s-kmorri11@math.unl.edu), 203 Avery Hall, Lincoln, NE 68588.
Equivalence and Duality for Rank-Metric and Matrix Codes.

Due to their applications in network coding, public-key cryptography, and space-time coding, both rank-metric codes and matrix codes, also known as array codes and space-time codes over finite fields, have garnered significant attention. We focus on characterizing rank-metric and matrix codes that are both efficient, i.e. have high dimension, and effective at error correction, i.e. have high minimum distance. A number of researchers have contributed to the foundation of duality theory for rank-metric and matrix codes, which has demonstrated that the inherent trade-off between dimension and minimum distance for a code is reversed for its dual code; specifically, if a code has high dimension and low minimum distance, then its dual code will have low dimension and high minimum distance. Thus, with an aim towards finding codes with a perfectly balanced trade-off, we study self-dual matrix codes. In particular, we enumerate the equivalence classes of self-dual matrix codes of short lengths over small finite fields. To perform this classification, we also examine the notion of equivalence for rank-metric and matrix codes and use this to characterize the automorphism groups of these codes. (Received August 16, 2011)

1077-94-543 **Pani Seneviratne*** (pseneviratne@aus.edu), Department of Mathematics & Statistics, American University of Sharjah, Sharjah, 26666, United Arab Emirates. *Codes from incidence matrices and line graphs of generalized Paley graphs.* Preliminary report.

We examine the binary codes from incidence matrices of generalized Paley graphs $GP(q, S)$, where q is an odd prime power. We show that the binary codes are $[\frac{qs}{2}, q-1, s]$, when s is even and $[qs, q-1, 2s]$, when s is odd, where $s = |S|$. By finding explicit PD-sets we show that these codes can be used for permutation decoding. (Received September 07, 2011)

1077-94-1183 **Gregory E Coxson***, 962 Wayne Avenue, Suite 800, Silver Spring, MD. *Constructions and Existence Results for Complementary Code Sets.* Preliminary report.

Complementary code sets offer an interesting alternative for waveform design in radar or communications. A popular approach for finding complementary sets is via Hadamard matrices, whose set of columns and set of rows are complementary. Complementary code matrices (CCMs), which include the Hadamard matrices, provide an alternative with several benefits. For instance, the KxN CCMs enjoy a one-to-one relationship to the sets of K length-N complementary codes. Also, in the binary case, the Hadamard matrices exist only for orders 1, 2, and those divisible by 4; we will show that the restrictions are not as tight for the CCMs, allowing a richer source of complementary sets. We will exhibit several Hadamard construction techniques that extend to the complementary code matrices. Finally, existence results will be derived for NxK complementary code matrices, yielding simple indicators for the existence of sets of K length-N complementary codes. While the primary focus will be the binary case, several results extend to the unimodular case. (Received September 17, 2011)

1077-94-1270 **Nigel Boston*** (boston@math.wisc.edu), Departments of Mathematics and ECE, University of Wisconsin, Madison, WI 53706. *Pseudocodewords and pseudoweights.*

This talk will present a survey of recent work on pseudocodewords. After introducing and explaining their importance, I shall describe a variety of algebraic tools that have been used to study them. There are various notions of pseudoweight for pseudocodewords and I shall explain how the above tools have been used to make progress on some open problems concerning pseudoweight bounds. (Received September 18, 2011)

1077-94-1322 **Vladimir Shpilrain*** (shpil@groups.sci.ccny.cuny.edu), Department of Mathematics, The City College of New York, New York, NY 10031. *Security assumptions in non-commutative cryptography.* Preliminary report.

We review and compare security assumptions in non-commutative cryptography that have been in circulation over the last decade or so, and discuss several new security assumptions that can be useful. (Received September 19, 2011)

1077-94-1403 **Amin Emad***, emad2@illinois.edu, and **Jun Shen** and **Olgica Milenkovic**. *Symmetric Group Testing.*

We describe a generalization of the combinatorial group testing problem termed symmetric group testing. Unlike in classical binary group testing, the roles played by the input symbols zero and one are "symmetric" while the outputs are drawn from a ternary alphabet. In addition, we propose generalized group testing by introducing thresholds in the symmetric group testing setup. Furthermore, we consider the probabilistic group testing with a Poisson distribution on the number of defectives. Using an information-theoretic approach, we derive sufficient and necessary conditions for the number of tests required for noise-free and noisy reconstructions in all these cases. Furthermore, we extend the notion of disjunct (zero-false-drop) and separable (uniquely decipherable) codes to the case of symmetric group testing. For the new family of codes, we derive bounds on their size based on probabilistic methods and provide construction methods based on coding theoretic ideas (Received September 19, 2011)

1077-94-1546 **Carina Curto** (ccurto2@math.unl.edu), **Vladimir Itskov** (vitskov2@math.unl.edu), **Katherine Morrison*** (s-kmorri11@math.unl.edu), **Zach Roth** (s-zroth1@math.unl.edu) and **Judy Walker** (jwalker7@math.unl.edu). *A coding theory perspective on combinatorial neural codes.*

We analyze combinatorial neural codes from a coding theory perspective. Specifically, we focus on the class of combinatorial codes known as receptive field codes. At first glance, these codes appear to perform horribly compared to various other codes with similar parameters, but we give insights as to why the brain might in fact favor them. (Received September 20, 2011)

1077-94-1621 **Finley Freibert*** (fjfrei01@louisville.edu), 328 Natural Science Building, University of Louisville, Louisville, KY 40292, and **Jon-Lark Kim**, 328 Natural Science Building, University of Louisville, Louisville, KY 40292. *Optimum Distance Profiles and Optimal Subcodes of Binary Self-Dual Type II Codes.*

Self-dual codes have widespread relations to various areas such as combinatorial designs, unimodular lattices, and group theory. A self-dual code is called *doubly-even* or *Type II* if the weights of the codewords are divisible by 4. Let C be a binary $[n, k]$ code and let $C_0 = C$. A sequence of linear subcodes of C, $C_0 \supset C_1 \supset \cdots \supset C_{k-1}$ is called a *subcode chain*, where the dimension of C_i is $k - i$ for $i = 0, \ldots k - 1$. Let $d_i := d(C_i)$ be the minimum distance of C_i. Then the sequence $d_0 \leq d_1 \leq \cdots \leq d_{k-1}$ is called a *distance profile* of C. Luo, Vinck, and Chen (2010) have studied the optimum distance profiles of Reed-Solomon codes, Golay codes, the first order Reed-Muller codes, and the second order Reed-Muller codes. In this talk, we examine optimum distance profiles and Optimal Subcodes of extremal Type II codes of lengths 24 and 32, and give some direction towards the optimum distance profile of the unique extremal Type II code of length 48. (Received September 20, 2011)

1077-94-1628 **Vitaly Skachek*** (vitaly.skachek@gmail.com), Coordinated Science Lab, University of Illinois at Urbana-Champaign, 1308 W. Main St., Urbana, IL 61801, and **Olgica Milenkovic** and **Angelia Nedic**. *Hybrid Noncoherent Network Coding.*

We describe a novel extension of subspace codes for noncoherent networks, suitable for use when the network is viewed as a communication system that introduces both dimension and symbol errors. We show that when symbol erasures occur in a significantly large number of different basis vectors transmitted through the network and when the min-cut of the networks is much smaller then the length of the transmitted codewords, the new family of codes outperforms their subspace code counterparts.

For the proposed coding scheme, termed hybrid network coding, we derive two upper bounds on the size of the codes. These bounds represent a variation of the Singleton and of the sphere-packing bound. We show that a simple concatenated scheme that represents a combination of subspace codes and Reed-Solomon codes is asymptotically optimal with respect to the Singleton bound. Finally, we describe two efficient decoding algorithms for concatenated subspace codes that in certain cases have smaller complexity than their subspace decoder counterparts. (Received September 20, 2011)

1077-94-1635 **K N Neupane*** (kneupane@fau.edu), Department of Mathematical Sciences, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431, and **R Steinwandt**, Department of Mathematical Science, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431. *Communication-efficient 2-round group key establishment from pairings.*

In a recent preprint, Vivek et al. propose a compiler to transform a passively secure 3-party key establishment to a *passively* secure group key establishment. To achieve *active* security, they apply this compiler to Joux's protocol and apply a construction by Katz and Yung, resulting in a 3-round group key establishment.

In this paper we show how Joux's protocol can be extended to an *actively* secure group key establishment with two rounds. The resulting solution is in the standard model, builds on a bilinear Diffie-Hellman assumption and offers forward security as well as strong entity authentication. If strong entity authentication is not required, then one half of the participants does not have to send any message in the second round, which may be of interest for scenarios where communication efficiency is a main concern. (Received September 20, 2011)

1077-94-1763 **Nathan Axvig*** (axvignd10@vmi.edu). *Using Pseudocodewords to Convey Information.* Preliminary report.

For many "modern" decoding algorithms, it is possible for the decoder to return vectors that do not correspond to codewords. Such output vectors are known as nontrivial pseudocodewords. In the case of the linear programming decoder, a decoder failure is declared if a nontrival psuedocodeword is found to be the output. Thus, the codeword and some of its information bits are lost. In this work, we aim to make the best of this bad situation. In particular, we discuss recent progress in designing systems that use linear programming pseudocodewords, in conjunction with codewords, to convey additional bits of information beyond those offered by the dimension of the original code. (Received September 20, 2011)

1077-94-1779 **Lara Dolecek***, Engineering IV, 56-147B, EE Department, UCLA, Los Angeles, CA 90095. *Flexible coding schemes with applications to emerging memory technologies.*

In this talk we will discuss a novel class of non-binary coding schemes for a channel model arising in emerging memory technologies. We will discuss theoretical properties of these codes, including symmetric and asymmetric error detection and correction properties, and their simplified encoders and decoders. We will also discuss how such codes can help address the spatio-temporal variability of practical multilevel Flash memories, and ways in which proposed constructions outperform existing coding solutions. (Received September 20, 2011)

1077-94-1810 **Martianus Frederic Ezerman** (frederic.ezerman@gmail.com), Laboratoire d'Information Quantique, CP 225, Université Libre de Bruxelles, Av. F. D. Roosevelt 50, B-1050, Bruxelles, Belgium, and **Radoslav M Kirov*** (rkirov@gmail.com). *Asymmetric Quantum Codes from Two-Point Divisors on Algebraic Curves.* Preliminary report.

It is known that codes from two-point divisors can be used to construct classical error-correcting codes with strictly better parameters than the one-point codes. The Duursma-Kirov method provides the currently best known lower bounds on the minimum distances of algebraic geometric (AG) codes.

In the theory of quantum error-correction, the observed presence of asymmetry in many binary quantum channels led to the mathematical study of asymmetric quantum codes (AQCs) where we no longer assume that the different types of errors are equiprobable.

AG codes are well suited to constructing AQCs with good parameters. We show that, similarly to the classical case, two-point divisors give us better AQCs than those derived from their one-point counterparts. Theoretical and numerical results on the gains in the parameters will be presented.

This is a joint work with M. Frederic Ezerman. (Received September 21, 2011)

1077-94-1865 **Qiyu Sun*** (qiyu.sun@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *A nonlinear sampling problem about signals with finite rate of innovation.* Preliminary report.

In this talk, I will discuss the problem how to locally identify innovation positions of signals in a perturbed shift-invariant space. (Received September 21, 2011)

1077-94-2457 **Kalyan S Perumalla*** (perumallaks@ornl.gov), PO Box 2008, MS-6085, ORNL, Oak Ridge, TN 37831-6085. *Discrete Event Execution and Reversibility: Challenges in the Path to Asynchrony for Massively Parallel Computing.* Preliminary report.

To keep up with the increasing number of processing elements in parallel/distributed computing, traditional tightly-coupled time-stepped models must give way to asynchronous models, such that the coupling among model components across processors is relaxed. Two challenges in defining mathematical models amenable to efficient asynchronous execution are: (1) the ability to define/determine discrete events of changes to component state over time with guaranteed bounds on stability and accuracy, despite the staggering of updates, and (2) the ability to take the model backward in time with minimal memory cost, in order to make corrections to local computations that may occur due to relaxation of global synchrony. We illustrate these considerations in some applications of interest, such as molecular dynamics and fluid dynamics, and allude to some ways in which applied mathematics research could impact asynchronous computing. (Received September 22, 2011)

1077-94-2760 **Nathan Cohen*** (ncohen@fractenna.com). *Fractal Antennas, Resonators, and Invisibility Cloaks: Nuggets from the Tortuous Path.*

Since 1988 self similarity has been discovered to be a key tool that has defined a new branch in RF and electronics. Focusing on antennas, resonators, metamaterials, and related devices, fractal structures accomplish a variety of benefits simultaneously, not achieved with other techniques. These include, among others: wider bandwidth; multibandedness; phasing control; shrinking sizes; higher gains; part (component) reduction; and cost reduction. In addition self similarity is a prescription for frequency invariance, one of a few key insights that fractals have shown so far in natural law. Here, examples of these applied mathematical benefits of fractals will be shown, including a live demonstration. (Received September 22, 2011)

1077-94-2962 **Mark Iwen** (markiwen@math.duke.edu), Department of Mathematics, Duke University, Durham, NC 27708, **Fadil Santosa*** (santosa@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455, and **Rachel A Ward** (rward@math.utexas.edu), Department of Mathematics, University of Texas, Austin, TX 78712. *A symbol-based approach to bar code decoding*

Information encoded in a bar code can be read using a laser scanner or a camera-based scanner. For one-dimensional bar codes, which are in most prevalent use, the information that needs to be extracted are the widths of the black and white bars. The collection of black and white bars may be viewed as a binary one-dimensional image. The signal measured at the scanner amounts to the convolution of the binary image with a smoothing kernel. The challenge is that the smoothing kernel, in addition to the binary image, is also unknown. We present an approach that is based on the language of bar code and devise a sparse representation of the unknown using the symbol dictionary. A greedy algorithm is propose. We further show that the algorithm recovers the correct bar code when there is no noise, but more importantly, we show that it is robust to noise and unknown properties of the smoothing kernel. (Received October 05, 2011)

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1077-97-102 **Marie Nicole Ermete*** (ermet1mn@gmail.com), **Natasha Dawn Brackett** and **Karli Nicole Powell**. *The Role of Dynamic Representations in Development of Algebraic Concepts.* Preliminary report.

One of the goals of mathematics education is to allow students to understand mathematical ideas from various perspectives. The ability to move among representations allows the student to become better problem-solvers. Based on the symbolic mediation model proposed by Kaput, Blanton, and Moreno (2008), this talk lays out a theoretical framework for the use of dynamically-connected representations to help students develop algebraic concepts. In addition, research on the use of data collection devices suggests that real-time connection of representations is essential for students to make linkages among various aspects of the concepts (Lapp, 2000). This talk discusses the use of technology that dynamically links multiple representations as a tool so that the learner can make connections of algebraic concepts. This particular study is situated in a College Algebra class where students had access to both a computer algebra system (CAS) and dynamically linked representations. Results regarding both student learning and teacher change from two semesters (one using a basic graphing calculator and the other using CAS) will be shared. Directions for future research will also be discussed (Received July 27, 2011)

1077-97-184 **Amanda Cangelosi** and **Hugo Rossi***, 155 S 1400 E. *Incorporating the Common Core State Standards Integrated Secondary Curriculum in a Teacher Training Course.*

As the Common Core State Standards begin to be implemented in schools, introducing new material and teaching methods, teacher education courses are presented with a necessity and opportunity for enrichment. We take a first look at "Teaching and Learning Algebra," a course for current Utah secondary teachers that uses the Common Core State Standards as a backbone, integrating the traditional high school courses and weaving in advanced mathematical topics. Student work and reflections will be shared, emphasizing secondary teachers' personal interest and classroom applicability. (Received August 08, 2011)

1077-97-303 **Peter R Turner*** (pturner@clarkson.edu). *Applied Mathematics Outreach to Middle and High Schools: Opportunities and Resources.*

This introductory talk will provide an overview of some of the ways in which applied mathematics and modeling content can be incorporated into middle and high school programs. The use of contests has proved a valuable motivator. Some of these contests and their effect on student performance will be presented. With the increased flexibility in mathematics curricula under the proposed common core standards, the inclusion of modeling and applications will be of growing importance in the next few years. Other resources and SIAM's potential role in developing appropriate content for students and their teachers will also be described. (Received August 19, 2011)

1077-97-317 **Michael E Martin*** (michael.e.martin@gmail.com), 6319 Sherwood Lane, Merriam, KS 66203. *Using Dynamic Web Tools Across the Early Undergraduate Mathematics Curriculum.*

The presenter has developed and utilized a wide array of webMathematica tools for the first two years of undergraduate mathematics courses. These tools have been utilized for a number of years in several courses at a very large community college in Kansas City and also at other institutions. This talk will highlight both the tools and the results in incorporating them for interactive, dynamic learning and exploration. The presenter also utilizes WolframAlpha and Wolfram's Demonstrations project in his courses and will relate that to their precursor, webMathematica. The work has been distinguished in receiving the ICTCM Award for Excellence and Innovation in the Utilization of Technology in Collegiate Mathematics. (Received August 21, 2011)

1077-97-395 **Kathleen R Fowler*** (kfowler@clarkson.edu), Clarkson University Department of Mathematics, 8 Clarkson Avenue, Potsdam, NY 13676-5815. *Applied Mathematical Modeling and Research Opportunities for Middle School, High School, and Pre-Freshmen Students.*

We present a variety of outreach activities that we have implemented to help students in grades 6-12+ understand the role of mathematics in solving real-world problems. At the middle school level, we describe a workshop given to local middle school teachers to promote math modeling and project-based learning. For middle and high school students, we give examples of coaching students in national problem solving and open-ended modeling competitions. Also, we describe experiences mentoring high school students on research projects for a state-wide competition. At the pre-freshmen level, we describe a summer research experience for in-coming freshmen. All of these programs have challenges but ultimately results in an enriching, enlightening experience for all those involved, which in some cases include undergraduate and graduate student mentors, faculty, and local teachers. (Received August 29, 2011)

1077-97-521 **Richard Millman*** (richard.millman@ceismc.gatech.edu), 489 RockSprings Rd. NE, Atlanta, GA 30324, and **Daniel Connelly** and **Cher Hendricks**. *The Mathematics of Proofs in Number Theory and Algebra for High Achieving High School Students.* Preliminary report.

The goals of the course are to construct valid proofs (sometimes motivated by examples) and identify the fallacious reasoning of incorrect proofs, learn/revisit some facts from elementary number theory and algebra in more depth and apply them to group theory and other areas of mathematics, to be prepared for higher-level abstract mathematics courses and to see what they might be like, to work individually and in teams to solve mathematical problems, and to development a mathematical habit of the mind. The course was taught to 19 high school students, all of whom have had three semesters of calculus, in a magnet school in a large metro area. The details of the course and the feedback from the students will be presented. (Received September 06, 2011)

1077-97-644 **Kristin L Umland*** (umland@math.unm.edu). *A Guided Tour of the Illustrative Mathematics Project.* Preliminary report.

The Common Core State Standards for Mathematics (CCSSM) provide an unprecedented opportunity for collaboration on improving mathematics learning and achievement in the United States at scale, but there is a tremendous amount of work to be done to make the promise a reality. The goal of the Illustrative Mathematics Project is to provide guidance to individual teachers, curriculum developers, states, assessment consortia, and testing companies by collecting and vetting high-quality tasks that illustrate the range and types of mathematical work that students should experience in a high-quality implementation of the CCSSM. It will grow to support additional tools and a forum for teachers and others to share ideas about how to implement the CCSSM. This talk will provide a brief introduction to the project, an insider view of the website, and an overview of future plans. (Received September 09, 2011)

1077-97-652 **Bernard L Madison*** (bmadison@uark.edu), Department of Mathematical Sciences, SCEN 301, University of Arkansas, Fayetteville, AR 72701. *Placement in College Mathematics.*

One of the troublesome aspects of the transition from school to college mathematics is the placement of students in the first college mathematics course. Placement is complicated by several factors including a lack of standardization of placement methods and the numerous possible first courses. Implementation of the Common Core standards and work by the MAA's placement testing task force show promise of easing the difficulties of and making more effective placement in college mathematics. This will be a report of MAA's ongoing placement test work that is based on research results on what students need to understand in order to succeed in precalculus and calculus. Connections to and consistency with the Common Core standards will be noted. (Received September 09, 2011)

1077-97-676 **Ningjun Ye*** (ningjun.ye@usm.edu), 118 College Drive #5045, Hattiesburg, MS 39406. *Assessing The Impact of a Computer-Based College Algebra Course.*

USM piloted the Math Zone in Spring 2007, a computer-based program in teaching MAT 101and MAT 099 in order to improve student performance. This research determined the effect of the re-design of MAT 101 on student achievements in comparison to a traditional approach to the same course. Meanwhile, the study investigated possible effects of the Math Zone program on students' attitude toward studying mathematics. This study showed that there was no statistically significant difference on MAT101 final exam scores between the Math Zone students and the Classroom students in Fall 2007, Spring 2008 and Fall 2008. At the same time, the study also showed that there was no statistically significant difference in students' attitude toward math between the two groups in each of the three semesters. However, this study revealed a significant relationship between the hours the students spent in the Math Zone and the scores they made on the final exams in Spring 2008, Fall 2008, Spring 2009 and Spring 2010. (Received September 09, 2011)

1077-97-753 **Brian J. Winkel*** (BrianWinkel@hvc.rr.com), PROF Emeritus Brian Winkel, Department of Mathematical Sciences, United States Military Academy, West Point, NY 10996. *Pictures of Personal Change and View of Change Needed to Enhance Transition to College Mathematics.* Preliminary report.

Will undergraduate mathematics faculty be ready for students who have participated in the Common Core State Standards? Will we be prepared to meet them where they are and take advantage of what they know and have experienced? Will we understand and embrace our broader role in mathematics education than we may have historically taken? Through a personal narrative of change occurring over 45 years of teaching undergraduates the presenter will share experiences with specific examples that make him believe teaching mathematics in context, with modeling and the full integration of technology for doing mathematics, is a reasonable way to embrace the transitioners and help them "Keep on truckin'." (Received September 12, 2011)

1077-97-762 **Sian L Beilock*** (beilock@uchicago.edu), 711 South Dearborn St #304, Chicago, IL 60605. *Math Anxiety: From Teacher to Student.*

Math anxiety is characterized by feelings of tension, apprehension, and fear about performing math. We show that when the math anxious individuals are female elementary school teachers, their math anxiety carries negative consequences for the math achievement of their female students. Early elementary school teachers in the U.S. are almost exclusively female (>90%) and we demonstrate that these female teachers' anxieties relate to girls' math achievement via girls' beliefs about who is good at math. 1st and 2nd grade female teachers completed measures of math anxiety. The math achievement of their students was also assessed. There was no relation between a teacher's math anxiety and her students' math achievement at the beginning of the school year. By school year's end, however, the more anxious teachers were about math, the more likely girls but not boys' were to endorse the stereotype that "boys are good at math and girls are good at reading" and the lower these girls' math achievement. We also looked at the neural correlates of teachers and adults with math anxiety and show how some math anxious people overcome their fear of math. Implications for the mathematics training of teachers and students is discussed. (Received September 12, 2011)

1077-97-978 **Kelly K. Sturner*** (ksturner@nimbios.org), NIMBioS, University of Tennessee, Knoxville, TN 37996, and **Suzanne Lenhart** (lenhart@math.utk.edu), University of Tennessee, Department of Mathematics, Knoxville, TN 37996. *Trees and Soil Microbes: Activities for Bringing Life (Science) to Mathematics.* Preliminary report.

We will present two examples of activites developed in connection with The National Institute for Mathematical and Biological Synthesis showing school-age audiences how math applies to life science topics. The first module, suitable for middle school students and developed around the theme of forest ecology and geometry, introduces an applied use of pi and also a forestry calculation known as basal area. The second module, designed for high school students, introduces the concept of mathematical modeling of biological phenomena using an example exploring predator-prey relationships in soil. Both modules are now freely available at www.nimbios.org. (Received September 15, 2011)

1077-97-1008 **David M. Bressoud*** (bressoud@macalester.edu). *Addressing the transition to college mathematics.*

This talk will set the stage for this special session on the transition to college mathematics by summarizing what we know about trends and bottlenecks, and providing a preliminary report of some of the findings from the MAA's Calculus Study: *Characteristics of Successful Programs in College Calculus.* (Received September 15, 2011)

1077-97-1080 **Zengxiang Tong*** (ztong@otterbein.edu), Department of Mathematical Sciences, Otterbein University, Westerville, OH 43081, and **Zhen Huang** (zhuang@otterbein.edu), Department of Mathematical Sciences, Otterbein University, Westerville, OH 43081. *An Extension of the Fundamental Theorem of Calculus.* Preliminary report.

The Newton-Leibniz Formula is now called the fundamental theorem of calculus in all calculus textbooks. However, most textbooks do not state this formula clearly or correctly. In this presentation, we will provide an example to show the flaw and will further suggest an extended Newton-Leibniz formula that we believe not only fix the flaw but also strengthens the natural connection between the indefinite integral and the definite integral, and enhance student's integration ability.

We think this presentation is valuable for all calculus instructors and textbook writers. (Received September 20, 2011)

1077-97-1094 **C. Kenneth Fan*** (girlsangle@gmail.com), Girls' Angle, PO Box 410038, Cambridge, MA 02141-0038. *Applied Mathematics at Girls' Angle: A Math Club for Girls.*

Girls' Angle uses applied mathematics in a variety of ways to help it engage and motivate girls to study mathematics. Through our Support Network, professional women who use math in their work visit our club and interact with our members. Through Community Outreach, the general public is invited to have our members solve math problems whose solutions will be put to actual use. We also use modern technology in a variety of ways to increase our reach. In this talk, I will detail Girls' Angle's ongoing relationship with applied math and applied mathematicians and explain how you can help us fulfill our mission. Time permitting, I will also explain how Girls' Angle tries to feed off of and channel motivation generated by contests. (Received September 16, 2011)

1077-97-1095 **C. Kenneth Fan*** (girlsangle@gmail.com), Girls' Angle, PO Box 410038, Cambridge, MA 02141-0038. *Girls' Angle: A Math Club for Girls.*

In this presentation the motivation behind the creation of Girls' Angle and its educational philosophy will be explained along with its major goals. Actual case studies at Girls' Angle where we were able to help a member improve at mathematics using techniques that would likely be difficult to implement at most schools will be detailed. We will also explain how you can be involved to help us fulfill our mission. (Received September 16, 2011)

1077-97-1254 **Padraig M. McLoughlin*** (mcloughl@kutztown.edu), 265 Lytle Hall, Department of Mathematics, Kutztown University of Pennsylvania, Kutztown, PA 19530. *On Doing Mathematics: Why We Should Not Encourge Feeling, Believing, or Interpreting Mathematics.*

P. J. Halmos recalled a conversation with R. L. Moore where Moore quoted a Chinese proverb. That proverb provides a summation of the justification of the methods employed in teaching students to do mathematics with a modified Moore method (MMM). It states, "I see, I forget; I hear, I remember; *I do, I understand.*"

In this paper we build upon the suggestions made in, *On the Nature of Mathematical Thought and Inquiry: A Prelusive Suggestion* (2004, ERIC Document ED502336) and attempt to explore why the differences between reading, seeing, hearing, witnessing, and doing give rise to the contrast between and betwixt feeling, believing, interpreting, opining, and knowing.

We refine in this paper the philosophical position proposed in the 2004 paper and accentuate how reading, seeing, or hearing do not lead to understanding whilst feeling or believing do not lead to truth. We submit that 'interpreting' gives the impression Math is as imprecise as Psychology and is rooted in relativism (the 'eye of the beholder') rather than certain conditional truth deduced from axioms. We posit that feeling, believing, & "interpreting mathematical phenomena," are actually *harmful* to authentic meaningful mathematical learning. (Received September 20, 2011)

1077-97-1282 **Janet E. Mertz*** (mertz@oncology.wisc.edu), McArdle Laboratory for Cancer Research, 1400 University Avenue, University of Wisconsin, Madison, WI 53706-1599, and **Jonathan M. Kane** (kanej@uww.edu), Depart. of Mathematical & Computer Sciences, University of Wisconsin, 800 West Main Street, Whitewater, WI 53190-1790. *Gender Differences in Mathematics: Facts from Recent Data.*

Boys frequently outperform girls in mathematics, resulting in a positive gender gap. Boys' mathematics scores usually exhibit greater variance than girls', resulting in a variance ratio greater than one. However, some nations consistently exhibit no gender gap and variance ratios of one. To identify reasons for these phenomena, we analyzed data from recent Trends in International Mathematics and Science Studies and Programme in International Student Assessments. We found that variance ratio and gender gap are unrelated to a country's wealth, major religion, and co-educational schooling. Instead, they are largely due to a variety of country-specific sociocultural factors. In particular, mathematics performance at the low, medium, and high levels for boys as well as girls exhibited a strong positive correlation with some measures of gender equity, especially participation rate and salary of women in the paid labor force relative to men. Other measures such as the percentage of girls participating on a country's IMO teams also correlate with measures of gender equity. Thus, sociocultural and socioeconomic factors appear to be the primary determinants of mathematics performance at all levels for both girls and boys, not intrinsic biological differences between the sexes or religion. (Received September 18, 2011)

1077-97-1488 **Cathy L Seeley*** (cseeley@austin.utexas.edu), 1616 Guadalupe, UTA, Ste. 3.206, Austin, TX 78731. *Preparing twelfth-graders for college mathematics.*

The Common Core State Standards give us a renewed opportunity to rethink high school mathematics. With more students expected to complete four years of academic high school mathematics, we have a responsibility to prepare them all to continue their mathematical studies. What opportunities and challenges does this changing mathematical preparation offer to higher education? We will look at the mathematical content that can be addressed at the twelfth-grade, or fourth-year level, including some topics not typically addressed. And we will discuss new pedagogical approaches that prepare students not only with mathematical knowledge, but also with the critical thinking and independent learning skills that will help them succeed in college. A recently developed fourth-year mathematics course will be shared as an example of a new generation of capstone mathematics courses for high school students that can engage them in rigorous, yet accessible mathematical tasks. (Received September 20, 2011)

1077-97-1542 **Sybilla Beckmann*** (sybilla@math.uga.edu), Department of Mathematics, Boyd Graduate Studies Building, University of Georgia, Athens, GA 30602. *The Mathematical Education of Teachers II and Progressions for the Common Core State Standards for Mathematics.* Preliminary report.

This presentation will describe two projects that can inform professional development programs for teachers. Both projects intend to support the successful implementation of the Common Core State Standards for Mathematics (CCSSM).

The Mathematical Education of Teachers II is a revision of the CBMS publication of about a decade ago that made recommendations on the experiences needed to prepare and develop teachers and on the participation of

mathematicians. Revisions take the CCSSM into account, including the Standards for Mathematical Practice, and have been informed by feedback from various groups.

The Progressions Project is developing progressions for each of the domains within the CCSSM. In fact, early drafts of progressions were the basis for the CCSSM. Each progression describes how mathematical ideas develop across grade levels. Portions of several progressions will be presented. Progressions can be used in professional development with groups of teachers. (Received September 20, 2011)

1077-97-1688 **Patricia Hale*** (phale@csupomona.edu), Cal Poly Pomona, Dept. of Math and Statistics, 3801 W Temple AVE, Pomona, CA 91768. *Progress and Persistent Barriers for Women in Advanced Mathematics.*

Over the past few decades there has been considerable effort to increase the number of women and other under-represented groups in advanced mathematics. In this presentation, data will be presented on the current status of women in academic careers and how this has changed over time. Common threads among demonstrated practices and research at institutions that support women in mathematical careers will be examined. Barriers that persist at the faculty, post-doc, and graduate student level will be discussed. (Received September 20, 2011)

1077-97-1879 **Patrick Callahan*** (callahan.web@gmail.com), 823 H Avenue, Coronado, CA 92118. *Transforming geometry through transformations.*

Traditional approaches to geometry have focused on memorizing lists of names of shapes and theorems. The list of names and "facts" in elementary grades and "theorems" in secondary often seem to be rather ad hoc. Felix Klein gave a unifying approach to geometry in his 1872 Erlangen Program. At the heart of this approach is that geometry is characterized by symmetries or geometric transformations. Geometric transformations are not a new approach to geometry, but they have received very little attention in most K-12 mathematics curricula. The CCSS have put geometric transformations back into the forefront of K-12 geometry. This is a change from previous state standards and has been identified as one of the priority needs for professional development. I will share data from recent research on students' and teachers' understanding of transformations, including work from our NSF funded project "Learning and Teaching Geometry". The mathematics will center on middle school but look at implications of a transformational approach to geometry at both the high school and elementary levels. (Received September 21, 2011)

1077-97-1959 **Erica Dakin Voolich*** (voolich@gmail.com), Somerville Mathematics Fund, 244 Summer St., Somerville, MA 02143. *Scrapheap Showdown and Pi Night: Two Ways to Reach out the the Local Community.*

The Somerville Mathematics Fund was founded in 2000 with the mission to encourage and celebrate mathematics achievement in Somerville MA, a multi-ethnic community near Boston. I will present two of the ways we reach out to students and the community. The Scrapheap Showdown is our annual high school challenge where the students arrive to see a pile of junk and are given a problem to solve in the next few hours. The Pi Night is a celebration which usually attracts up to 250-300 people to eat pizza and work on math activities. Photographs and articles are available on

http://somervillemathematics.blogspot.com/ and
http://www.somervillemathematicsfund.org/ (Received September 21, 2011)

1077-97-2056 **Daniel T Kaplan*** (kaplan@macalester.edu), Mathematics, Statistics, and Computer Science, Macalester College, 1600 Grand Avenue, Saint Paul, MN 55105. *Being CRAFTY in the Transition to College Mathematics.*

Over the last century, the college mathematics curriculum diffused into high schools. In 1900, it was common to teach what's now Algebra/Trig in the first years of college, with calculus a college-senior level course. Today, strong students routinely see calculus in 12th grade and often never take a college mathematics course. Weak students — or those from weak schools — are relegated to repeating algebra in college, aiming for a hypothetical calculus course that they are unlikely ever to take.

I'll argue that we will improve students' exposure to college mathematics — and coincidentally improve enrollments in college-level courses — by shifting the focus of "college mathematics." The blueprint has been provided by the MAA CRAFTY reports developed over the past decade in consultation between mathematicians and partner disciplines. These reports are remarkably consistent across disciplines: a call for more modeling, multi-variate topics, more statistics, and more computing. I'll show how college mathematics can be taught in a CRAFTY way, and how this can open the door for students, even those with limited algebra skills to learn important mathematics that, traditionally, was seen by very few students: the same topics called for by the CRAFTY reports. (Received September 21, 2011)

1077-97-2080 **Paul E Seeburger*** (pseeburger@monroecc.edu), 1000 E. Henrietta Rd., Rochester, NY 14623. *Playing with Multivariable Calculus Concepts Wearing 3D Glasses.* Preliminary report.

A tour of an NSF-funded project that seeks to develop geometric intuition in students of multivariable calculus. This online exploration environment allows students (and instructors) to create and freely rotate graphs of functions of two variables, contour plots, vectors, space curves generated by vector-valued functions, regions of integration, vector fields, parametric surfaces, implicit surfaces, etc. 3D glasses can be used for a real 3D perspective! Come get a pair and try it out! A series of assessment/exploration activities has also been created to help students "play" with the 3D concepts themselves, and to assess improvements in geometric understanding gained from these activities. Topics of these explorations include Dot Products, Cross Products, Velocity and Acceleration Vectors, and Lagrange Multiplier Optimization, and more are being developed. Preliminary results of the first four years of these assessments will be shared. The grant project is titled, Dynamic Visualization Tools for Multivariable Calculus (NSF-DUE- CCLI #0736968). See http://web.monroecc.edu/calcNSF/. (Received September 21, 2011)

1077-97-2151 **W James Lewis*** (jlewis@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68502. *A statewide partnership to support professional development for mathematics teachers.* Preliminary report.

The NSF Math Science Partnership, NebraskaMATH is building a statewide partnership to meet the professional needs of mathematics teachers in Nebraska, while the NSF grant NebraskaNOYCE is focused on working with high need school districts. We will discuss how these programs and other resources are enabling University of Nebraska-Lincoln faculty to provide opportunities for Nebraska's K-12 mathematics teachers to learn to teach the mathematical practice standards envisioned by the Common Core State Standards in Mathematics (Received September 21, 2011)

1077-97-2251 **Manmohan Kaur*** (mkaur@ben.edu), Department of Math and CS, 5700 College Road, Lisle, IL 60532. *Research Experiences in Quantum Information Systems.* Preliminary report.

Quantum Information Systems is a topic of immense interest not only because of its theoretical beauty but also due to its ground breaking potential to help make quantum computers a reality. Quantum computers can have a wide range of repurcussions influencing every aspect of modern life - from internet banking, to secure phone calls, to other privacy issues that we currently take so much for granted. Mathematically, a quantum channel is a completely positive trace preserving map on finite-dimensional space. In the language of quantum information theory, a channel describes the transfer of quantum information, or qubits, from 'Alice' to 'Bob'. The topic has intimate connections with non-commutative functional analysis, in particular, operator space theory. It especially lends itself to undergraduate research because some calculations can be performed by students without graduate level of mathematical sophistication. The topic is interdisciplinary, at the intersection of operator space theory, quantum information theory and cryptology. In this talk we will give a brief overview of this subject and explain how we have used it to motivate students to further study mathematics and to convince them of all the wonderful ways in which mathematics continues to change our world. (Received September 21, 2011)

1077-97-2342 **Matthew Thomas*** (mthomas@math.arizona.edu), Department of Mathematics, University of Arizona, **Guadalupe Lozano** (guada@math.arizona.edu), Department of Mathematics, University of Arizona, **Cody Patterson** (cpatterson@math.arizona.edu), Department of Mathematics, University of Arizona, and **Jennifer Eli**, Department of Mathematics, University of Arizona. *Developing a Protocol for Analyzing the Quality of Classroom Interactions in an Undergraduate Calculus Course.* Preliminary report.

Research in mathematics education indicates that students in interactively engaged classrooms are more successful on tests of basic conceptual knowledge. Despite this, undergraduate mathematics courses are largely dominated by lectures in which students take a passive role. To better understand the phenomenon of interactively engaged classrooms at the undergraduate level, 15 one-hour-long videos of first-semester calculus classrooms were recorded and coded using a modified version of a quality of mathematics instruction protocol. In this session, we will discuss the development of this protocol, wherein lessons were broken down into interaction episodes, with each episode quantified by aspects of the interaction such as who initiated the episode and the number of words spoken by students and the instructor. Preliminary findings will be discussed. Results of these analyses will be used to measure types and quality of classroom interactions in an undergraduate calculus course and explore possible correlations between teaching practices and development of student understanding of calculus concepts. (Received September 22, 2011)

1077-97-2493 **Cathy Kessel*** (cbkessel@earthlink.net), **Bonnie Saunders**, **Maura Mast** and **Tanya Leise**. *Discussion: Participation of Girls and Women in Mathematics.* Preliminary report.

Each talk in the session will describe different aspects of participation of girls and women in mathematics, in elementary school, middle school, undergraduate majors, and professional honors and awards. Some aspects are examined via statistical studies. Others occur on a much smaller scale, in the context of programs and projects. At the end of the session, the speakers and the audience will have an opportunity to discuss what can be synthesized from these different findings and viewpoints. (Received September 22, 2011)

1077-97-2506 **Bruce Carpenter*** (carpent@illinois.edu), 273 Altgeld Hall, 1409 W. Green St, Urbana, IL 61801, and **Debra Woods** (dwoods2@illinois.edu), 273 Altgeld Hall, 1409 W. Green St., Urbana, IL 61801. *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 a Maker Cube, the system combines Constructionist learning ideas and Formative assessment to bring about a radically different approach to math education. (Received September 22, 2011)

1077-97-2656 **Shubhangi Sadanand Stalder*** (shubhangi.stalder@uwc.edu), 1500 N. University Drive, Waukesha, WI 53188, and **Paul Arthur Martin** (paul.martin@uwc.edu), 518 South 7th Avenue, Wausau, WI 54401. *Two for One: Combining Developmental and Intermediate Algebra into a Four-Credit Course Using Youtube and ALEKS.* Preliminary report.

In addition to the time and financial cost for some college students who have to take both developmental math (Mat 091) and intermediate algebra (Mat 105), failure rates in these courses are typically high. To try to improve these issues, we combined these two courses into a three- or four-credit pilot version of a combined course. We covered four modules:vocabulary, arithmetic, equations, and graphing and applications. Students had to watch lectures on Youtube prior to class time and attempt to answer "video log questions." Class time was used for additional practice, discussions, oral exams, and group work. We used the ALEKS software for some in-class work and for testing. Our pilot students showed no significant differences with non-pilot students (from four semesters) using several pre-measures and in percent of non-grades (audits, incompletes,withdrawals). Among the 48 pilot students who completed at least Mat 091, 12 completed both Mat 091 and Mat 105 (all from the four-credit version).Mat-091 grades were significantly higher among pilot than non-pilot students. Additional analyses showed that pilot Mat-091 grades exceeded non-pilot with ALEKS which exceeded non-pilot without ALEKS. (Received September 22, 2011)

1077-97-2781 **Osvaldo Daniel Soto*** (osoto85@hotmail.com), 3763 33rd St., San Diego, CA 92104. *Teacher Change in the Context of a Proof-Centered Professional Development.*

As proving is a central activity in the study of mathematics, a teacher's own proof schemes (in the sense of Harel and Sowder, 1998) enable and constrain her instructional approaches. Though it is acknowledged that teachers' knowledge of mathematics is a cornerstone on which their instructional practices are based (e.g., Ball and Bass, 2003), little research exists documenting professional developers' attempts to influence teachers' proof schemes and the results of these attempts. This case study examines the development of one teacher's proof schemes in the context of an NSF funded proof-centered professional development (PD). Specifically, the study asked, what changes were observed in one participant's proving and proof schemes as she participated in the PD? While the study focuses on the developments of one participant's proof schemes, it also describes the rich learning environment in which the development occurred. It was found that during the two intensive summers of PD, that the participant showed evidence of a transition from empirical to deductive proof schemes. (Received September 22, 2011)

1077-97-2797 **Robert E. Wieman*** (rwieman@vsu.edu), P.O. Box 9068, 1 Hayden Drive, Virginia State University, VA 23806. *Assessment of Enhanced College Algebra at Virginia State University in its Second Year.* Preliminary report.

Virginia State University has implemented a dramatic enhancement of its College Algebra Course. This enhancement is embodied in two primary changes to the curriculum: weekly group activities, with emphasis on skills used in the students' major, and rigorous assessment and improvement of core pre-algebra and algebra skills using the ALEKS Web-based learning system. These additions to the course have entailed increasing the credit hours from 3 to 4 and introducing a weekly 2-hour "lab" session in which the group activities are conducted.

In this presentation, we elaborate on the purpose and implementation of these enhancements, and assess their impact on student performance in the class thus far. We conclude with an analysis of the challenges we have experienced and consideration of possible refinements. (Received September 22, 2011)

1077-97-2827 **Ryota Matsuura*** (matsuura@stolaf.edu), 1520 St. Olaf Avenue, Northfield, MN 55057, **Sarah Sword** (ssword@edc.org), 55 Chapel St., Newton, MA 02458, **Mary Beth Piecham** (mpiecham@edc.org), 55 Chapel St., Newton, MA 02458, **Glenn Stevens** (ghs@math.bu.edu), 111 Cummington St., Boston, MA 02215, and **Al Cuoco** (acuoco@edc.org), 55 Chapel St., Newton, MA 02458. *Assessing Mathematical Habits of Mind for Teaching.*

Focus on Mathematics (FoM) is a targeted Math and Science Partnership funded by the National Science Foundation since 2003. As part of the work of FoM, we are developing a long-term research program with the ultimate goal of understanding the connections between secondary teachers' mathematical knowledge for teaching and secondary students' mathematical understanding and achievement.

Our hypothesis is that teachers who not only possess strong content knowledge but also the mathematical habits of mind (MHoM) used by many mathematicians teach in a way that results in increased student learning and achievement. Recognizing the need for evidence-based research to refine and test this conjecture, we are engaged in a focused study centered on the following question: What are the mathematical habits of mind that high school teachers use in their professional lives and how can we measure them?

In this initial phase of research, we are engaged in ongoing work to identify and precisely define MHoM, and to operationalize this framework into paper and pencil assessment problems that accurately and uniquely measure mathematical habits of mind for teaching. In this session, we will focus on the development of the assessment, sharing examples of problems and data from the field tests. (Received September 22, 2011)

1077-97-2875 **Carlos W Castillo-Garsow**, **Carlos Castillo-Chavez*** (ccchavez@asu.edu) and **Sherry Woodley**. *The Mathematical and Theoretical Biology Institute Community Learning Model.*

MTBI has mentored a large number of US students from underrepresented groups since 1996. This community (over 400) has seen about 13 of its alumni earn PhDs each year (mostly in math biology or related fields) with 8 PhDs awarded to individuals from underrepresented US minority groups, since 2005. Three institutions, Cornell, Iowa and Arizona State, have granted about 70 percent of them. However, the MTBI program was designed for education in research, not for research in education, and the mechanisms of success have therefore never been adequately studied. We describe our efforts to study MTBI from an educational theory perspective through our initial preliminary analysis of the MTBI community model from the perspective of four researchers: Piaget, Vygotsky, Bandura, and the MTBI students themselves. (Received September 22, 2011)

1077-97-2889 **George W. Hart*** (hart@momath.org), http://momath.org, New York, NY. *Exhibit Designs for the Museum of Mathematics.*

The Museum of Mathematics will open in Manhattan in Fall, 2012. We have rented a 20,000 square foot space in midtown Manhattan and are currently designing hands-on exhibits to engage people of all ages. Our goal is to present the richness of mathematics to the public, emphasizing fun, creative, and surprising activities which make clear that math encompasses far more than what most people see in school curricula. This talk will be a very visual survey of the exhibits currently planned along with a status report on the site and our expected opening. For more information, see http://momath.org (Received September 22, 2011)

1077-97-2913 **James R. Valles, Jr.*** (jvalles@smwc.edu), 1 Saint Mary-of-the-Woods College, St Mary-of-the-Woods, IN 47876, and **Rebecca Ortiz** and **Xiaobo She**. *Understanding Representations and Manipulatives through the Eyes of Preservice Teachers.* Preliminary report.

One teaching method that can be used to encourage students to learn in a math course is by integrating written assignments as reflection tools into the student assessments. By having students reflect on classroom lessons and topics covered, one can gauge various student factors, such as self-efficacy and the student's perceived relevance of the topic, as related to their expected learning outcomes.

At Texas Tech University, MATH 3370 (Elementary Geometry) is a mathematics course intended to prepare students to be middle school mathematics teachers and elementary school teachers by providing a basic background in geometry. This talk will focus on the use of written assignments given to different MATH 3370 sections that focus on the students' abilities to integrate representations and manipulatives into their mathematical content knowledge. Since the NCTM defines a representation as the capturing of a mathematical concept in some form and also as the form itself, there will be discussion regarding preservice teachers' perceptions of concepts as well as associated representations. (Received September 22, 2011)

1077-97-2939 **William G McCallum*** (wmc@math.arizona.edu) and **Guadalupe Lozano-Teran** (guada@math.arizona.edu). *Listening to Students About the Transition from High School to College.* Preliminary report.

Students going from high school to college often encounter a cliff rather than a ramp. A natural tendency among faculty from both high school and college is to want to shift the blame to the other side. In this talk we will present video clips from a project at the University of Arizona interviewing students about their own experiences in making this transition, with valuable lessons for both groups. (Received September 23, 2011)

1077-97-2943 **Jay P Belanger*** (belanger@truman.edu). *Self paced mathematics in college and high school.*

Truman State University has recently turned all of its College Algebra and Trigonometry sections into self-paced classes. This allows students with varying backgrounds to spend less time on the sections they are familiar with and more time on the material they have difficulty with. The self-paced nature of the class is achieved with the assistance of computer software. Since the software also provides testing, this system also adds uniformity to the class. Because of this, Truman State can offer college credit to high school students where the high school students must meet the exact same standards for passing the class as the college students. (Received September 23, 2011)

1077-97-2944 **Philip M. Sadler*** (psadler@cfa.harvard.edu), Director, Science Education Department, Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, MS-71, D-315, Cambridge, MA 02138. *Factors Influencing Success in College Calculus.* Preliminary report.

This retrospective cohort study studies 10,492 college calculus students' backgrounds in 352 instructors' classrooms at 135 randomly selected 2- and 4-year colleges and universities. Performance in college calculus is especially influential in career decisions as poor performance can prematurely end the pursuit of potential science, technology, engineering, computer science, and health careers. We identify predictors of performance while controlling for demographic differences to reveal the relationship between the decisions made by high school mathematics teachers and later success in introductory college calculus. This study reveals the most common student pathways to college calculus and gauges the specific impact of variety of potentially important factors in later success, including: taking calculus in high school, taking math for all four years of high school, teaching practices of mathematics teachers, and the role of technology. (Received September 23, 2011)

Table of Contents for MAA Abstracts of Invited Addresses, SIGMAA Guest Lecturers, Presentations by Teaching Award Winners, and Session Papers

The presenter of each talk is indicated by an asterisk (*) in the abstract.

MAA ABSTRACTS

MAA Invited Addresses, SIGMAA Guest Lectures, and Presentations by Teaching Award Winners

1077-A0-3 **Carolyn Gordon***, Dartmouth College, Hanover, NH. *The sound of geometry.*

We will explore the relationship between spectral data and the geometry of an object in various interrelated settings: combinatorial graphs with their adjacency spectra; strings and drumheads (i.e. real intervals, planar domains or, more generally, Riemannian manifolds) with their frequency spectra; and metric graphs, which combine the features of strings and combinatorial graphs. Most of the talk will be accessible to advanced undergraduate students. (Received March 09, 2011)

1077-A0-4 **Jennifer Quinn***, University of Washington, Tacoma, Tacoma, WA. *Mathematics to DIE for: The battle between counting and matching.*

Positive sums count. Alternating sums match. So which is "easier" to consider mathematically? From the analysis of infinite series, we know that if a positive sum converges, then its alternating sum must also converge but the converse is not true. From linear algebra, we know that the permanent of an n x n matrix is usually hard to calculate, whereas its alternating sum, the determinant, can be computed efficiently and it has many nice theoretical properties.

In this talk, you will judge a combinatorial competition between competing techniques of counting versus matching. Be prepared to explore a variety of positive and alternating sums involving binomial coefficients, Fibonacci numbers, and other beautiful combinatorial quantities. How are the terms in each sum concretely interpreted? What is being counted? What is being matched? Do alternating sums always give simpler results? Which is the most elegant? The outcome is not predetermined. You decide! (Received March 09, 2011)

1077-A0-5 **Seth M. Sullivant***, North Carolina State University, Raleigh, NC. *Phylogenetic algebraic geometry.*

The main problem in phylogenetics is to reconstruct evolutionary relationships between collections of species, typically represented by a phylogenetic tree. In the statistical approach to phylogenetics, a probabilistic model of mutation is used to reconstruct the tree that best explains the data (the data consisting of DNA sequences from homologous genes of the extant species).

In algebraic statistics, we interpret these statistical models of evolution as geometric objects in a high-dimensional probability simplex. This connection arises because the functions that parametrize these models are polynomials, and hence we can consider statistical models as algebraic varieties.

The goal of the talk is to introduce this connection and explain how the algebraic perspective leads to new theoretical advances in phylogenetics, and also provides new research directions in algebraic geometry. The talk material will be kept at an introductory level, with background on phylogenetics and algebraic geometry. (Received March 09, 2011)

1077-A0-6 **Rekha R Thomas*** (`rrthomas@uw.edu`). *Sum of squares polynomials in optimization.*

Polynomials that are nonnegative over the reals have been studied by mathematicians for over a century and were the topic of Hilbert's 17th problem. The classical technique for certifying the nonnegativity of a polynomial is to express it as a sum of squares of polynomials when possible. This can be cast as a "semidefinite program", a modern tool in optimization that generalizes linear programming. These connections have allowed sums of squares polynomials to play an important role in optimization with fascinating geometry and many open questions. In this talk I will explain some of the main uses of nonnegative and sums of squares polynomials in optimization and how different types of mathematics and computational challenges naturally intertwine to produce results here. In the four accompanying talks in this session you will see some of the myriad dimensions of this fascinating interdisciplinary subject in both theory and applications. (Received September 14, 2011)

1077-A0-7 **Mary Lou Zeeman***, Bowdoin College, Brunswick, ME. *Mathematical challenges in climate and sustainability.*

How are climate and sustainability applications shaping mathematics questions? What makes these research challenges different from other applications? How do we prepare students to work in these areas? In this talk and the associated MAA Invited Paper Session we will discuss these questions, describing some of the pressing research questions, and some of the interdisciplinary curriculum innovations they have inspired. (Received March 09, 2011)

1077-A0-26 **Sommer Gentry***, U. S. Naval Academy, Annapolis, MD. *Rational rationing in healthcare: Observations for organ allocation.*

The notion of rationing healthcare is taboo: people quite naturally feel no one should limit the resources spent extending a human life, particularly theirs or their loved ones'. Transplantation can transform the lives of organ recipients, but must be rationed by access to the far-too-small supply of donated organs, so it is a microcosm of the ethical dilemmas and accumulated inefficiencies and difficult tradeoffs in allocating healthcare. Mathematics and operations research can increase the supply of live donor kidneys, maximize the number of life years gained from transplantation, or redistrict the geographic boundaries to make organ allocation more fair. I will share my experiences from the transplant community. (Received June 12, 2011)

1077-A0-38 **Steve Abbott***, Middlebury College, Department of Mathematics, Middlebury, VT. *Turning theorems into plays.*

The critical success of Tom Stoppard's *Arcadia* in the early 1990s fundamentally altered the perception that mathematics represented an off-putting and off-limits part of the intellectual spectrum for artists interested in writing for a popular audience. Since *Arcadia*, we have witnessed the emergence of a host of successful plays that deal with mathematics and mathematicians in thoughtful and creative ways. Some of the most well-known examples include *Proof*, by David Auburn, winner of the Pulitzer Prize in 2000, and *Copenhagen*, by Michael Frayn, which won the 2001 Tony Award for best play. Beyond these highly celebrated scripts, one can find a rich array of plays that are perhaps even more authentically mathematical. Set at a (mostly) fictional mathematics conference on the bitter English coastline in the winter of 1911, *The Five Hysterical Girls Theorem*, by Rinne Groff is a dark comedy about love, genius, aging and priority. In (Received June 29, 2011)

1077-A0-44 **Barry Mazur*** (barry.mazur@gmail.com). *Why is it plausible?* Preliminary report.

We have handy ways of discovering what stands a chance of being true. Any such way that is systematic, and that has been successful so far, goes under the catch-phrase *heuristic method*. They abound, these methods—explicitly formulated, or not. They lead us, perhaps, to a mere hint of a possibility that a mathematical statement might be plausible. At that point we might go about garnering other shades of plausibility arguments (as Polya wrote inspiringly about) and evidence of different colors, such as: analogies with things that are indeed true, computations, special case justifications, etc. Perhaps our thinking will reach the stage of some title of commitment such as **conjecture**. The end-game here is proof, of course. I want to focus on the beginning game, though, and spend the hour thinking of the nature of our current heuristic methods, and their fine structure. (Received September 17, 2011)

1077-A0-46 **Edward Goldstein***, Department of Epidemiology, Harvard School of Public Health, Boston, MA. *Epidemiology of influenza strains: Competition, prediction, and associated mortality.*

We use the US CDC regional outpatient surveillance data on influenza-like-illness (ILI) and virologic surveillance data to define a weekly incidence proxy for each of the three major influenza strains: A/H3N2, A/H1N1 and influenza B. We show that the cumulative seasonal incidence of each strain is affected by the early circulation of the other two strains and devise a prediction algorithm for the cumulative incidence of each strain in an evolving influenza season, calibrating its parameters against historical data. We relate the above incidence proxies to the weekly mortality data for various causes and in the process estimate the corresponding annual baselines for non-influenza associated mortality. (Received July 7, 2011)

1077-A0-49 **Frank Wattenberg***, U. S. Military Academy, Department of Mathematics, West Point, NY. *Examples of how mobile/Web technologies can impact how, when, where, what, and why students learn.*

This interactive talk will include both big ideas and examples. The Web and mobile devices can deliver interactive content using cell-assisted GPS, accelerometers, gyroscopes, compasses, and cameras. This content can be used in both formal and informal education and break down the barriers between classroom and field. For example,

Tree rings play an important role in our understanding of the Earth's past climate. Students near a tree could access core samples from that tree and compare them with its environment – for example, stressed trees show greater variability – and with meteorological and historical records and samples from other trees. They could apply statistical techniques to isolate the various signals and study the Mann Hockey Stick controversy.

Many students have difficulty understanding three dimensions. For two dimensions students specify the window into a graph by giving x- and y-ranges. For 3D they need to specify the location of a camera, aim, and focal length. Students could be given a series of photographs of well-known objects from unusual perspectives. Their job would be to reproduce the photographs using mobile device equipped with a digital camera and the score would depend on both accuracy and speed to reward 3D understanding. (Received July 7, 2011)

1077-A0-1847 **Susan Loepp***, Bronfman Science Center, Williams College, Williamstown, MA 01267. *Teaching, Mentoring, and Advising Undergraduate Research: Lessons Learned On the Streets.*

Graduate students in mathematics are, of course, trained to do research in math. In their graduate school education, teaching, mentoring, and advising undergraduate research are not often emphasized. Yet many of us find ourselves in positions where we are expected to spend an enormous amount of time and energy on these activities. Without any formal training, how do we learn effective techniques for teaching, mentoring, and advising? In this talk, I will discuss my personal struggle with these issues, and lessons I have learned along the way. (Received September 21, 2011)

1077-A0-2560 **William Dunham*** (wdunham@muhlenberg.edu). *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 many 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 1990 Barney Oliver, a former recipient of the National Medal of Science, shared with me an elegant trigonometric argument where the symmetry of the formula was mirrored by the symmetry of the proof itself.

The first two of these, Heron's and Newton's, I'll mention only briefly. The second pair, Euler's and Barney's, I'll prove in detail. Taken together, these should remind us why the history of our discipline is such a fine source for wonderful mathematics. (Received September 22, 2011)

1077-A0-2744 **Cindy Wyels***, One University Dr., Mathematics Program, CSU Channel Islands, Camarillo, CA 93012. *Unexpected Adventures and Undergraduate Research.*

The debate over whether undergraduates are able to engage in meaningful mathematical research appears to be resolved, at least among members of the MAA. Yet the issue of which students are ready to succeed at and benefit from undergraduate research is less well understood. This talk will outline arguments for providing undergraduate research opportunities to students who are likely to be overlooked when seeking suitable research-ready students and provide stories of unexpected adventures experienced by some of these students and their faculty guides. (Received September 22, 2011)

1077-A0-2872 **Matthew E DeLong*** (mtdelong@taylor.edu). *Learning to teach and teaching to learn.* Preliminary report.

Learning to teach is a lifelong process. The subtleties of human learning make teaching a difficult art to master. Moreover, ongoing changes in knowledge, culture and technology, and the uniqueness of each student, mean that even a master teacher's development is never complete. Thus the developing teacher, whether novice or experienced, not only teaches for learning but also teaches to learn, about the subject, the students, the self and the way that good teaching can lead to meaningful and lasting learning. This best occurs in a collaborative community committed to their own, and to each other's, growth. In such a community, experienced teachers have important and unique contributions to make to the development of new teachers, and new teachers have reciprocal contributions to make to the growth of their more veteran colleagues. In this talk, I will reflect upon the trajectory of my not-yet-finished development as a teacher, and in particular the ways in which collaborative communities have both aided my development, and also given me the opportunity to invest in the development of others. I hope to encourage us all, not only to continue to learn to teach, but also to work for academic cultures conducive to collaborative growth. (Received September 22, 2011)

Algebraic Statistics

1077-AA-34 **Bernd Sturmfels*** (bernd@math.berkeley.edu), Department of Mathematics, University of California, Berkeley, CA 94720, and **Poitr Zwiernik**. *Binary Cumulant Varieties.*

Algebraic statistics for binary random variables is concerned with highly structured algebraic varieties in the space of 2x2x...x2 tensors. We demonstrate the advantages of representing such varieties in the coordinate system of binary cumulants. Our primary focus lies on hidden subset models. Parametrizations and implicit equations in cumulants are derived for hyperdeterminants, for secant and tangential varieties of Segre varieties, and for certain context-specific independence models. (Received June 21, 2011)

1077-AA-291 **Elizabeth S. Allman*** (e.allman@alaska.edu), **James H. Degnan** and **John A. Rhodes**. *Species trees from gene trees.*

A fundamental problem in evolutionary biology is to determine relationships between species. Are humans most closely related to chimpanzees or to gorillas? To answer such questions, some genetic data like DNA sequences might be collected and aligned, and then a Maximum Likelihood or Bayesian analysis undertaken to give the tree or distributions on trees best depicting the evolutionary relationships for these data.

If, however, the DNA sequences are from genes, then this paradigm constructs a *gene tree*, and it is well known that a gene tree may disagree with the true species tree. Kingman introduced the *coalescent model* to probabilistically model the phenomenon of gene lineages coalescing within a species tree.

In this talk, we consider the information content of gene tree distributions, and how we can summarize gene tree distributions while still retaining enough information to identify the underlying species tree. More formally, we discuss the identifiability of the species tree parameter under the coalescent model.

This talk will be non-technical and accessible. (Received August 18, 2011)

1077-AA-1821 **Luis David Garcia-Puente*** (lgarcia@shsu.edu), Department of Mathematics and Statistics, Sam Houston State University, Huntsville, TX 77341-2206. *What is an algebraic statistical model?*

Algebra has seen many applications in statistics, but it is only rather recently that algebraic geometry has been used to study statistical models and inference problems. This connection is based on the fact that most statistical models are defined either parametrically or implicitly via polynomial equations. The idea is summarized by the phrase "Statistical models are semialgebraic sets". In this introductory talk, I will present the basics of algebraic geometry and statistics needed to understand this phrase. I will further illustrate this point with several examples of classical statistical families and their corresponding algebraic descriptions. (Received September 21, 2011)

1077-AA-2366 **Jason Morton*** (morton@math.psu.edu), Department of Mathematics, McAllister Building, The Pennsylvania State University, University Park, PA 16802. *Graphical models and monoidal categories.* Preliminary report.

Probabilistic undirected factor graph models generalize graphical models by replacing the clique complex associated to a graph with an arbitrary simplicial complex. The algebraic version focuses on the Zariski closure of the space of probability distributions modeled. Monoidal categories are a categorical formalism with associated graphical languages which are useful in representation theory, quantum information and foundations, and topological quantum field theory. I will describe work in progress on how the notion of discrete undirected and directed probabilistic (and algebraic) factor graph models can be understood in terms of a coherent graphical language for a certain type of monoidal category with additional structure. (Received September 22, 2011)

1077-AA-2393 **Dustin Cartwright***, Department of Mathematics, Yale University, PO Box 208283, New Haven, CT 06520-8283. *Hypothesis testing on tensors.* Preliminary report.

In statistics, hypothesis testing seeks to determine whether or not given data is likely to have been produced by a given model. One way to describe the way that data can result from a model is through the algebraic process of implicitization. In general, implicitization produces polynomial equations vanishing on an algebraic variety, such as the Zariski closure of the set of set of probabilities for a model. I will talk about some ways by which implicit equations can be used for statistical hypothesis testing on matrices and tensors, starting from a re-interpretation of the chi-square test and working up to higher order tensors. (Received September 22, 2011)

1077-AA-2461 **Alexander Engström*** (alexander.engstrom@aalto.fi). *Betti numbers of ideals from graphs.*

Many important ideals in algebraic statistics are defined from graphs. I will discuss how the betti numbers and other algebraic invariants can be derived from topological properties of graphs. (Received September 22, 2011)

Applications of Dynamical Systems

1077-AB-103 **Robert L. Devaney*** (bob@bu.edu), Mathematics Department, Boston University, 111 Cummington Street, Boston, MA 02215. *Chaos, Complex Dynamics, and Undergraduate Research Projects.*

Complex dynamics offers wonderful opportunities for undergrads to get actively involved in interesting research projects. After all, we researchers in this field are still trying to understand the simple quadratic function $z^2 + c$ which, when iterated, yields incredibly beautiful yet still not understood objects like the Mandelbrot and Julia sets. So how about other complex functions? In this talk I will describe briefly some of the results that undergrad students and I have come up with in a series of seven papers over the past six years, all involving the rational maps $z^2 + c + \lambda/z^2$. We shall see that adding the pole at 0 to the quadratic family changes the Julia sets dramatically but often yields structures that are understandable. This is joint work with my former students Yakov Shapiro, Mark Morabito, and Robert Kozma. (Received July 27, 2011)

1077-AB-557 **Martin Golubitsky*** (mg@mbi.osu.edu), Mathematical Biosciences Institute, 1735 Neil Avenue, Columbus, OH 43210. *Patterns of Oscillation in Network Systems.*

Networks of differential equations can be described abstractly by a directed graph whose nodes correspond to systems of differential equations and arrows correspond to coupling between the systems. Suppose that $x(t)$ is a T-periodic solution and $x_i(t)$ and $x_j(t)$ are the coordinates of $x(t)$ corresponding to nodes i and j. The two nodes are *phase-related* if there exists θ such that $x_j(t) = x_i(t + \theta T)$. The phase relation θ is *rigid* if it remains unchanged on perturbation of the coupled system. In this talk we discuss joint work with D. Romano and Y. Wang that shows how rigid phase-shifts are related to network architecture (the graph) and network symmetries. (Received September 07, 2011)

1077-AB-1019 **Richard McGehee*** (mcgehee@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *A Dynamical Systems Approach to Paleoclimate Models.* Preliminary report.

Simple mathematical models have been used to explore the Earth's past climates. Some of these models can be examined from the viewpoint of dynamical systems, perhaps leading to new ways to think about the Earth's climate system. (Received September 15, 2011)

1077-AB-1739 **Bjorn Sandstede***, Division of Applied Mathematics, Brown University, 182 George Street, Providence, RI 02906. *Snakes and ladders.*

I will discuss localized stationary 1D and 2D structures such as hexagon patches, localized radial target patterns, and localized 1D rolls. These solutions have observed in semiconductor lasers, vegetation patches, buckling patterns of cylindrical shells, binary fluids, and chemical reactions. They can exhibit snaking: in parameter space, the localized states lie on a vertical sine-shaped bifurcation curve so that the width of the underlying periodic pattern, such as hexagons or rolls, increases as we move up along the bifurcation curve. I will give an overview of recent analytical and numerical work in which this phenomenon is investigated. (Received September 20, 2011)

1077-AB-2388 **Christopher K R T Jones*** (ckrtj@email.unc.edu), Department of Mathematics, UNC-CH, Chapel Hill, NC 27516-3250. *Lagrangian Dynamics and the incorporation of data into ocean models.*

Over the past decade or so, there have been considerable advances in understanding ocean flows through the structure of their fluid particle (or Lagrangian) dynamics. The question discussed here is how this might change the way data are collected and how such data are incorporated into the ocean models. (Received September 22, 2011)

The Beauty and Power of Number Theory

1077-AC-52 **Ken Ono*** (ono@mathcs.emory.edu), Dept. of Math and Computer Sci., 400 Dowman Drive, Emory University, Atlanta, GA 30322. *The beauty and power of some recent REU papers in number theory.*

Much of the beauty in number theory arises from the fact that the problems are often quite simple to state. Power is often required to solve such problems. The speaker will describe recent results by his REU students on partitions and algebraic number fields. The results are simple to state, but their proofs required some power. (Received July 11, 2011)

1077-AC-176 **Joseph H. Silverman***, Mathematics Department - Box 1917, Brown University, Providence, RI 02912. *Number Theory and Dynamical Systems.* Preliminary report.

A discrete dynamical system consists of a set S and a self-map $\phi : S \to S$, and one is then interested in classifying the points of S according to their behavior under iteration of the map ϕ. This subject has a long and storied history when S is an analytic space, for example $\mathbb{R}$, $\mathbb{C}$, or $\mathbb{CP}^1$, and there are many deep and beautiful results of a geometric and analytic nature. During the past 25+ years people have developed an arithmetic theory of discrete dynamics, in which S is an arithmetic set such as $\mathbb{Z}$, $\mathbb{Q}$, or $\mathbb{P}^1(\mathbb{Q})$, and the map ϕ is a polynomial or rational function. In this setting one studies arithmetic properties of orbits under iteration of ϕ. In this talk I will give a survey of this new field of arithmetic dynamics, including some of its history, some known results, and some of the conjectures that motivate current research. (Received August 07, 2011)

1077-AC-857 **Frank H Thorne*** (thorne@math.sc.edu). $1 + 2 + 3 + 4 + \cdots$.

In a 1913 letter to Hardy, Srinivasa Ramanujan wrote that $1 + 2 + 3 + 4 + \cdots = -\frac{1}{12}$.

It is, and long has been, rather common for mathematicians of Hardy's stature to receive unsolicited manuscripts making similarly ridiculous claims. Typically these are consigned to the rubbish in short order. However, Hardy did not throw away Ramanujan's letter. Indeed, he later asked for Ramanujan to visit him in England.

In this talk, we will ask why Ramanujan's letter did not meet its expected fate. Indeed, we will ask the absurd question: *Is there some chance that Ramanujan was right?* (Received September 13, 2011)

1077-AC-1670 **Amanda Folsom*** (amanda.folsom@yale.edu), Yale University, Mathematics Department, P.O. Box 208283, New Haven, CT 06520-8283. *Patterns in partitions.*

There are patterns in numbers all around us, but how could something as basic as "1+1=2" have fascinated mathematicians for centuries? In this talk, we will discuss curiosities, both new and old, surrounding "integer partitions," which, given a positive integer n, are the non-increasing sequences of positive integers which sum to n. (For example, $4 = 3 + 1 = 2 + 2 = 2 + 1 + 1 = 1 + 1 + 1 + 1$, so there are 5 partitions of 4.) Despite the fact that partitions are so simple to define, they have led to many fundamental, difficult, surprising, and unsolved problems in mathematics. We will discuss both celebrated past work on partitions due to Euler, Ramanujan, Hardy, Rademacher, Watson, and Atkin to name a few, and also more recent joint work with Kent and Ono, and of Bruinier-Ono. (Received September 20, 2011)

Clever Counting or Beautiful Ejection?

1077-AD-238 **David M. Bressoud*** (bressoud@macalester.edu). *The Benefits of Bijections.* Preliminary report.

This talk will survey bijective proofs of determinant identities, especially the Weyl denominator formulas as well as the Dyson conjecture and its q-analog that was conjectured by George Andrews and proven by Doron Zeilberger and this author. (Received August 16, 2011)

1077-AD-286 **Arthur T. Benjamin*** (benjamin@hmc.edu), Math Department, Harvey Mudd College, 301 Platt Blvd, Claremont, CA 91711. *Counting on Students: Combinatorial Proofs with Undergraduates.*

Some of my favorite combinatorial proofs have been discovered with undergraduates. We'll present clever counting arguments and beautiful bijections involving Fibonacci numbers, squares, cubes, binomial coefficients, and Ramsey numbers. Sum-thing fun for everyone! (Received August 18, 2011)

1077-AD-345 **James G. Propp*** (propp@jamespropp.org). *A not-quite-bijective enumeration of domino tilings of Aztec diamonds.*

Back in the 1980s, Noam Elkies, Greg Kuperberg, Michael Larsen, and I proved that the number of domino tilings of an Aztec diamond of order n is $2^{n(n+1)/2}$. One of our proofs used a procedure we called domino shuffling. Although domino shuffling can be turned into a bijection between the set of domino tilings of the Aztec diamond of order n and the set of bit-strings of length $n(n+1)/2$, it is most naturally viewed not as a one-to-one function but as a many-to-many relation, where each set of size k in one set corresponds to a set of size k in the other set. (Received August 24, 2011)

1077-AD-1478 **Bridget Eileen Tenner*** (bridget@math.depaul.edu), Department of Mathematical Sciences, DePaul University, Chicago, IL 60614. *Descriptive derangements for a sum of spheres.*

A bijective correspondence can reveal a wealth of information about a set, beyond just its cardinality. In addition to explaining why the set has a particular size, it often illuminates many other aspects of the set itself. As an example, we examine a bijection between derangements of a set and spheres in the wedge sum describing the homotopy type of a complex, obtained by Ragnarsson and Tenner. (Received September 19, 2011)

1077-AD-1760 **Lara K. Pudwell*** (Lara.Pudwell@valpo.edu), Department of Mathematics & Computer Science, 1900 Chapel Drive, Valparaiso, IN 46383. *Beautiful Bijections for Permutation Patterns.*

In this talk, we will explore several examples of beautiful bijections involving permutation patterns. Along the way, we will see that clever counting can be classy, but bijections have the benefit of giving additional structural information about enumeration problems. We will also see examples when beautiful bijections show two sets of permutations are equinumerous even when a clever counting argument is nowhere to be found. (Received September 20, 2011)

1077-AD-2139 **Georgia Benkart*** (benkart@math.wisc.edu), Department of Mathematics, University of Wisconsin-Madison, 480 Lincoln Dr., Madison, WI 53706. *Beautiful Bijections and Clever Counting in Representations.*

Representations of groups and algebras have a rich combinatorics that often is revealed by counting arguments and bijections. This talk will illustrate this by presenting some examples. (Received September 21, 2011)

1077-AD-2904 **Tom Roby*** (tom.roby@uconn.edu). *A Beautiful Bijection that Counts and Does More: The Robinson-Schensted-Knuth Correspondence.*

One of the most beautiful bijections in combinatorics was first carefully formulated by C. Schensted to cleverly count n-permutations whose longest increasing subsequences were of a given length. But this algorithm, now known as the RSK-correspondence, turns out to have lovely and surprising symmetries as well as deep connections to the representation theory of symmetric groups and Lie algebras. In this talk we will discuss from scratch how the algorithm works, note some of its properties, and indicate the larger context in which it (and its many variants) fall. We will assume no background knowledge on the part of the audience, and undergraduates should be able to follow most of it. (Received September 22, 2011)

Climate Change and Sustainability

1077-AE-703 **Gidon Eshel*** (geshel@gmail.com), geshel@gmail.com, and **Andrew Ma** (geshel@bard.edu) and **Olivia Romeo** (geshel@bard.edu). *Short Term (Non-Asymptotic) Linear Stability of Ecosystems: The Role of Non-Self-Adjointness in Homogeneous and Heterogeneous Agricultural Systems.*

We demonstrate motivating undergraduate research of advanced linear algebra using 3 species Lotka-Volterra systems, on a single node and a spatially distributed mesh, as the choice toy problems.

We investigate short term linear stability of asymptotically stable systems under stochastic forcing, emphasizing propensity for variance growth due to constructive interactions of modes, and contrasting homogeneous systems (monocultures) from heterogeneous ones (where the same area is divided into numerous "crops" differing in their LV coefficients).

We show that while potentially instantaneously higher yielding, monocultures exhibit higher variance than heterogeneous systems under unit stochastic perturbation, which at times include collapse. By contrast, only degenerate heterogeneous systems occasionally collapse.

We show that the choice between monocultures and heterogeneous land uses is essentially a gamble that an excitation of a singular mode directly toward ruin will not be realized. If such a perturbation is realized, heterogeneous land use is the better choice, If it is not, monocultures may prove a more prudent choice.

The work thus demonstrates a viable, tractable path for reasonably well-trained undergraduates toward research of advances topics in leaner algebra. (Received September 22, 2011)

1077-AE-1777 **John Marshall*** (johncmarshall54@gmail.com), EAPS, MIT, Blg 54, Rm 1526, Cambridge, MA 02138. *Teaching with 'Weather in a Tank'.*

According to the American Meteorological Society (AMS), roughly 85 universities offer undergraduate degrees in meteorology and/or oceanography in the United States, and the undergraduate meteorology population is rapidly expanding. Laboratory fluid experiments, however, play a minor role in the education of these students. This is in the context of a field of research that is increasingly dominated by large coordinated programs to gather observations, present and manipulate those observations using Web resources, and attempt to simulate them on the computer. We argue here that an educational experience that focuses on fundamentals, and involves the study of idealized laboratory abstractions in the context of real-world data, would greatly aid our students' understanding and intuition about the dynamics of a fluid on a rotating, differentially heated sphere and how that dynamics helps to shape the climate of the Earth.

In this presentation I will report on the 'Weather in a Tank' project in which six universities collaborated to improve the teaching of atmosphere/ocean dynamics using rotating laboratory experiments and real-time data, in the process helping students move more adeptly between theory, models, and observations. (Received September 20, 2011)

1077-AE-1780 **Chris Danforth*** (chris.danforth@uvm.edu). *A Toy Climate Laboratory for Chaos and Differential Equations.*

This talk describes the use of a physical fluid dynamics experiment as the basis for undergraduate explorations of nonlinear dynamics, differential equations, data assimilation, predictability, and evolutionary algorithms. Measurements from a vertically oriented, hula-hoop shaped thermal convection loop are compared to forecasts made by (1) a low-dimensional Lorenz-like model derived from first principles, (2) the output of Eureqa, an algorithm designed to infer natural laws from free-form data by mimicking the principles of evolution, and (3) a hi-dimensional Computational Fluid Dynamics simulation. Special attention will be paid to the value of combining theoretical, numerical, and experimental investigations. (Received September 20, 2011)

1077-AE-1822 **Frank Wattenberg*** (Frank.Wattenberg@usma.edu), United States Military Academy, Department of Mathematical Sciences, West Point, NY 10996. *Mathematical Modeling and Public Policy Decisions Aimed at Mitigating Climate Change.*

Understanding the ramifications of the public policy decisions we are currently making either by default or by action requires a deep understanding of climate and energy science and of economics. Because of the complexity of the issues involved mathematics and, most importantly mathematical modeling, play a central role. This talk looks at how we can simultaneously develop better decision-makers and help our students master the skills, knowledge, and perspectives that mathematicians bring to bear on consequential public policy decisions aimed at mitigating climate change. We focus on several classroom-ready examples for the undergraduate mathematics curriculum. For example, we examine the implications of various courses of action related to gasoline taxes. Interestingly, the problems that naturally arise involve more theoretical as well as applied mathematics. The examples we discuss have been used at all levels from freshman to senior including math majors as well as other majors and pre-majors. (Received September 21, 2011)

1077-AE-1825 **John B Little*** (little@mathcs.holycross.edu), Department of Mathematics and Computer Scienc, College of the Holy Cross, Worcester, MA 01610. *Environmental Mathematics in a First Year Program.* Preliminary report.

I will report on a year-long Environmental Mathematics seminar that I am teaching in the Montserrat first year program at the College of the Holy Cross. The course focuses on elementary modeling topics in the first semester and data analysis in the second, with a strong environmental focus throughout. This course is part of a cluster of seven seminars with common themes, readings and activities. The students in these seminars live in one residence hall to facilitate discussions and co-curricular activities. (Received September 21, 2011)

1077-AE-1828 **Kerry A Emanuel***, Rm 54-1814, MIT, 77 Massachusetts Avenue, Cambridge, MA 023139. *A Model Hierarchy for Undergraduate Education in Radiative and Convective Heat Transfer.*

Much of today's undergraduate climate education relies on highly qualitative expositions of climate physics, in addition to discussions related to earth's climate history. Part of the problem is that a deep understanding of climate physics relies on knowledge of quantum physics, which many undergraduates lack, while at the same time, the equations governing radiative transfer do not usually admit simple solutions, and because radiative transfer is non-local, solutions are often non-intuitive. How do we bridge the yawning gap between hand-waiving descriptions on the one hand, and full-up radiative and convective transfer calculations on the other? In this talk, I will present a model hierarchical approach that begins with simple one- and two-layer models that admit analytic solutions and progresses upward through simplified multi-layer models that have limited parameter sets and, finally, highly detailed single-column models with accurate solutions of the equations of radiative and convective heat transfer. The virtues and possible drawbacks of this approach will be discussed. (Received September 21, 2011)

1077-AE-1867 **Rikki B. Wagstrom*** (rikki.wagstrom@metrostate.edu), College of Arts & Sciences, Metropolitan State University, 700 East Seventh Street, Saint Paul, MN 55106. *Exploring Sustainability in a Developmental-Level Mathematics Course.*

In 2008, Metropolitan State University in Minnesota began offering a college-algebra-prerequisite course integrating (environmental) sustainability issues. This presentation will discuss the challenges of developing and teaching this course, and how the course curriculum and pedagogies have evolved over the past three years to address many of these challenges. Particular issues discussed include the following: (1) presenting a coherent sustainability narrative through the use of quantitative reasoning and algebraic skills, (2) promoting mathematical competency in all required areas, and (3) making content personal for students. Input from anonymous student surveys will also be discussed in this presentation. (Received September 21, 2011)

1077-AE-2788 **Guadalupe I Lozano*** (guada@math.arizona.edu). *Sustainability in pre-calculus: leveraging biofuels data to write novel conceptual problems on function behavior and other concepts.*

One aspect of writing problems, or collections of problems, addressing the theme of sustainability in calculus courses, entails negotiating a balance between the data and the conceptual value of the problem(s) to be written, without compromising either one or the other. Say, for example, one sets out to mine biofuels data to illustrate exponential growth patterns in a pre-calculus course. Since examples of data exhibiting approximately exponential growth are rather sporadic and may actually not have predictive value (e.g. a nearly exponential growth in the number of alternative-fueled vehicles running on 85% Ethanol, E85, within the last decade) one is faced with the choice of writing problems that illustrate trends that depart from the existing data, or leveraging the actual growth patterns in the existing data in creative, yet conceptually valuable ways. In my talk I will show examples of how to do the latter, namely I will illustrate how one might leverage existing data on biofuels production/consumption to write conceptual problems that illuminate particular aspects of function behavior, including exponential growth patterns. (Received September 23, 2011)

Contemporary Unsolved Problems

1077-AF-1011 **C Eugene Wayne*** (cew@bu.edu), Department of Mathematics & Statistics, Boston University, 111 Cummington St., Boston, MA 02461. *Partial Differential Equations: The Navier Stokes Equation.*

The Navier-Stokes equations describe fluid motions in a wide range of physical circumstances and hence have applications in systems ranging from the oceans to the atmosphere. In spite of their importance, basic questions about the existence of smooth solutions of these equations in three-dimensional domains still exist. In this talk I will describe the physical origin of these questions and explain why the answers to them are so different in two and three dimensions, as well as why two-dimensional fluid mechanics is of interest in a three-dimensional world. (Received September 15, 2011)

1077-AF-1281 **Michael Sipser*** (sipser@mit.edu), 77 Massachusetts Ave, Room 2-365, Cambridge, MA 02138. *Beyond Computation: The P versus NP question.*

In a remarkable 1956 letter, the great logician Kurt Godel asked the famous mathematician and computer pioneer John von Neumann whether certain computational problems could be solved without resorting to brute force search. In so doing, he foreshadowed the P versus NP problem, one of the great unanswered questions of contemporary mathematics and theoretical computer science. A solution to this problem would reveal the theoretical limitations of computer power for solving puzzles, cracking codes, proving theorems, and optimizing many practical tasks. We'll discuss all this and more... (Received September 18, 2011)

1077-AF-1795 **Joel Hass*** (hass@math.ucdavis.edu), 1 Shields Ave., University of California, Davis, CA 95616. *The Smooth Four Dimensional Poincare Conjecture.*

A homotopy sphere is a manifold with the same homotopy groups as a sphere. The n-dimensional Poincare Conjecture states that an n-dimensional homotopy sphere is homeomorphic to the n-sphere. In the topological category, with the homeomorphisms only required to be continuous, the conjecture is now known to hold in all dimensions.

The smooth Poincare conjecture asks whether a smooth n-dimensional homotopy sphere is smoothly homeomorphic to the n-sphere. The answer in this case is known in all dimensions except four. It is still not known whether a smooth 4-manifold that is homotopy equivalent to a sphere is diffeomorphic to the 4-sphere.

This talk will given an overview of this conjecture, explain why techniques that work in other dimensions fail in dimension four, and discuss some possible approaches. (Received September 21, 2011)

1077-AF-2094 **William Arthur Stein*** (wstein@gmail.com), Seattle, WA 98122. *The Birch and Swinnerton-Dyer Conjecture.*

I will give an introduction to the Birch and Swinnerton-Dyer Conjecture, which is considered by many to be one of the most central open problems in number theory. The conjecture, which was discovered based on extensive numerical computations in the 1960s, asserts that the rank of a certain finitely generated abelian group equals the order of vanishing of a certain complex analytic function at the point 1. I will use Sage to illustrate and motivate the conjecture with examples, then survey the current status of results toward the conjecture. (Received September 21, 2011)

Knot Theory Untangled

1077-AG-776 **Colin C Adams*** (cadams@williams.edu), Bronfman Science Center, Williams College, Williamstown, MA 01267. *Hyperbolic knots.*

A knot is hyperbolic if its complement can be given a metric with constant curvature -1. Thurston demonstrated that many knots are hyperbolic and the hyperbolic structure can be used to distinguish knots and to better understand the relationships between them. In this talk, we will discuss the various invariants that come out of the hyperbolic structure and what is known about them and what isn't known about them. We will also discuss directions that might be fruitful for further research. (Received September 12, 2011)

1077-AG-963 **Erica Flapan*** (eflapan@pomona.edu), Department of Mathematics, Pomona College, Claremont, CA 91711. *Intrinsic properties of graphs embedded in* $\mathbb{R}^3$.

Knot theory is the study of the topology of embeddings of simple closed curves in $\mathbb{R}^3$. A natural extension of knot theory is the study of the topology of embeddings of graphs in $\mathbb{R}^3$. However, in contrast with knots, the structure of a graph can be complex, and this can affect all of its embeddings. If every embedding of a graph has a particular property, then we say that property is *intrinsic* to the graph. For example, a graph is said to be *intrinsically knotted* if every embedding of the graph in $\mathbb{R}^3$ contains a knot. In this talk we will discuss intrinsic knotting and other intrinsic properties of graphs. (Received September 14, 2011)

1077-AG-1741 **Francis Bonahon*** (fbonahon@math.usc.edu), Department of Mathematics, University of Southern California, Los Angeles, CA 90089-2532. *Knot theory: past, present, future.*

As a branch of mathematics, knot theory began in the 1880s. We will present a very brief history of the subject. Compressing 130 years of mathematics into a 25 minute talk of course precludes any attempt at exhaustive coverage. We will distinguish several eras in the development of the field by focusing on ideas, concepts and techniques. (Received September 20, 2011)

1077-AG-1900 **Jason Cantarella***, UGA Math Department, Boyd GSRC, Athens, GA 30602. *The Geometry of Knots.*

This talk will be an overview of some natural questions about the geometry of knots. For instance, how much rope does it take to tie a knot? If you build a knot out of sticks, how many sticks are required? Some of these questions require some fairly high technology, but many of the questions are approachable for students. One of the main purposes of the talk will be to outline a number of the presenter's favorite interesting open problems which are suitable for student (and faculty) research projects. (Received September 21, 2011)

1077-AG-1971 **Jim Hoste*** (jhoste@pitzer.edu), Pitzer College, 1050 N Mills Ave, Claremont, CA 91711. *Twisted Alexander Polynomials.* Preliminary report.

One of the oldest problems in knot theory is: Given knots K and J, how can we determine if they are the same or different? In 1928 James Alexander introduced a polynomial invariant of knots now known as the Alexander polynomial. If two knots have different Alexander polynomials, then this proves that they are different knots. In more recent years the Alexander polynomial has been extended to the "twisted" Alexander polynomial. In this talk will discuss both of these invariants and explain how to compute them for an infinite class of knots known as 2-bridge knots. Even for this relatively simple family of knots, many interesting questions and conjectures remain open. (Received September 21, 2011)

1077-AG-2085 **Tim D Cochran*** (cochran@rice.edu), MS-136 Math. department, PO Box 1892, Houston, TX 77251-1892. *4-dimensional aspects of knot theory.*

Knots are circles embedded in three-dimensional Euclidean space. A knot is considered to be "unknotted" if it is the boundary of a two-disk embedded in three-dimensional space.

We discuss four-dimensional aspects of knot theory. For example when is a knot the intersection between a knotted two-sphere in 4-dimensional space and a hyperplane? What knots are the boundary of an embedded two disk in $\mathbb{R}^3 \times [0, \infty)$? Why would one ask such questions? What invariants can help us? (Received September 21, 2011)

Semidefinite Optimization and Nonnegative Polynomials

1077-AH-900 **Steven J. Gortler*** (sjg@cs.harvard.edu), 33 oxford st., cambridge, MA 02138. *Graphs, Distances, and Semidefinite Programming.*

In this talk I will discuss the difficult problem of determining the position of a set of points in space (up to an unknowable Euclidean transform) given the pair-wise distances between some of the pairs of points. This problem arises in sensor network localization and molecular shape determination. (It is also related to the problem of reconstructing a low rank matrix given a subset of its entries.) The most powerful algorithms for this problem are based on semidefinite programming. The main tool we will focus on is something called an equilibrium stress matrix. It turns out that this matrix can tell us when the problem is well posed (has a unique solution), and also when we can expect semi-definite programming techniques to succeed for such a problem.

This talk will cover joint work with Alex Healy, Dylan Thurston and Yuanchen Zhu. (Received September 14, 2011)

1077-AH-2831 **Russ Tedrake*** (russt@mit.edu), 32 Vassar St., MIT 32-380, Cambridge, MA 02139. *Sum of Squares Optimization applied to Walking Robots and Robotic Birds.*

In this talk, I will present an algorithm which combines randomized motion planning algorithms, popular in robotics, with nonlinear region of attraction (ROA) estimation using sums of squares. I'll describe the application of these ideas to bipedal locomotion, quadrupedal locomotion over rough terrain, and small unmanned airplanes that dart through forests and land on a perch. These application domains have motivated a number extensions to the basic ROA analysis, include computations of finite-time invariance around trajectories, regions of attraction to limit cycles, and extensions to hybrid systems and stochastic systems. (Received September 22, 2011)

1077-AH-2925 **Amir Ali Ahmadi*** (a_a_a@mit.edu), 195 Binney st., Apt. #4401, Cambridge, MA 02142. *Computational and Algebraic Aspects of Convexity.*

The role of convexity in modern day mathematical programming has proven to be remarkably fundamental, to the point that tractability of an optimization problem is nowadays frequently assessed by whether the problem benefits from some sort of underlying convexity. A very basic question therefore is to understand if we are even able to decide in an efficient manner whether a given optimization problem is convex. By using tools from computational complexity theory, I will show that the answer to this question is unfortunately negative even when attention is restricted to polynomial optimization problems of moderate degree.

On the other hand, I will show that algebraic techniques based on the concept of sum of squares (sos) decomposition of polynomials provide efficient algorithms for deciding convexity of a large class of polynomials that we care about in applications. I will define a related notion known as sos-convexity and study its relationship to convexity. This is very much parallel to Hilbert's study of the relationship between sum of squares and nonnegativity. I will reveal some remarkable and unexpected connections to Hilbert's result. A deeper understanding of these connections is currently missing and requires a new set of ideas. (Received September 23, 2011)

1077-AH-2956 **Grigoriy Blekherman*** (greg@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Nonnegative Polynomials and Sums of Squares.*

I will review the history and motivation behind the problem of representing nonnegative polynomials as sums of squares. Such representations are of interest for both theoretical and practical computational reasons. However, some basic and explicit questions about nonnegative polynomials and sums of squares remains open. Our journey will begin with Hilbert's theorem, which shows that nonnegative polynomials that are not sums of squares exist, and end with recent results on the nature of the relationship between nonnegative polynomials and sums of squares. On the way we will see a fascinating blend of ideas from convex and algebraic geometry that are used to attack these questions. (Received September 23, 2011)

Spectral Problems in Geometry

1077-AI-862 **Christopher M Judge*** (cjudge@indiana.edu), IU Mathematics Dept, Rawles Hall, BLOOMINGTON, IN 47405, and **Luc Hillairet** (Luc.Hillairet@univ-nantes.fr), Laboratoire de mathématiques, 2 rue de la Houssinière BP, 92208 4432 Nantes Cedex 3, Pays de L., France. *The music of triangles.*

Though, triangles are among the simplest geometric shapes, we know little about their vibrational frequencies. In this talk I will discuss the spectra of special triangles that tile the plane and ask what happens for a random triangle? For example, can frequencies overlap for the random triangle? Joint work with Luc Hillairet shows that no overlapping occurs. (Received September 13, 2011)

1077-AI-988 **Gregory Berkolaiko** and **Peter Kuchment*** (kuchment@math.tamu.edu), Mathematics Department, Texas A&M University, College Station, TX 77843-3368, and **Uzy Smilansky**. *A nodal domain count mystery.*

In this talk we address the nodal count (i.e., the number of sub-domains where the function preserves its sign) for eigenfunctions of Laplace or Schroedinger operators with Dirichlet boundary conditions in bounded domains (billiards). The classical Sturm theorem claims that in dimension one, the nodal and eigenfunction counts coincide: the n-th eigenfunction has exactly n nodal domains. The Courant Nodal Theorem claims that in any dimension, the number of nodal domains of the n-th eigenfunction cannot exceed n. However, it is known that in dimensions higher than 1 the equality may hold for only finitely many eigenfunctions. Thus, in most cases a "nodal deficiency" arises. Moreover, examples are known of eigenfunctions with an arbitrarily large index n that have just two nodal domains. One can say there is essentially no understanding of the nodal deficiency.

We show that, under some conditions, the nodal deficiencies coincide with the Morse indices of critical points of some functional. (Received September 15, 2011)

1077-AI-1435 **Sajjad Lakzian** (SLakzian@gc.cuny.edu) and **Christina Sormani*** (sormanic@member.ams.org). *Distances between Riemannian Manifolds.*

Given two Riemannian manifolds, one may measure the distance between them using the Lipschitz, Gromov-Hausdorff and Intrinsic Flat distances. We will present new approaches to estimating these distances given information on subdomains in the manifolds. Then we will apply these results to understand the Gromov-Hausdorff and Intrinsic Flat limits of sequences of Riemannian manifolds which converge smoothly away from singular sets. (Received September 19, 2011)

1077-AI-1911 **Pierre Albin***, palbin@illinois.edu. *Isospectral noncompact surfaces.* Preliminary report.

I will discuss work in progress with Clara Aldana and Frederic Rochon concerning isospectral noncompact surfaces (Received September 21, 2011)

1077-AI-2161 **Emily B Dryden*** (emily.dryden@bucknell.edu), Department of Mathematics, Bucknell University, Lewisburg, PA 17837, and **Victor Guillemin** and **Rosa Sena-Dias**. *Building Polygons from Spectral Data.*

Given certain geometric data, how many convex polygons can you build with that data? We consider this question when the data includes the number of edges, the set of normal vectors to the edges, and the sums of the lengths of the edges with a given normal vector. By making a few assumptions, we show that the answer can be made much smaller than one might initially guess. We'll mention applications of this result to the problem of whether symplectic toric manifolds and orbifolds are determined by data arising from the spectrum of the Laplace operator. (Received September 21, 2011)

1077-AI-2471 **Peter Buser*** (peter.buser@epfl.ch), Section de Mathematiques, SB-MATHGEOM, Station 8, Lausanne, Switzerland, and **Hugo Parlier** (hugo.parlier@gmail.com), Departement de Mathematique, University of Fribourg, CH-1700 Fribourg, Switzerland. *On the distribution of simple geodesics.*

In joint work various estimates for the distribution of the simple geodesics (infinite complete and/or closed) on a compact hyperbolic surface have been obtained recently. The lecture outlines some of the techniques and discusses how the distribution may be represented graphically. (Received September 22, 2011)

SIGMAA on the Philosophy of Mathematics

1077-AJ-59 **Stephen Yablo*** (yablo@mit.edu), Linguistics & Philosophy, 32-D808, MIT, 77 Massachusetts Ave, Cambridge, MA 02139. *Explanation and Existence.* Preliminary report.
Platonists hold that mathematical objects "really exist." Nominalists deny this. The standard argument for platonism, which emphasizes the indispensability of mathematics to physical science, has fallen on hard times lately. Why should calculus have to be true, to help with the representation of facts about the motion of bodies? Platonists have responded that math also plays an *explanatory* role - e.g. honeycomb has a hexagonal structure because that is the most efficient way to divide a surface into regions of equal area. Two questions, then. Can physical outcomes occur for mathematical reasons? If so, how does this bear on debates about the existence of mathematical objects? (Received July 13, 2011)

1077-AJ-71 **Arthur M Jaffe*** (Arthur_Jaffe@harvard.edu), Department of Mathematics, Science Center, 1 Oxford Street, Cambridge, MA 02138. *Is Mathematics the Language of Physics?*
We explore whether modern mathematics is an adequate tool to describe the natural science of our world. In other words, to what extent is "mathematics is the language of physics." (Received July 18, 2011)

1077-AJ-83 **Agustin Rayo*** (arayo@mit.edu), MIT Dept. of Linguistics and Philosophy, 77 Massachusetts Ave 32-d932, Cambridge, MA 02139. *A Trivialist Account of Mathematics.*
I sketch an account of mathematics according to which the truths of mathematics are not unlike the truths of logic. I argue that just like nothing is required of the world to satisfy the demands of a truth of logic, nothing is required of the world to satisfy the demands of a truth of pure mathematics. (Received July 21, 2011)

1077-AJ-1045 **Juliet Floyd*** (jfloyd@bu.edu). *Turing and Wittgenstein.* Preliminary report.
On 30 July 1947 Wittgenstein penned a series of remarks that have become well-known to those interested in his writings on mathematics. It begins with the remark "Turings 'machines': these machines are humans who calculate. And one might express what he says also in the form of games". Though most of the extant literature interprets the remark as a criticism of Turing's philosophy of mind (that is, a criticism of forms of computationalist or functionalist behaviorism, reductionism and/or mechanism often associated with Turing), its content applies directly to the foundations of mathematics. For immediately after mentioning Turing, Wittgenstein frames what he calls a "variant" of Cantor's diagonal proof. We present and assess Wittgenstein's variant, contending that it forms a distinctive form of proof, and an elaboration rather than a rejection of Turing or Cantor. (Received September 15, 2011)

1077-AJ-1755 **Charles Parsons*** (parsons2@fas.harvard.edu), Department of Philosophy, Emerson Hall, Harvard University, Cambridge, MA 02138. *Structuralism and its discontents.*
By "structuralism" I mean primarily the structuralist view of mathematical objects, different versions of which have been developed and defended by several philosophers, although the underlying ideas come from much older views at least implicit in the writings of Dedekind, Hilbert, Bernays, and probably others. My own version tries to stay closer to the usual language of mathematics than some others, so that although the basic mathematical objects are "only structurally determined," no new ontology is needed to develop this idea. (For details see *Mathematical Thought and its Objects* (Cambridge 2008), chs. 2-4.)

Structuralist views have been subjected to various objections. To the extent that time permits, I will try to canvass some of them and suggest replies. (Received September 22, 2011)

1077-AJ-1994 **Jody Azzouni*** (Jody.Azzouni@tufts.edu). *The relationship of derivations in artificial languages to ordinary rigorous mathematical proof.* Preliminary report.
The relationship between formal derivations, which occur in artificial languages and mathematical proof, which occurs in natural languages is explored. The suggestion that ordinary mathematical proofs are abbreviations or sketches of formal derivations is rejected. The alternative suggestion that the existence of appropriate derivations in formal logical languages is a norm for ordinary rigorous mathematical proof is explored and qualified. (Received September 21, 2011)

Arts and Mathematics, Together Again

1077-B1-92 **Jeffrey W Clark*** (clarkj@elon.edu). *Using Escher's Work to Demonstrate Symmetries of the Plane.*

The works of Maurits Cornelis Escher are much beloved among mathematicians for his use of symmetry and geometry. This talk will discuss uses of Escher's work to demonstrate symmetries of the plane for a range of courses from Analytic Geometry through Abstract Algebra. (Received July 25, 2011)

1077-B1-207 **Ricardo V Teixeira*** (teixeirar@uhv.edu), University of Houston - Victoria, 3007 N. Ben Wilson, Victoria, TX 77904. *Fourier Transform helps relaxation.*

The effects of gong sounds vary from person to person and are therefore used in sound therapy. I will explain, with examples, how the sound of gongs, using different mallets, can help people with various diseases and anxieties.

This research is not mine, however I have made a big study on the various results and theories behind this amazing topic, and I would like to share them (Received August 11, 2011)

1077-B1-219 **Michael Olinick** (molinick@middlebury.edu), Department of Mathematics, Warner Hall, Middlebury College, Middlebury, VT 05753, and **Robert P. Martin*** (martin@middlebury.edu), Department of Computer Science, Middlebury College, Middlebury, VT 05753. *Artists Respond to the Enigma of Alan Turing.*

British mathematician Alan Turing broke the Nazis' prized Enigma cipher, created the foundations of modern computer science, and pioneered the fields of artificial intelligence ("Can Machines Think?") and neural networks. Turing was arrested for homosexuality and forced to undergo hormone treatments perhaps leading to his apparent suicide by cyanide poisoning at age 41. In recent years, many artists have responded to Turing's brilliant achievements and tragic death in disparate media: drama, novel, short story, film, painting, sculpture, statuary, music, and opera. We will explore some of the artistic responses to the life and works of this remarkable individual as the centennial year of his birth begins. (Received August 14, 2011)

1077-B1-229 **Andrea N Young*** (younga@ripon.edu). *Improv Techniques for the Mathematics Classroom.* Preliminary report.

Although the goals of improvisational comedy and mathematics education may seem diametrically opposed–one is to entertain and the other is to instruct–in fact, the ideas of the former can help to achieve the latter. In this presentation, I will demonstrate how some of the most fundamental tenets of improv can be used to create an open and engaging mathematics classroom. Specific examples of improv exercises that have been successful in the classroom will be given. (Received August 15, 2011)

1077-B1-290 **Andrzej K Brodzik*** (abrodzik@mitre.org), 202 Burlington Road, Bedford, MA 01730. *Between pattern and chance.*

Identification or design of "interesting" patterns is at the center stage of many mathematical and artistic investigations. Yet it is often not the pattern itself but the process of pattern generation that is of most interest. In 1913 Marcel Duchamp introduced the three standard stoppages which he subsequently used, by dropping them from a height of one meter in a random manner on a canvas, to create a painting. Since then the insertion of chance into the creative process in general and into pattern creation in particular became widely accepted. In this talk we consider the intimate relationship between pattern and chance in the mathematical and concrete arts. In particular, we examine the intertwining of pattern and chance in popular in many branches of science and engineering algebraic constructions known as ideal sequences and in their extensions, ideal quilts. (Received August 18, 2011)

1077-B1-355 **Anne M. Burns*** (aburns@liu.edu), Department of Mathematics, Long Island University, Brookville, NY 11548. *Variation of Parameters.* Preliminary report.

Varying the parameters in a system of differential equations can produce some attractive animations. A system of differential equations involving two dependent variables, x(t) and y(t), can be viewed as a vector field in the xy-plane. For each t a vector in the plane is obtained. This vector has a length and a direction. Traditionally the vector field is plotted over a rectangular grid. In this presentation I will show how to choose certain paths along which to plot the vector field and how to assign colors as functions of length and/or direction. Some of the parameters that can be continuously changed are: the path along which the vector field is plotted, the constants in the equations x(t) and y(t) and the coefficients in the formulas for color and vector lengths. (Received August 25, 2011)

1077-B1-412 **Samer S Habre*** (shabre@lau.edu.lb), Department of Computer Science and Mathematic, P.O. Box 13-5053, Chouran, Beirut, 1102 2801, Lebanon. *Linear Iterative Systems and String Art.*

In this presentation the phase portraits for linear homogeneous iterative systems corresponding to the center axis of the Trace-Determinant plane is discussed in details. The investigation gives a sufficient condition for the solutions of such systems to form closed cycles. In other situations the cycles formed are infinite but the phase portraits exhibit some interesting behavior and are artistic in nature resembling a form of art called string art. This art is introduced and the similarity with the infinite cycles is exposed. (Received August 30, 2011)

1077-B1-430 **B Lynn Bodner*** (bodner@monmouth.edu), Mathematics Department, Monmouth University, Cedar Avenue, West Long Branch, NJ 07764. *Recreating a 14th Century 14-Pointed Star Polygon Design Found on the Mimbar of the Mausoleum of Barquq in Egypt.*

The most ubiquitous star polygons found in geometric Islamic art are those that may be created within regular n-gons that are constructible in the Euclidean sense, where n = 4, 5, 6, 8, 10, 12, or 16. That is, these polygons may be constructed using only a compass and straightedge. For n = 7, 9, 11, 13, 14, 18, the regular n-gons may only be constructed approximately using these tools. Of these, we will explore the conceptualization and creation of a 14-pointed star polygon design found on panel of the mimbar of the Mausoleum of Barquq in Cairo, Egypt, dating from 1386. It appears as EGY 1318 of the Pattern in Islamic Art: The Wade Photo Archive and as Plate 168 of Bourgoin's Arabic Geometrical Pattern and Design, a rich source of 190 Islamic patterns, first published in 1879 and based upon drawings of Islamic monuments in Cairo and Damascus. More specifically, our exploration seeks to answer the question, "How did the original designer of this pattern determine, without mensuration, the proportion and placement of the star polygons comprising the design?" We also propose a plausible Euclidean "point-joining" compass-and-straightedge reconstruction, using the Geometer's Sketchpad software program, the electronic equivalent of the compass and straightedge. (Received August 31, 2011)

1077-B1-451 **Reza Sarhangi*** (rsarhangi@towson.edu), Towson University, Department of Mathematics, 8000 York Road, Towson, MD 21252. *Polyhedral Modularity in a Special Class of Decagram Based Interlocking Star Polygons.* Preliminary report.

The main effort in this presentation is to study a series of Persian mosaic designs that have been illustrated in scrolls or decorated the surfaces of ancient structures. The common element for the course of study in these designs is a special ten pointed star polygon. This special concave polygon, which is called a decagram for convenience, is the dominant geometric shape of a series of polyhedral tessellations that all consist of the same common motifs. The decagram can be created through the rotation of two concentric congruent regular pentagons with a radial distance of 36° from each others' central angles. However, to create a decagram-based interlocking pattern, a craftsman-mathematician needs to take careful steps to locate a fundamental region. The rectangular-shaped fundamental regions, which are constructed using radial grids, have different proportions for their dimensions. This presentation includes a few patterns that are considered aperiodic (quasiperiodic) tillings, in the language of modern mathematics. (Received September 02, 2011)

1077-B1-559 **William Kronholm*** (wkronholm@whittier.edu), Whittier College, Department of Mathematics, Whittier, CA 90608, and **Aaron Bocanegra** (aaronbocanegra@gmail.com), SCI-Arc, 960 East 3rd Street, Los Angeles, CA 90013. *Math/Art: Collaborative Practices.*

The talk reports on the course "Math/Art: Collaborative Practices" created by the authors and offered at Whittier College in the Fall 2011 semester. The course was a research and design lab in which students worked in teams to explore what it means for artists and mathematicians to collaborate while working together to create and exhibit their own math/art projects. (Received September 07, 2011)

1077-B1-633 **Gwen Laura Fisher*** (gwen@beadinfinitum.com), CA , and **Blake Mellor** (bmellor@lmu.edu), CA. *Using tiling theory to generate weaving patterns with beads.*

Bead weavers create wearable fiber art by joining seed beads with needle and thread, including flat weaves that resemble woven fabric. Each bead in the weave is held in place by thread passing through its hole and the holes of neighboring beads. The resulting patches of fabric are commonly used to make jewelry, especially bracelets and necklaces. We show how tilings of the plane, especially periodic tilings, can be used as the basis for flat bead weaving patterns called angle weaves, including right angle weave, based upon the regular tiling by squares. We describe specific ways to create infinitely many intricate and beautiful beading patterns from periodic tilings, including edge-only angle weaves, edge-and-vertex angle weaves, vertex-only angle weaves, and across-edge angle weaves. We introduce the notion of star tilings and their associated weaves. We explain how some weaves can be generated in different ways. Lastly, we prove that there are infinitely many angle weaves, and we give necessary and sufficient conditions for when a particular tiling of the plane will induce an angle weave. (Received September 08, 2011)

1077-B1-698 **Christine von Renesse*** (cvonrenesse@westfield.ma.edu). *Exploring the Mathematics of Tuning a Musical Instrument using Straws.*

This talk will show connections between the tuning of musical instruments, its history, some "nice" fractions and ratios, (ir)rational numbers, and some exponents and roots. Straws (Pan flutes) are being used to explore how length corresponds to "nice sounding" intervals. The mathematics is appropriate for liberal art majors or future elementary school teachers but can be used for a lower level class for mathematics majors as well. The activity is part of a series of books "Discovering the Art of Mathematics" developed under a CCLI-NSF grant. See http://artofmathematics.westfield.ma.edu. (Received September 10, 2011)

1077-B1-702 **Susan McBurney*** (smcburney@prodigy.net). *The Projective Ornament of Claude Bragon.*

Many ancient systems of ornamentation have been admired, copied and adapted for contemporary use. Other designers however created original and unique systems with very successful results. One of these designers was Claude Bragdon who, in the early 19th century, pioneered a system that used projective geometry to represent four-dimensional solids to great effect in the two-dimensional plane. This presentation will examine some of the basics of his methods and serve to illustrate the rich visual vocabulary available to artists as well as mathematicians through such means. (Received September 10, 2011)

1077-B1-868 **Gary R Greenfield*** (ggreenfi@richmond.edu), Dept. of Math. and Comp. Sci., University of Richmond, Richmond, VA 23173. *Stigmmetry Prints.* Preliminary report.

Stigmergy is a form of self-organization that is brought about by indirect coordination of agents or actions. In 2011, P. Urbano proposed a model based on stigmergy for simulating the nest formation that occurs when ants of the species T. albipennis collect virtual grains of sand. By making different colonies of the species sensitive to different colors of virtual sand grains, Urbano produced what he called "sand paintings". We further exploit this technique by carefully assigning centers, radii, and colors to colonies in such a way that the stigmergy model self-organizes a uniform density grid of virtual sand grains into sand paintings that exhibit various types of color preserving, and color reversing, symmetry. We call these compositions "stigmmetry prints". We present our methods and give examples. (Received September 13, 2011)

1077-B1-894 **Luke Wolcott*** (lwolcott@uw.edu). *Three stories from the math-art frontier.* Preliminary report.

I'll outline three recent math-art collaborations. Media involved: illustration and dance, electronic pop music, and ritual performance. Themes explored: my PhD research in stable homotopy theory, the research mathematics experience, and negative-dimensional space. (Received September 14, 2011)

1077-B1-1047 **Craig M. Johnson*** (johnsonc@marywood.edu), 2300 Adams Ave, Scranton, PA 18411. *Limits of Picture Sequences.*

The works of M.C. Escher are provocative and inspirational. His sequences of objects that gradually change shape provide fertile ground for mathematical thought. Several of his creations have prompted my re-discovery of three well-known geometrical formulae. (Received September 15, 2011)

1077-B1-1238 **Meg Dillon*** (mdillon@spsu.edu), Mathematics Department, 1100 S. Marietta Pkwy, Marietta, GA 30060. *Art First: How Artists Discovered the Projective Plane Before Mathematicians Knew It Was There.* Preliminary report.

The history of mathematics in the West features many stories in which mathematics was discovered by mathematicians and found later to be of use outside mathematics. The art world, though, discovered projective geometry before the mathematics community took up serious study and development of the subject. Italian artists started using and teaching perspective techniques for painting starting early in the 14th century. While Pappus's Theorem dates to the fourth century, and is often cited as the earliest theorem of projective geometry, it was not until the first half of the nineteenth century that projective geometry came into its own within mathematics. This talk will trace the curiously inverted relationship between artists and mathematicians in this story. (Received September 18, 2011)

1077-B1-1280 **David A Reimann***, Department of Mathematics, and Computer Science, Albion, MI. *Modular construction of knot and link patterns from simple tangles on k-uniform tessellations.*

Knots and links are a common theme in artworks that span cultures and time periods. While Celtic knots can be realized in a physical form, it is more common to see these knots as a surface decoration on of paper or stone. The construction of Celtic knots by the Bain method uses a tessellation by squares where arcs connect vertex points of the squares. A new method of creating more complex knots and links is presented which uses a modular approach that begins with a k-uniform tessellation. Each regular polygon is decorated with a simple tangle that that has arcs connecting uniformly spaced points on the sides of the polygons. A variety of complex knots and links can be created using this procedure. The use of a collection of tangles to comprise the knots and links allows one to use knot theory to analyze such knots and links. Examples of visually interesting knots and links created using this procedure are presented. (Received September 18, 2011)

1077-B1-1776 **Susan Goldstine*** (sgoldstine@smcm.edu) and **Ellie Baker**. *Building a Better Beaded Bracelet: Transformations, Tessellations, and Tori.*

Jewelry fashioned from bead crochet ropes has caught the imagination of crafters and trendsetters every few decades for the past century, and bead crochet bracelets are in the midst of a surge in popularity. A bracelet consists of a narrow tube of crocheted seed beads sewn together to form an uninterrupted hollow band. Creating symmetric color patterns on bead crochet bracelets is challenging because the beads form a continuous spiral along the length of the bracelet, making it difficult to align design motifs uniformly.

We have devised a new technique for translating bracelet patterns into plane tilings and used this to create bracelet designs substantially more intricate than those available in current pattern books. This talk centers around bracelets based on Escher-style tessellations of the plane and on wallpaper symmetry patterns, and it includes a classification of the wallpaper groups that can be adapted into bracelet form. (Received September 20, 2011)

1077-B1-1792 **Radmila Sazdanovic*** (radmilas@math.upenn.edu), Department of Mathematics, 209 South 33rd Street, David Rittehouse Lab, Philadelphia, PA 19104-6395. *Diagrammatics: Art, Language, and Mathematics.*

Image is written and the writing forms images- both have numerous layers of semantics and deliver different information depending on the viewers interests and background. The main topic of this talk is diagrammatics which arises naturally in the new area of mathematics called categorification (M. Khovanov, A. Lauda, B. Elias, R. Sazdanovic), and the pictorial language used to study problems such as quantum computing and teleportation (S. Abramsky, B. Coecke). In this context, diagrammatic approach provides a proper intuition and we will show examples of purely visual proofs, as well as the artists' take on it (Hiroko and Ritsuko Izuhara, Aftermoon studio). (Received September 21, 2011)

1077-B1-2296 **Mark Kozek*** (mkozek@whittier.edu), Mathematics Department, Whittier College, Whittier, CA 90608-0634. *Mathematics in Literature and Cinema.* Preliminary report.

In this preliminary report we reflect upon our interdisciplinary course *Numb3rs in Lett3rs & Fi1ms: Mathematics in Literature and Cinema*. Recently, writers and filmmakers from countries such as Argentina, Greece, Japan, Spain, Sweden, and the United States have relied upon mathematics to provide the framework for their creative pieces. Although these may vary in mathematical rigor and literary/cinematic quality, the writers and filmmakers deserve praise for highlighting the much neglected connection between mathematics and the creative arts - a link that is both rich and deep.

We explore this connection by studying pieces of fiction or cinema that possess literary merit in which the use of mathematics is sound. We aim for these mathematical concepts to fall outside of the topics traditionally seen in the high school or calculus curriculum, yet are still accessible to most undergraduate students. Similarly we hope to eschew the more obvious examples of mathematical literature and cinema found in popular culture in favor of broadening our students' cultural horizons. We note that by "literature" we mean all written genres and by "cinema" we include all dramatic media and genres (theatre, television, documentaries...). (Received September 22, 2011)

1077-B1-2365 **Benjamin Himpel*** (himpel@imf.au.dk), Centre for Quantum Geometry of Moduli Spaces, Department of Mathematical Sciences, Aarhus U, Ny Munkegade 118, bldg. 1530, Aarhus, 8000. *On the geometry of music.* Preliminary report.

We attempt to answer the question posted by Dmitri Tymoczko, how his geometry of chords relates to perceptual judgements of chord similarity. (Received September 22, 2011)

1077-B1-2486 **Debra L. Hydorn*** (dhydorn@umw.edu), University of Mary Washington, 1301 College Avenue, Fredericksburg, VA 22401. *Fostering Artistic Explorations with Geometer's Sketchpad.*

I have taught a first-year seminar on the mathematics of art and design for several years. For the first of two individual projects for the course students design and produce a tessellation. The second project is "student's choice." Due to the structured nature of the tessellations project, the resulting art is generally of fairly high quality, even though the work is done by hand and some students are less confident in their artistic abilities. Results for the student's choice project, however, have not been as creative, perhaps owing to the open nature of the assignment. After exploring different tools for creating computer-generated art, I decided to try a new project assignment for this course. For this project students use Geometers Sketchpad and, using the same operations they used to create their tessellation, produce geometric digital art. They are encouraged to find geometric patterns and designs that they can mimic using Sketchpad and then explore ways to transform the design. To aide them in learning to use Sketchpad, I have created several videos using Jing that demonstrate the basic functions of Sketchpad and its use to create designs and patterns. Example Jing videos and student projects will be shared in this presentation. (Received September 22, 2011)

1077-B1-2572 **Gareth E Roberts*** (groberts@radius.holycross.edu). *Composing with Mathematics: Final Projects in a Math and Music Course.*

As a major requirement for a math and music course I have taught several times, students are asked to complete a final project consisting of a musical composition and performance demonstrating some of the mathematical concepts discussed in the course. After studying examples of how composers utilize mathematical concepts in their work, (e.g., Bach, Hadyn, Bartók, Davies and Reich), students seek to integrate their own analytic and artistic skills by composing a piece of music featuring some mathematical connection. Many students find the assignment challenging yet gratifying and consider it their favorite aspect of the course. We'll discuss and listen to some recent examples, and explain how students with little or no musical background are prepared for such a difficult assignment. (Received September 22, 2011)

1077-B1-2731 **Joshua Brandon Holden*** (holden@rose-hulman.edu), CM #125, 5500 Wabash Ave., Terre Haute, IN 47803. *Braids, Cables, and Cells: An Interesting Intersection of Mathematics, Computer Science, and Art.* Preliminary report.

The mathematical study of braids combines aspects of topology and group theory to study mathematical representations of one-dimensional strands in three-dimensional space. These strands are also sometimes viewed as representing the movement through a time dimension of points in two-dimensional space. On the other hand, the study of cellular automata usually involves a one- or two-dimensional grid of cells which evolve through a time dimension according to specified rules. This time dimension is often represented as an extra spacial dimension. The ideas of representing both strands in space and cellular automata have also been explored in many artistic media, including drawing, sculpture, knitting, crochet, and weaving.

Previous work as been shown that rules for cellular automata can be written in order to produce depictions of braids. This talk will extend the previous system into a more flexible one which more realistically captures the behavior of strands in certain media, such as knitting. Some theorems about what can and cannot be represented with these cellular automata will be presented. (Received September 22, 2011)

1077-B1-2738 **Douglas Dunham*** (ddunham@d.umn.edu), Department of Computer Science, 320 HH, 1114 Kirby Drive, Duluth, MN 55812-3036. *A family of butterfly patterns.* Preliminary report.

M.C. Escher created a repeating Euclidean pattern of butterflies, his Regular Division Drawing number 70. This pattern has symmetry group 632 in orbifold notation (or $p6$ in crystallographic notation). The pattern has a 6-fold rotation axis at the meeting points of left front wings, and a 3-fold rotation axis at meeting points of right rear wings of the butterflies. This pattern also exhibits color symmetry, the color group being S_3, the symmetric group on three colors. We generalize Escher's butterfly pattern by considering the family of all such patterns with symmetry group $pq2$ in orbifold notation, where p and q are both greater than or equal to three. The patterns are spherical, Euclidean, or hyperbolic depending on whether $(p-2)(q-2)$ is less than, equal to, or greater than four, respectively. Thus, except for eight possibilities, the patterns are hyperbolic. Depending on p and q, the patterns exhibit different kinds of color symmetry. We will show a number of such patterns. (Received September 22, 2011)

1077-B1-2825 **Jennifer Wilson*** (wilsonj@newschool.edu). *Creative Variations.*

I present several projects from a recently offered sophomore level class titled Math and Images. Covering a range of topics from number theory to discrete math, the projects combine mathematical ideas with analyses of art works by Sol Lewitt, Arlene Stamp and others, and require the students to create their own works of art in response. I also discuss several mathematical problems motivated by the students' design processes that were subsequently explored in class. (Received September 22, 2011)

1077-B1-2937 **Margaret E Kepner*** (renpek1010@yahoo.com), 3716 Livingston Street NW, Washington, DC 20015. *A visual representation of the decomposition of the integers into prime factors.*

In the work Prime Goose Chase, a traditional quilt pattern is used as the organizing structure for a visual table of the prime factorization of the integers from 1 to 256. The step-by-step development of this piece is explored, with an emphasis on how key elements have been represented through the use of shape, color, lines, and other visual attributes. I explore the interaction of mathematical concepts and artistic considerations on the choices made during the design process. Various alternative presentations of the same subject matter are considered. (Received September 23, 2011)

1077-B1-2954 **Marcus Pendergrass*** (mpendergrass@hsc.edu), P.O. Box 174, Hampden-Sydney, VA 23901. *Semigroups, L-Systems, and Algorithmic Composition.* Preliminary report.

A class of deterministic algorithms for generating musical compositions is presented. These algorithms take their inspiration from *Lindenmayer systems*, a class of symbolic dynamical systems from mathematical biology. L-systems have been used for composition by modern classical composers such as Tom Johnson and Hanspeter Kyburz. Our approach adds an extra layer of structure utilizing semigroup theory. Basic properties of these systems are drawn out, and example compositions are presented. (Received September 23, 2011)

Capstone Course: Innovations and Implementations

1077-C1-27 **Kien H Lim*** (kienlim@utep.edu), Department of Mathematical Sciences, 500 W. University Avenue, El Paso, TX 79968-0514. *Using Error-Eliciting Problems via a Classroom Voting System in a Capstone Course to Foster Conceptual Understanding and Mathematical Habits of Mind.*

An error-eliciting problem refers to an assessment item that can potentially draw out errors caused by a misunderstanding/misapplication of a concept/procedure. Consider this problem: Which inequality is appropriate for finding of the values of k that will make $2x^2 + 5x - k$ always positive? Only 5 out of 29 prospective 4-8 math teachers correctly selected $25 + 8k < 0$, 10 selected $25 + 8k > 0$ and 11 selected $25 - 8k > 0$. Such an answer distribution is an impetus for prospective teachers to discuss among themselves which answer is correct and why. With proper orchestration, they can enhance their understanding of the discriminant and become aware of students' tendency to mistake positive discriminant for positive function. In addition to addressing common misconceptions, error-eliciting problems can be used to help prospective teachers to (a) become aware of their own impulsive disposition; (b) experience the need for mathematical habits of mind such as attending to meaning of symbols, sense making, considering falsity, and checking for correctness via a different approach; and (c) make connections among concepts, procedures, and representations. A classroom voting system can enhance the learning environment because students generally find the "game show" atmosphere exciting (Received June 12, 2011)

1077-C1-151 **Meredith L Greer*** (mgreer@bates.edu) and **Chip Ross** (sross@bates.edu). *Senior Seminar, Across a Department and Across the Years.* Preliminary report.

The Bates College Mathematics Department provides two capstone experiences, each with different goals. One is a senior thesis, in which a student works one-on-one with a faculty member. Since 1998 we have also offered a senior seminar, which highlights group work and innovative presentation, and which is the subject of our talk. Typically more than half our majors select the seminar as their capstone. We compare overall departmental goals for the seminar with specific implementations by faculty members. We discuss the variations that occur as topics, class sizes, and even students' tastes change. We suggest structures for ensuring high levels of individual engagement within a group-oriented framework. Seminar participants produce papers, presentations, and other documentation of their work; we present samples of these to demonstrate the degree of mathematical achievement and independence we expect our students to gain. We report results from two forms of assessment: an assessment of our capstone options led by outside facilitators in 2010, and a recent 20-year survey of Bates alums who had been math and natural science majors. Above all, we hope to convey why the seminar experience at Bates continues to be a rewarding and enjoyable way to complete a major in mathematics. (Received August 10, 2011)

1077-C1-181 **Pete Johnson*** (johnsonp@easternct.edu), Mathematics and Computer Science Department, Eastern Connecticut State University, 83 Windham St., Willimantic, CT 06226, and **Hari P. Koirala**. *Showcasing students' mathematical understanding through portfolios: A capstone course for mathematics majors on a secondary teaching track.*

At many colleges and universities, a significant number of the mathematics majors are also preservice secondary mathematics teachers. At Eastern Connecticut State University, we have developed a capstone course for mathematics majors who are also preservice teachers of secondary mathematics. This course attempts to provide an answer to a common student question: "What do my undergraduate math courses have to do with teaching high school students?" This course seeks to integrate and deepen students' knowledge of the undergraduate curriculum and to demonstrate connections between undergraduate and secondary mathematics. The major assignment in the course is a portfolio of students' work. Through a set of six entries from across the undergraduate curriculum, students demonstrate their understanding of mathematics and show how more advanced content is connected to teaching secondary mathematics. We have also developed and validated a portfolio scoring rubric to assess student mathematical understanding. The data from this assessment are collected every year and used as a major data sources for NCATE/NCTM accreditation of our education program. Our presentation will include samples of students' work and data from students' scores on these portfolios. (Received August 08, 2011)

1077-C1-213 **Greisy Winicki Landman*** (greisyw@csupomona.edu), Dept of Mathematics and Statistics - Cal Poly, 3801 W Temple Ave, Pomona, CA 91768. *Our capstone course - principles and tasks.* Preliminary report.

Our capstone course is a year-long experience developed by the math-educators at the department of mathematics. Its main purpose was to create a bridge between the content of the courses of the major in mathematics and the credential process required by the state of California. During this course the students: a) create robust connections between the concepts and skills learned during their math courses and the ones emphasized in secondary school mathematics; b) develop a deeper understanding of the role played by the structure (definitions, notation, theorems, problems, etc) of the topics taught in their teaching; c) experience genuine discovery learning in significant mathematics by using manipulatives and technology; d) read articles from different mathematics journals (College Mathematics Journal, Mathematics Magazine, Primus, etc), journals for math teachers (Mathematics Teacher, Mathematics in School, Communicator) and write reflective entries about their experience; e) design a game for school students and implement them in three different schools during the academic year. Specific examples of the tasks assigned will be shared. (Received August 12, 2011)

1077-C1-280 **Aaron Luttman*** (aluttman@clarkson.edu), **Joseph Skufca**, **Brian Leventhal** and **Clarice Dziak**. *A Vertically Integrated Model for a Mathematics "Capstone".*

Capstone experiences for mathematics majors take many different forms, but, in accordance with the "capstone" analogy, a large proportion of them are relegated to the senior year of study. Rather than waiting until students are in their final year to begin to acculturate them into the mathematical community and into mathematical ways of thinking, we have developed an integrated approach to incorporating our students into mathematics that begins in the first year, with additional components in each of the following years. The first year component for our mathematics majors is an inquiry-based mathematical modeling course using software packages such as Excel, Maple, and Matlab. In the third year, students choose between two seminar courses, one covering topics related to teaching and the other covering topics related to research and work in industry. Beyond the required courses, our "professional experience" requires students to demonstrate proficiency in three core areas, through extra- and co-curricular activities. Our current paradigm was developed in response to a mandate from the university to include "professional issues" as a core component of every major, and we detail the development and implementation of our four-year-spanning mathematics major capstone experience. (Received August 18, 2011)

1077-C1-410 **Risto Atanasov*** (ratanasov@email.wcu.edu), **Tuval Foguel** (tsfoguel@email.wcu.edu) and **Jeffrey Lawson** (jlawson@email.wcu.edu). *Optimizing Capstone With Multiple Constraints.*

Over the last four years of the senior capstone seminar at Western Carolina University, we have redesigned the course substantially with the goals of satisfying the University criteria for engaged student learning and following CUPM guidelines. The principal outcomes of the revised course are for each student to make connections between courses across the curriculum, to comprehend professionally written mathematics, to hone written communication skills through expository writing, to improve oral communication skills, and to prepare a résumé for a mathematics-related career. We have developed four assignments, one of which is preparing a résumé, working closely with University Career Services. For the other three assignments, each student writes a paper and gives a presentation, both prepared in LaTeX. These assignments demand increasing levels of independence and mathematical maturity, culminating in either independent research or a detailed review of a research journal article. In this talk we discuss how capstone can assess the individual student as well as the overall curriculum. More importantly, we address how to balance the many roles that our capstone is asked to serve while preserving a comprehensive and holistic mathematical learning experience. (Received August 29, 2011)

1077-C1-437 **Sandra Fillebrown*** (sfillebr@sju.edu), Department of Mathematics, Saint Joseph's University, 5600 City Avenue, Philadelphia, PA 19131. *Capstone Course: Why it didn't work for us.*

Saint Joseph's University, a small liberal arts school, implemented a Capstone course for the mathematics major beginning in the spring of 2007. It was a required course for all seniors, although certain students were exempt such as those doing a year-long honors research project. The course was successful in meeting its objective of providing a learning experience where students could synthesize material from their previous 7 semesters. However, for purely practical reasons, we decided in the fall of 2010 to remove the Capstone course from our program. Requiring the Capstone course had the unintended consequence of limiting the electives we could offer our sophomores and juniors. While we believe that the course served our seniors well, we could not justify keeping it. This talk will go into more detail about our approach to the Capstone course and the reasons we stopped offering it. (Received September 01, 2011)

1077-C1-668 **Rachel Esselstein*** (resselstein@csumb.edu), 100 Campus Center Dr, Building 53, Seaside, CA 93955. *The Right Model Makes All The Difference!* Preliminary report.

A capstone project is required for every graduating student from California State University, Monterey Bay. Due to dramatic growth in the number of senior math majors as well as the extreme work load required of faculty advisers, our department developed a new model for the capstone which not only addressed workload issues but also had the highest student success rate we had ever seen. In this presentation we will describe the changes we made and how they have informed our ideas on assessment, high-impact practices, and student success. (Received September 09, 2011)

1077-C1-770 **Dana C. Cox** (dana.cox@muohio.edu), Department of Mathematics, 301 S. Patterson Ave, Oxford, OH 45056, and **Mary Beisiegel*** (mary_beisiegel@gse.harvard.edu), 50 Church Street, 4th floor, Cambridge, MA 02138. *Surveying U.S. Mathematics Teacher Preparation Programs: What is the status of the capstone course?* Preliminary report.

There have been a handful of reports on implementations of individual courses that fit the Conference Board of the Mathematical Sciences description of a capstone course. However, the status of the mathematics capstone course in the United States is largely unknown; there has thus far been no systematic study of the extent or characteristics of its varied implementations. We will present preliminary results from a 2011 national survey of universities that may offer an upper-level capstone course in either the mathematics department or college of education for mathematics majors pursuing secondary certification. From the 1,713 institutions listed by the Carnegie Foundation for the Advancement of Teaching, we selected a stratified random sample of 200 institutions, weighted appropriately for each of nine classification groups (e.g., PhD granting institutions with high research activity). Our survey investigates the prevalence and nature of capstone courses with attention to mathematical content, course descriptions, logistics (including resources used), goals, instructional style, and instructor background. Data collection is currently underway; analysis of the data will be completed in 2011 and will provide structure for this proposed session. (Received September 12, 2011)

1077-C1-1121 **Daniel E. Otero** (otero@xavier.xu.edu), 3800 Victory Parkway, Cincinnati, OH 45207-4441, and **Joseph F. Wagner***. *A formative three-semester capstone experience.*

In 2008, the mathematics major program at Xavier University underwent a substantial revision, including the institution of a capstone experience. This takes the form of a sequence of three one-credit seminars beginning in the spring of the third year and culminating in the production of a senior project at the end of the fourth year. The design places third- and fourth-year students together in the spring as the former begin considering their projects while the latter are completing theirs. Benefits of this design include a strengthening of the local learning community, a continuity of program quality and purpose, and a forum for fourth-years to practice presenting their results as the third-years discover what is expected of a quality project. The spring seminar also discusses issues of inculturation into the mathematical community (use of library resources, professional societies, technical writing, presentation skills, etc.). The second semester is reserved for students to meet regularly with a faculty advisor for support as they carry out their research. The completed project involves producing a substantial paper and a 30-minute formal oral presentation to the department. We will present lessons learned from administering the program and assessing student work. (Received September 16, 2011)

1077-C1-1383 **Marcella Louise Wallowicz CSFN*** (smwallowicz@holyfamily.edu), School of Arts & Sciences, Holy Family University, 9801 Frankford Avenue, Philadelphia, PA 19114. *Assessing Mathematics and Mathematics-Secondary Education Majors through a Senior Seminar Capstone Experience.* Preliminary report.

This paper describes a culminating experience for senior mathematics and mathematics secondary education majors at Holy Family University. The senior seminar synthesizes various components from the undergraduate mathematics experience and introduces students to 2 essential topics in advanced mathematics: collaborative problem-solving and mathematical research techniques. Topics vary depending on student interest. The student who has successfully completed this course will become proficient in communicating in the language of mathematics, both written and orally; demonstrate a mastery of the breadth of undergraduate mathematics; and complete an in-depth and independent mathematics-related research project, integrating mathematical knowledge and techniques from several different areas. (Received September 19, 2011)

1077-C1-1673 **Rosemary C Farley***, Manhattan College Parkway, Department of Mathematics & Computer Science, Bronx, NY 10471. *A Capstone Course for Secondary Education Students.*

At Manhattan College, secondary mathematics education students take a capstone course designed specifically for them. In this course, students revisit important topics in the high school curriculum from a mathematically advanced perspective, incorporating the mathematical knowledge they have attained in their college mathematics classes to an analysis of high school topics. Various technological tools are used where appropriate. The presentation will provide specific examples of what has worked in this course, including information about student research projects that evolved from course materials. Many of these students subsequently presented at undergraduate mathematics conferences and examples of such presentations will be available. (Received September 20, 2011)

1077-C1-1764 **Kathryn Weld*** (kathryn.weld@manhattan.edu). *Problem Seminar: A Capstone Course.* Preliminary report.

At Manhattan College all senior Mathematics and Mathematics Education majors take a problem solving capstone course. This talk will address how such a course might build mathematical maturity and hone written and oral communication skills in a diverse student body with a broad range of individual ability, while at the same time create a supportive atmosphere that encourages students to enjoy mathematics. The talk will describe how to find problems of appropriate difficulty, how to grade these problems so as to develop individual student writing and simultaneously encourage collaborative work, how use of a knowledge survey has helped to identify key areas of weakness in the curriculum, and how the course encourages students to attend and give presentations at Undergraduate Conferences. (Received September 20, 2011)

1077-C1-2198 **Kristin A Camenga*** (kristin.camenga@houghton.edu). *Communication, Problem Solving and Independence in a Capstone Course.*

We share one model for a capstone course which has as its central goals development of mathematical communication and problem solving skills. Assignments are structured to move students toward independence in these areas, starting with brief presentations of problem statements and class discussions of common readings and gradually increasing independence in reading, writing, speaking and listening. Students complete two major projects: one a group project on a topic related to the course theme and the other an independent project to solve and extend a problem. Both projects have written and oral components and address different audiences, one popular and one mathematical. We will share assignments and rubrics used, as well as examples of student work. (Received September 21, 2011)

1077-C1-2449 **Kurt Herzinger*** (kurt.herzinger@usafa.edu), 2354 Fairchild Dr., Suite 6D124, USAF Academy, CO 80840-6252, **Beth Schaubroeck** (beth.schaubroeck@usafa.edu), 2354 Fairchild Dr., Suite 6D124, USAF Academy, CO 80840-6252, and **Dale Peterson** (dale.peterson@usafa.edu), 2354 Fairchild Dr., Suite 6D124, USAF Academy, CO 80840-6252. *Starting a capstone experience: A user's guide.* Preliminary report.

In this talk, we discuss the experience of creating a research capstone experience from scratch. We will also share lessons learned from the first two years of our capstone experience. In particular, we discuss the students' undergraduate research projects, their attendance and presentations at conferences, assessment of their overall mathematical skills, and how these and other elements of the capstone experience prepare them for their careers. (Received September 22, 2011)

1077-C1-2531 **Marc Chamberland*** (chamberl@math.grinnell.edu), Department of Mathematics and Statistics, 1116 8th Avenue, Grinnell, IA 50112. *A Course in Experimental Mathematics.*

Experimental Mathematics is the utilization of advanced computing technology in mathematical research for discovering new patterns and relationships, testing and falsifying conjectures, replacing lengthy hand derivations with the computer, and suggesting approaches for a formal proof. With support from the NSF, a course in Experimental Mathematics was developed and taught. The course is integrative (covers many different mathematical areas), incorporates an REU-like research experience, and models how some current mathematical research is done. (Received September 22, 2011)

1077-C1-2592 **Daniel R. Shifflet*** (dshifflet@clarion.edu). *Online Discussion Boards in Seminar: Discovering Exciting Tidbits Missed Inside the Classroom Walls on the Outside.*

With only a 1 credit hour dedication, Clarion University's Capstone Seminar leaves little time for students to work on anything besides the typically required research report and accompanying presentation. So where do our majors pick up all the little exciting pieces of math left out of their required courses? Do we let them graduate without hearing about The Millennium Prizes, Chaos Theory, The 4-Color Theorem, or The Birthday Problem? Where do they learn about the real life catastrophes that can occur from not checking your work (see Mars Climate Orbiter) or our database of corny math jokes? When else do they get exposed to LaTeX, a necessary tool of graduate school? Having little in-class time to spare for these topics I turned to our course online discussion board to save me. By asking questions, posting links, and staring philosophical conversations, our math majors were able to share in their discovery of these interesting topics online and become a little more excited about their chosen field of study. (Received September 22, 2011)

1077-C1-2690 **Karrolyne Fogel*** (kfogel@callutheran.edu) and **Chris Brown**. *Fostering Communication Skills and Independence in a Capstone Project.* Preliminary report.

CLU students currently complete a two semester capstone sequence focused on developing mathematical communication skills and independent engagement. In the first semester, students select topics of individual interest and write research proposals, in essence designing their own courses of study for the second semester. Students are fully engaged in this process: selecting the research topic, interviewing faculty, designing a schedule, even selecting the grading criteria. In the second semester, students carry out the research proposed, under the guidance of a faculty mentor, culminating in both an oral presentation and written thesis. In both semesters, students learn to formally write longer mathematics papers, from structural, mathematical, and technical (LaTeX) perspectives. We discuss our techniques for developing mathematical writing and presentation skills, as well as our attempts to encourage student participation in local conferences. We also discuss challenges, such as dealing with diverse topics and equitable grading when project goals and faculty expectations differ. (Received September 22, 2011)

1077-C1-2823 **Jeremy Case*** (jrcase@taylor.edu), 236 W. Reade Ave, Taylor University, Upland, IN 46989. *A Capstone Course in January.* Preliminary report.

The dynamics of a capstone course over four weeks provides special opportunities to cap the major. Meeting daily for extended periods of time allows deeper connections between the various strands of mathematics. With more opportunities for focused reading and classroom discussion, a capstone course in January can also raise ethical issues surrounding the limitations and appropriate uses of mathematics. In addition to outlining the course and its usefulness in giving feedback, we will give some strategies on developing stronger ties between students and the major in such a course. (Received September 22, 2011)

Developmental Mathematics Education: Helping Under-Prepared Students Transition to College-Level Mathematics

1077-C5-50 **Robert E. Burks*** (reburks@nps.edu), COL Robert E. Burks, PhD., Department of Operations Research, Naval Postgraduate School, Monterey, CA 93940. *The use of Pop Culture and Competition to Enhance Learning Mathematics (Survivor Math).*

Traditional student success in undergraduate level mathematics, science, and engineering (MSE) courses depends on a firm understanding of pre-calculus material. Instructors at the United States Military Academy have identified a set of fundamental pre-calculus concepts that all students must possess in order to effectively understand the concepts presented in a strong MSE core academic program. However, every year a growing number of freshmen enter under-prepared for success in a MSE sequence. I will discuss a modification of the popular television game show, Survivor, as conducted in an undergraduate first semester developmental mathematics course and graduate level statistics course. The focal point of this classroom application is a group-based competitive drill and practice activity designed to increase conceptual understanding of fundamental concepts. This application takes advantage of available technology to boost instruction creativity and student interest in the classroom. The results of this activity include: increased understanding of the fundamental concepts, increased confidence in mathematics exams, and increased preparedness for the mathematics concepts presented in future MSE courses. (Received July 06, 2011)

1077-C5-121 **Susan S Gray** (sgray@une.edu), 11 Hills Beach Road, Biddeford, ME 04005, **Barbara J Loud** (barbara.loud@regiscollege.edu), 235 Wellesley Street, Weston, MA 02493, and **Carole P Sokolowski*** (carole.sokolowski@merrimack.edu), 315 Turnpike Street, No. Andover, MA 01845. *Factors Related to Using Algebraic Variables to Represent Quantitative Relationships.*

The study of college mathematics requires students to use variables to represent quantitative relationships. Research has shown that students who have a well-developed concept of variable are more likely to be successful in calculus (Authors, 2005). In this study, 300 undergraduates, enrolled in developmental or college algebra courses, completed a written test in which they used and interpreted variables. Test problems differed in terms of type of task (write an expression, interpret an expression, write an equation, compute a value) and type of variable (first letter of referent vs. generic x or y). Success rates were quite low, with some significant differences in type of task. Students were most successful computing numerical values, but had difficulty writing the corresponding algebraic equations that described those computations. Success rates did not differ for type of variable. This research provides information about undergraduate algebra students' uses and interpretations of variables to represent quantitative relationships in equations or expressions and describes some common difficulties. To inform instruction, the testing instrument can be used in the classroom to assess students' uses and interpretations of variables and to identify areas of difficulty. (Received July 28, 2011)

1077-C5-163 **James R. Henderson*** (henderso@pitt.edu), 504 E. Main Street, Titusville, PA 16354. *Streamlining Basic Algebra Instruction.*

A first course in basic algebra is, for many, a significant emotional experience. Given this, it does no good to encourage students to believe the material is more difficult than they already think it is. All too often this is precisely what happens, and I place much of the blame on the textbook industry. In subject after subject, textbook presentation is unnecessarily Balkanized into topics, subtopics, and sub-subtopics. For example, discussion of graphing linear equations in two variables often involves lines with positive slope and lines with negative slope, lines that pass through the origin and lines that don't, vertical lines, and horizontal lines, all in spite of the fact that, given their treatment in a developmental algebra class, only vertical and non-vertical lines warrant different treatment. This is in no way unique, as can be seen with textbook accounts of, among other things, linear equations in one variable, multiplying polynomials, and factoring quadratic expressions. To best maximize chances for student success, it is imperative that material be presented in an accessible, coherent, unified way, not as a mish-mash of techniques applicable in narrowly defined circumstances. I will address ways of doing just that. (Received August 04, 2011)

1077-C5-202 **Alvina J. Atkinson*** (aatkinso@ggc.edu), 1000 University Center Lane, School of Science and Technology, Lawrenceville, GA 30043, and **Barry D. Biddlecomb** (bbiddlec@ggc.edu) and **D. Natasha Brewley** (dbrewley@ggc.edu). *Designing Developmental Mathematics for Student Success.*

A state of crisis exists in developmental education in the state of Georgia. According to USG data, out of more than 37,000 students who entered the system in Fall 2004, 6,627 were required to take developmental mathematics. Of those only 38.9% exited within two semesters. Forty-five percent had not exited by Fall 2006 and were not enrolled at that time. In Fall 2007, a redesign of developmental mathematics at the presenter's institution resulted in an innovative self-paced course in which technology is used to individualize the mathematical learning of students. The course has resulted in a 49% exit rate with an mean time in the course of 1.6 semesters while raising the college algebra grades of developmental students compared with similar students in the UGG. This proposal presents the model for the course and quantitative data showing it's effectiveness and offers suggestions on implementing the model at other institutions. (Received August 11, 2011)

1077-C5-630 **Leonid Khazanov*** (lkhazanov@bmcc.cuny.edu), 370 Ocean Parkway (Apt. 9J), Brooklyn, NY 11218, and **Fred Peskoff** (fpeskoff@aol.com). *Can Peer Coaches Improve Student Success in Developmental Mathematics Courses?*

Developmental mathematics students often have poor study skills and habits that impede their success. The presenters will discuss their grant funded study involving an intervention in which peer coaches worked with "high risk" elementary algebra students by tutoring them in mathematics as well as helping them improve their study skills. A peer coach is an upper level mathematics student (who has completed precalculus)recruited to serve as both a tutor and mentor. The purpose of this presentation is to provide the audience with information which will enable them to implement similar interventions at their colleges. The presenters will discuss the details of both recruiting and training peer coaches to work successfully with high risk developmental mathematics students. The training involves teaching the coaches how to become effective mentors and tutors who are sensitive (and responsive) to the needs of their clients, who have weak mathematics skills as well as high math anxiety. It is hoped that similar programs can successfully model the presenters' intervention which demonstrated that coaching significantly improves both retention and pass rates of high risk students. (Received September 08, 2011)

1077-C5-641 **Aaron Wong*** (aaron.wong@nsc.nevada.edu), 1021 E Paradise Hills Drive, Henderson, NV 89002. *Modularized Math Remediation: Implementation and data.*

The mission of Nevada State College is to increase access to higher education within our region. However, Nevada is among worst states in mathematical achievement, so most of our students come to us needing a full year of remediation, beginning from prealgebra. We developed a new delivery of our remedial mathematics over the last two years to improve student success and retention while maintaining high standards. At last year's meetings, we outlined the structure of the new remediation program. The basic idea was to replace the 15 week semesters with 5 week modules, requiring mastery of each module before proceeding to the next. This year, we will discuss the initial Fall 2011 implementation of the program as well as the first set of data. (Received September 09, 2011)

1077-C5-1367 **Sarah Hutcheson Jahn*** (jahn@csp.edu), Concordia University, 275 Syndicate St. N, St. Paul, MN 55104, and **Robert J. Krueger**. *Meeting the Needs of Under-Prepared Students.* Preliminary report.

Concordia is a small Christian university in St. Paul, Minnesota with many first generation college students from inner city public schools. Over the past six years, the math department has developed their own placement exam and review materials to help identify under-prepared students. In addition, we revamped the developmental math courses to offer students a blend of face-to-face instruction and individual computer-aided practice with support and immediate feedback. In this session, two faculty members who have worked on these changes from the beginning will discuss their successes and challenges in meeting the needs of students who are under-prepared to study college math. (Received September 19, 2011)

1077-C5-1411 **Jesse W Byrne*** (jbyrne@uco.edu), Department of Mathematics & Statistics, 100 N University Drive, Edmond, OK 73034, and **Charlotte K Simmons** (cksimmons@uco.edu), College of Mathematics & Science, 100 N. University Drive, Box 177, Edmond, OK 73034. *What Csn We Do For Amanda?* Preliminary report.

Until this past summer, all developmental mathematics courses on our campus, a primarily undergraduate institution (PUI), were outsourced to a community college and our mathematics department played no role in developing the curriculum, nor teaching the courses. In the Spring 2011 semester, we learned from our President that our department would be responsible for developmental mathematics at our university, effective with the summer term. As of this fall, there are 900 plus students enrolled in these courses. In this talk, we will share our journey, including our strategy for creating a two-track curriculum for developmental mathematics, our placement process, our approach to teaching these courses, as well as our results thus far. (Received September 19, 2011)

1077-C5-1527 **Carla Rudder*** (carla.rudder@zu.ac.ae). *Energize: Strategies to Keep Students Going and Going.*

At a Gulf University approximately 46% of students enroll in a developmental mathematics course before enrolling in college mathematics courses. The majority of who major in the liberal arts. The goal of the developmental mathematics course is to ensure students have the proper foundation to be successful in subsequent mathematics courses. In order to make the course enjoyable for the students and to assist in their success, several strategies and classroom practices were adopted. The focus of the mathematics faculty was to create an environment where students are active participants in the classroom. To achieve this goal, a new text was created to allow students to work during class instead of solely listening. Using this text, the class becomes a forum for discussion. Students are encouraged to work together to further their understanding and improve their confidence. The text includes non-mathematical situations in order to teach problem solving heuristics before transitioning to mathematical situations. Also by including the use of technology, a medium students are highly familiar with, they experience mathematics in a comfortable environment. (Received September 20, 2011)

1077-C5-1909 **Jan O. Case*** (jcase@jsu.edu), MCIS Department, 700 Pelham Road North, Jacksonville, AL 36265, and **Jessica Bentley**. *An Integrated Media Approach to Developmental Mathematics Instruction.*

Jacksonville State University has joined the National Repository of Online Courses Pilot Research Project for Arithmetic with the goal of improving the success rate of students who are underprepared in mathematics. NROC is an open source program developed by the Monterey Institute for Technology and Education with funding support from The Bill and Melinda Gates Foundation. The pilot program uses case studies from high schools, community colleges, and universities throughout the United States. JSU's participation began in the Fall 2011 semester with courses taught at Gadsden State Community College, our local partner institution, with plans to expand to both campuses in the Spring 2012 semester. NROC resources are being used to transform existing traditional basic mathematics courses into hybrid courses. Data to be examined includes course completion rates, pass rates, and test scores. ACT and Compass scores are used to control for the initial level of competency of the students. Online interviews with NROC researchers are used to examine changes in the attitude, persistence and competence of students experiencing the environment. Demonstration of the program and preliminary statistical analysis from JSU's participation will be presented. (Received September 21, 2011)

1077-C5-1958 **Karoline Auby*** (kauby@uwlax.edu), 1725 State Street, UW-La Crosse, La Crosse, WI 54601, **James Sobota** (jsobota@uwlax.edu), 1725 State Street, La Crosse, WI 54601, and **Maighread McHugh** (mmchugh@uwlax.edu), 1725 State Street, La Crosse, WI 54601. *Digital Learning Materials: Analysis of student early preparation in College Algebra.*

A collection of media-rich learning objects was developed utilizing teams of students, faculty and staff. These materials are being used in a variety of undergraduate mathematics courses. One collection was designed to assess and strengthen the algebraic skills of incoming freshmen in order to inform and prepare them for a final exam in a college algebra course, (a credit by exam version) which is administered during the second week of the semester. The collection has grown to support students who have placed in remedial level mathematics courses.

An analysis of survey data of student perceptions, time on task and performance will be presented. A record number of students are placing in remedial math, and this rise has had a potential impact on the motivation to take the exam in an attempt to get "back on track" by satisfying the prerequisites in math and science courses. Interesting data relating to student motivations and student demographics will be presented. (Received September 21, 2011)

1077-C5-2068 **Karen G Santoro*** (santoroka@ccsu.edu). *Trying to Bridge the Gap: Outcomes and Implications of a Remedial Mathematics Intervention Program.* Preliminary report.

In this talk we present the new programs offered at Central Connecticut State University to help students requiring mathematics remediation meet the state's proficiency requirement. In particular, we will discuss our MATH 099 Summer Institute which has, over the two years it has run, successfully placed more than 80% of participants out of remedial math. The Institute provides on-campus workshops along with online practice problems developed especially for the CCSU developmental curriculum. Issues that, based on the outcome data, appear to impact student outcomes in these programs will be examined as will the potential implications of these intervention efforts for participants' success in subsequent college-level mathematics courses. (Received September 21, 2011)

1077-C5-2570 **Mary R Parker*** (mparker@austincc.edu). *Experiences in Designing and Teaching Statway.* Preliminary report.

Statway is a national project to provide a two-semester path to and through a college-level Elementary Statistics for students with arithmetic skills, but not necessarily algebra skills. In these classes, students learn the mathematical and intellectual skills needed for college-level statistics along with the statistics content. This talk will focus on how we decided which mathematical skills to include and how we integrated them with the statistics content. I will also discuss some of my experiences teaching the course.

Statway is a project of the Carnegie Foundation for the Advancement of Teaching and the Charles A. Dana Center. http://www.statway.org/ Teams from nineteen community colleges across the country participated in developing the courses in 2010-2011 and began teaching them in Fall 2011. (Received September 22, 2011)

1077-C5-2583 **Sarah V. Cook*** (sarah.cook@washburn.edu). *Developmental Mathematics: Try, Try, and Try Again.* Preliminary report.

This talk will focus on recent efforts to improve the success rates of the developmental courses Basic Algebra and Intermediate Algebra at Washburn University. Discussion will center on the comparison of sections using a traditional three-day-a-week-lecture format to sections using a two-day-a-week-lecture/one-day-a-week-lab format. Also, recent adjustments to the objectives for the courses will be presented along with reasons for changes. (Received September 22, 2011)

1077-C5-2673 **Jessica Deshler*** (deshler@math.wvu.edu), **Edgar Fuller** (ef@math.wvu.edu), **Betsy Kuhn** (bkuhn@math.wvu.edu), **Doug Squire** (dsquire@math.wvu.edu) and **Vicki Sealey** (sealey@math.wvu.edu). *An evaluation of the success of students who transition from a developmental Math Workshop into College Algebra, Trigonometry and Calculus I.* Preliminary report.

Students at WVU are placed into mathematics classes by the scores they receive on the MAA placement test published by Maplesoft through their MapleTA system. We test approximately 5000 students each summer and of these, approximately 30% are placed into a pre-college algebra workshop that provides remediation in core mathematical areas needed for success in university level mathematics courses including arithmetic and basic algebra. Students who complete the Math Workshop continue into college algebra, trigonometry and calculus. The workshop provides a self-paced review of arithmetic and algebra using the MyLabsPlus system and content from the Martin-Gay Beginning and Intermediate Algebra text. Students pass the Math Workshop by completing homework sets and passing mastery exams. Our data has shown that students who complete the Math Workshop are twice as likely to pass college algebra within their entering population. Moreover, students who enter college algebra based on placement alone with no remediation are 4 times more likely to withdraw than those who have completed the Math Workshop. Additional success rate data will be presented for students who then progress to trigonometry and calculus. (Received September 22, 2011)

1077-C5-2834 **Maria Belk***, mbelk@bard.edu, and **Lauren Rose**, rose@bard.edu. *Creating Pathways to Math Success at a Liberal Arts College.* Preliminary report.

Bard College is a liberal arts college with close to 2000 students. While many of our students enter college ready for calculus, we also have some students who need to start with precalculus, and some students who would have difficulty in a precalculus course. In the past few years, we have made several changes to help these students succeed in their math courses and to create a pathway for students with weak backgrounds to major in math and science. We added a Math Placement Exam as a way to identify students in need, we created an evening Math Study Room staffed by peer tutors, and we added two 2-credit algebra review courses for students who want to improve their algebra or precalculus skills. In this talk, we will go over the details of these changes, and discuss our impressions of how these changes have helped students to succeed in their math and science courses. (Received September 22, 2011)

Early Assessment: Find Out What Your Students Understand (and Don't Understand) Before They Take the Test

1077-D1-1184 **Rebecca Anne Dibbs*** (rebecca.dibbs@unco.edu), School of Mathematical Sciences, University of Northern Colorado, Campus Box 122, 501 20th St., Greeley, CO 80634. *Formative assessment and learning trajectories in first semester calculus.* Preliminary report.

Adding formative assessment to a mathematics classroom raises student achievement; however, little is known about how formative assessment raises achievement. Do students in classrooms using formative assessment learn the material faster, but on the same learning trajectory, or learn the material differently? I investigated the learning trajectories of a class of first semester undergraduate calculus course using Oehrtman's Approximation Framework and formative assessments. In this presentation I will discuss how formative assessment influenced the learning trajectories of the course, helped facilitate transfer of limit concepts throughout the course, and aided the acquisition of the approximation framework language; the data collection plan for the next semester will also be discussed. (Received September 17, 2011)

1077-D1-1615 **Rodica Cazacu*** (rodica.cazacu@gcsu.edu), Department of Mathematics, Georgia College, Milledgeville, GA 31061. *Making sure the students understand a concept by watching them working with it.*

After several years of teaching and trying different methods in my classroom, I realized that it does not meter how many examples I will work in class or assign for my students to work, when it comes to the test the students seem to forget the essential. So I decided to check out their understanding by introducing a pre-test workshop where I bring problems and exercises that summarize the material they have to know for the test and let them work in small groups while I am watching. In this talk I will describe such a workshop and the impact it has on students' results by comparing them with results from previous classes where I did not use this method. (Received September 20, 2011)

1077-D1-2177 **Christopher K Storm*** (cstorm@adelphi.edu), Department of Mathematics and Computer Scienc, Post Hall 211, Adelphi University, Garden City, NY 11530. *Voting your way to good discussions.* Preliminary report.

Classroom voting is a teaching method which requires each student in the classroom to actively engage with new material by discussing and then voting on true/false and multiple choice questions presented to the class. Project MathVote: Teaching Mathematics with Classroom Voting is an ongoing NSF-funded study of this pedagogy. We present some preliminary results from this study with a focus on how to use classroom voting to promote "good" classroom discussion. Through both the voting results and the discussions surrounding the vote, an instructor gains an excellent picture of how students are thinking about a topic and can react accordingly. (Received September 21, 2011)

1077-D1-2484 **John A Velling*** (jvelling@brooklyn.cuny.edu), 2900 Bedford Avenue, Brooklyn, NY 11210. *MathLynx: the Online and CAS-based Mathematics Pedagogy Environment - Tools for Learning and Practice.*

MathLynx is the first interactive online text/tutorial/evaluation mathematics pedagogy environment. For two years the author has been using interactive text with randomly generated embedded examples and supporting materials. Student practice sessions are tracked and feedback is immediate. Practice sessions are directly related to limited repetition evaluation (test) sessions.

Anecdotal evidence indicates that by changing the notion of success from ability to perform algebraic manipulation to ability to complete complex tasks, a surprisingly high proportion of students given opportunity to familiarize themselves with the algorithmic pieces of said tasks are able to succeed.

Material and evidence from calculus of one variable and multivariable classes will be presented. (Received September 22, 2011)

1077-D1-2634 **Gulden Karakok*** (gulden.karakok@unco.edu), **Aaron Wangberg** (awangberg@winona.edu) and **Nicole Engelke** (nengelke@fullerton.edu). *An Enhanced Implementation of the WeBWorK Online Homework System as a Formative Assessment Instrument.* Preliminary report.

In this presentation we will share our advancement and implementation of the free open source online homework system WebWorK as a formative assessment instrument. Unlike the traditional homework system implementations that record students' final answer, our enhanced instrument captures and reproduces the actual students' solutions of calculus problems in real time. This powerful instrument further records students' modifications to their solutions after they are prompted that their final answer is incorrect. We have been using the advanced instrument throughout a calculus course for weekly quizzes. As students work on their weekly quiz, the ability to capture all student attempts and solutions specifically helps us to gain understanding of students' misconceptions of a given topic before they are compounded by new material. During our talk we will show examples of students' solutions of function composition problems and how the advanced instrument helps us to recognize some of the misconceptions on this particular topic. (Received September 22, 2011)

1077-D1-2735 **Brenda Burns-Williams*** (bdburns@ncsu.edu), Campus Box 8205, Raleigh, NC 27695, and **Megan Sawyer** (mesawyer@ncsu.edu), Campus Box 8205, Raleigh, NC 27695. *Using Online Pretests and Try It Quizzes for Early Assessment and Remediation.* Preliminary report.

Do your students think they are prepared for a test only to be surprised by their low score? We will discuss how we use a series of online Pretest and Try It quizzes to help each individual student master course material effectively. The Pretest quizzes diagnose a student's weaknesses with course material then provide specific feedback for incorrect responses including directions on how to access online material for remediation, whereas the Try It quizzes provide an opportunity for students to determine if they have mastered the objective. The quizzes are given using Moodle, an online learning management system. Preliminary assessment of data shows a decrease of 15% in the number of students who fail or withdraw from the course. (Received September 22, 2011)

1077-D1-2915 **Brian P Kelly*** (bkelly@bryant.edu), 1150 Douglas Pike, Smithfield, RI 02917. *Formative Assessments in Upper Division Mathematics.*

When formative assessments are discussed for K-12 education it often means pre/post testing used to individualize instruction and confirm the correlation to learning goals. These examples are ill-suited to higher education because class time is at a premium. We emphasize examples drawn for college geometry and the calculus based probability and statistics course. These have the common thread that they advance the course content, provide the students with a non-threatening assessment, and give the instructor a more precise idea of the strengths and weaknesses of individual students. (Received September 23, 2011)

Effective Use of Dynamic Mathematical Software in the Classroom

1077-D5-468 **David A. Brown*** (dabrown@ithaca.edu), Department of Mathematics, Ithaca College, Ithaca, NY 14850. *Rolling Wheels: Explore Curve Sketching via GeoGebra and Mathematica.*

Cycloids, hypocycloids, epitrochoids, and more generally, curve sketching via truncated Fourier series, provide students the opportunity to explore the interplay among geometry, functions, and number theory. This lesson (used in multivariable calculus and a course in mathematical experimentation) asks the students to investigate these topics by first considering rolling wheels and how points on the wheels can trace curves. GeoGebra and Mathematica are used to simulate these evolving curves and we provide lessons using both software packages. As students move on to explore a wheel rolling on a wheel rolling on yet another wheel, they develop functions which are truncated Fourier series. The lesson asks students to explore (via GeoGebra and/or Mathematica) the parameters involved in these functions, leading them to realize that number theory is playing a role in the structure of the resulting curves. The lesson also allows students to experience their artistic side as they manipulate parameters. We even make a connection with automotive engineering. (Received September 03, 2011)

1077-D5-700 **Hillary Einziger*** (einziger@math.psu.edu). *An iPad-based activity for learning to sketch the graph of the derivative of a given graph.*

This lesson plan uses graphs created in GeoGebra as the basis for an activity in which students use an iPad and stylus to practice sketching derivative graphs. Students are presented with the graph of a function, shown on a screen through a projector, and then one student at a time volunteers to try to sketch the derivative graph. Other students can offer suggestions and comments, and then they compare the sketch with the actual graph of the derivative. This lesson provides students with instant feedback as to whether they understand the concepts, it encourages students to discuss and experiment with their ideas, and it allows all the students in the class to see several different perspectives on how to solve similar problems. The lesson as planned requires only one iPad and a projector, as well as the presentation app Explain Everything. In a classroom equipped with multiple iPads or other tablets, this could easily be modified into a small group activity, where each group would consider the graphs and discuss how to draw the derivatives. Creating the graphs in GeoGebra and then saving them as PDF files allows the use of the iPads, so that students can draw directly on the given graphs. (Received September 10, 2011)

1077-D5-778 **Andrew J Rich*** (arich@macalester.edu), Macalester College, 1600 Grand Ave, Saint Paul, MN 55105, **Daniel T Kaplan** (kaplan@macalester.edu), Macalester College, 1600 Grand Ave., Saint Paul, MN 55105, **Randall J Pruim** (rpruim@calvin.edu), Dept. of Mathematics, Calvin College, Grand Rapids, MI 49546, **Nicholas J Horton** (nhorton@smith.edu), Smith College, Northampton, MA 01063, and **JJ Allaire** (jj.allaire@gmail.com). *Taylor Polynomials in R.* Preliminary report.

In keeping with the format of the session, we will present a lesson on Taylor Polynomials that makes use of interactive graphical software in R. Although R is best known for its important uses in statistics and is a professional-level technical computing environment, it is quite suitable for teaching introductory university-level courses such as calculus. It's also free, and can be run using a browser-based interface (RStudio), which makes it easy to deploy to students in the classroom. The Taylor Polynomial lesson will make use of the symbolic differentiation capabilities built in to R. It illustrates how the quality of the approximation varies with the order and highlights the difference between Taylor polynomials and least-squares polynomials.

In addition to the Taylor Polynomial lesson, we have R software for teaching a complete introductory calculus course, including integration and differentiation operators and several interactive, graphical lessons on various aspects of calculus. Like the R software itself, our calculus software and lessons are free and available on line through Project MOSAIC: www.mosaic-web.org. Instructions for installing the software will be given there at www.mosaic-web.org/JMM2012. (Received September 12, 2011)

1077-D5-787 **Itai Seggev*** (itais@wolfram.com), Wolfram Research, 100 Trade Center Drive, Champaign, IL 61820. *Becoming One with Bifurcations in 3D!*

In this talk we will argue that bifurcations in ordinary differential equations are best understood by means of "3D bifurcation diagrams". By plotting the rate function–as a function of both the dependent variable and the bifurcation parameter–and slicing it with appropriate planes, the stability and nature of a bifurcation can be determined. A Mathematica package for automatically creating these diagrams from a rate function will be presented. (Received September 12, 2011)

1077-D5-1201 **Brandon Milonovich*** (bamilono@syr.edu). *Exploring regressions through Geometer's Sketchpad and Microsoft Excel.* Preliminary report.

Students often have difficulty in understanding what a regression is, especially once students are taught more complicated regressions beyond that of the linear nature. The scope of this lesson can be modified for most grade levels, including lower level undergraduate courses. Students begin by exploring their own environment to find a line or curve to fit and will work through the lesson working with real world data and making immediate sense of the mathematics involved. Students begin with a very simple example demonstrated by the teacher and move to finding their own examples in linear and quadratic regressions, and eventually aim to discover more complicated approaches and curves. By working hands on with dynamic software, students can develop a personal connection to the mathematics they are doing which research shows to help develop better connections between concepts and allows learning to have more depth, and be maintained for a much longer period of time. (Received September 17, 2011)

1077-D5-1357 **Michael Todd Edwards*** (edwardm2@muohio.edu), **Robert M Klein** and **Steve Phelps**. *Mystery Plots: Motivating Algebraic Function Models using Dynamic Mathematics Software.*

Functions are central to the study of mathematics. As Froelich, Bartkovich, and Foerster (1993) note, "the concept of function is probably the most important idea in mathematics" (p. 1). Although students in introductory courses spend significant time working with functions, much of this time is spent transforming familiar functions - for instance, stretching, reflecting, and translating exponential, quadratic, square root, and sinusoidal functions - rather than creating original functions. The tendency to modify and "borrow" rather than create impacts students' attitudes regarding mathematics. Functions become "gifts" from teachers rather than objects of discovery in their own right. Mathematics is not construed as a creative area of study.

In this talk, we explore the use of dynamic mathematics software (DMS) as a medium for constructing algebraic function models that extend student knowledge of function. We share a strategy for developing original function sketches, the three-step **MTA process** (Measure - Trace - Algebratize). The MTA approach provides students with opportunities to explore and construct remarkably non-standard functions - often beautiful, unexpected, and thoroughly original. We share several examples of such functions in our talk. (Received September 19, 2011)

1077-D5-1499 **Jason McCullough*** (jmccullo@math.ucr.edu). *Epsilons and Deltas with GeoGebra.*
The rigorous definition of a limit is often neglected or even omitted in a Calculus class due to the difficulty students have in grasping the concept. I will present an interactive GeoGebra demo designed to illustrate geometrically existence and nonexistence of limits of some chosen functions. The activities are suitable for classroom demonstration or individual student use. (Received September 20, 2011)

1077-D5-1554 **Talitha M Washington*** (talitha.washington@howard.edu), Howard University, Department of Mathematics, Washington, DC 20059. *Taking Instruction with Numerical Computations to the Next Octave.*
Often times in a typical numerical analysis course, a computer program is used to implement the numerical schemes. GNU Octave is a freely redistributable software that provides a way to numerically solve problems through command-oriented programming, quite similar to Matlab. This talk will present ways to implement programming with GNU Octave for a typical numerical analysis course, discuss its similarities and differences to Matlab, analyze challenges that students may encounter, and offer ways it may be used in other courses such as calculus and linear algebra. (Received September 20, 2011)

1077-D5-1700 **Jennifer Bergner*** (jabergner@salisbury.edu). *Using Geometer's Sketch Pad to examine whether the SSA condition in Euclidean geometry is always ambiguous.*
In this presentation I will share a Geometer's Sketch Pad activity that uses the dynamic capabilities of the software to explore the situation in which two triangles have two sides of one congruent to two sides of the other, and a non-included angle of one congruent to a corresponding angle of the other (the "ambiguous" SSA condition). The students use GSP to examine and conjecture when this is not an ambiguous condition and why. This activity uses several nice features of GSP such as tables, sliders, and the calculator and can also be extended to explore some of the other standard congruence theorems from Euclidean geometry. (Received September 20, 2011)

1077-D5-1769 **Philip P. Mummert*** (phmummert@taylor.edu). *The Euler Line in GeoGebra.*
In Euclidean geometry the centroid, circumcenter, and orthocenter of a triangle are collinear (forming the "Euler line"). GeoGebra is a fantastic tool for illustrating the definition of each of these triangle centers (including the poor, forgotten incenter) and demonstrating their collinearity. Use of the dilation tool makes the proof of this remarkable fact even easier to follow. (Received September 20, 2011)

1077-D5-1952 **Paul E Seeburger*** (pseeburger@monroecc.edu), 1000 E. Henrietta Rd., Rochester, NY 14623. *Visualizing Lagrange Multiplier Optimization using CalcPlot3D.* Preliminary report.
In multivariable calculus, we teach our students the method of Lagrange multipliers to solve constrained optimization problems. As we introduce this topic, many of us use some form of visual presentation to help students understand how we develop the Lagrange multiplier equation, i.e., $\vec{\nabla} f(x,y) = \lambda \vec{\nabla} g(x,y)$. Using a freely available online multivariable calculus applet named CalcPlot3D, instructors can give a dynamic demonstration of the visual nature of Lagrange multiplier optimization during class. After class, students can complete a guided exploration of this topic using the same applet. As part of this activity, students complete a pre-test, answer exploration questions, and then complete a post-test. The pre- and post-tests measure what improvement occurs in their conceptual understanding of the geometric nature of Lagrange multiplier optimization by completing the visual exploration. Student responses to this online activity can be sent to instructors for grading. CalcPlot3D is part of an NSF-funded grant project titled Dynamic Visualization Tools for Multivariable Calculus (DUE-CCLI #0736968). See http://web.monroecc.edu/calcNSF/. (Received September 21, 2011)

1077-D5-2453 **J Alfredo Jimenez*** (jaj4@psu.edu), 76 University Drive, Hazleton, PA 18202. *Team Activities for the First Day of Class Using a Computer Algebra System.* Preliminary report.
I would like to present an activity that I use the first day of class to create an environment where students work collaboratively in teams, review some basic mathematical concepts, and use the computer algebra system Mathematica to produce some images, at the same time that they learn some basic commands. I have used this activity in calculus or linear algebra classes (first or second year level). The problems that I pose are simple: Draw the Mitsubishi logo, the Texaco logo, and a tetrahedron. These problems are easy to state, very visual, and yet, very challenging for students at this level. The activity is well received by the students, who normally

are fully engaged in solving the problems, brainstorming, and sharing their thoughts. (Received September 22, 2011)

1077-D5-2542 **Dan Gries**, **Barbara Margolius** and **Felipe Martins***, Department of Mathematics, Cleveland State University, Cleveland, OH 44115. *WeBWorK labs? A case study in differential equations.* Preliminary report.

WeBWorK is an online homework system, initially developed at the University of Rochester and currently supported by the MAA and NSF. WeBWorK is traditionally used as a practice and assessment tool. Under our NSF-CCLI grant, DUE-0941388 we have developed a library of Flash applets embedded in WeBWorK homework assignments for entry level university mathematics courses including calculus, pre-calculus and differential equations. This opens the possibility of creating dynamic WeBWorK pages that can be used for instruction, instead of just assessment. In this talk, we will present a case study, where we create a WeBWorK "lab" for exploring parameter dependency in Ordinary Differential Equations. (Received September 22, 2011)

1077-D5-2556 **Susan L Schmoyer*** (`sschmoyer@worcester.edu`), Mathematics Department, 486 Chandler Street, Worcester, MA 01602. *Teaching Transformations of Functions Using Sage.* Preliminary report.

Graphing functions using transformations (like vertical and horizontal shifts) is a skill usually introduced in college algebra and used in precalculus, calculus, and mathematical modelling. In this talk I will demonstrate a Sage worksheet that helps students to make the connection between an algebraic transformation of a function and its respective graph. Sage is a free, open source alternative to Maple, Matlab, and Mathematica. Part of the Sage worksheet is a "Transformations Guessing Game" that creates a random graph of a function and asks the student to find the formula of the function. This knowledge of transformations is then applied to create some basic mathematical models. (Received September 22, 2011)

1077-D5-2589 **Rejoice Mudzimiri*** (`mudzimir@math.montana.edu`), 101 Peter Koch Tower, Bozeman, MT 59715. *The Power of Symbolic Spreadsheets.*

Researchers have suggested that spreadsheets in general can support students in developing an understanding of variables. The availability of symbolic spreadsheets (spreadsheet that allow for the manipulation of variables) has the capacity to enhance explorations, visualization, pattern recognition and ultimately conceptual understanding. In this presentation I will use the TI-Nspire symbolic spreadsheet to demonstrate three pedagogical principles: 'wastefulness', variation or parameterization, and generalization using a 'simple' word problem. The activity is adapted from a senior capstone course for high school mathematics teachers. (Received September 22, 2011)

1077-D5-2604 **Phil Gustafson*** (`pgustafs@coloradomesa.edu`), Colorado Mesa University, Mathematics Department, Grand Junction, CO 81501. *Student Voice Waves: Investigations using Calculus and Freeware.* Preliminary report.

Modeling and analyzing student generated sound waves is a great way for students to gain a better appreciation for applications of integration and series expansions. In this presentation we share a classroom activity that makes use of the freeware Audacity and FreeMat to capture and display student voice waves as well as to analyze their frequency content. (Received September 22, 2011)

1077-D5-2616 **Daniel J Gries*** (`dgries@hopkins.edu`). *Communicating calculus concepts using graphically presented functions in Adobe Flash applets embedded in WeBWorK.*

We will present a collection of applets created in Adobe Flash, and embedded into WeBWorK problems, which allow for the exploration of calculus concepts using functions which are defined only in terms of graphs. The applets allow for graphical communication of functions in both directions: students see functions only as graphs, while also being asked to draw functions by hand which satisfy certain criteria. This approach allows for a greater conceptual focus by removing algebraic tasks from the assessment of student understanding, while also getting away from the notion that all functions need to be defined by algebraic formulas. We will talk about some of the different techniques for randomly generating a sufficiently rich collection of well-behaved functions, along with some of the computational care required in finding features such as extrema and inflection points. This work has been supported by the NSF-CCLI grant DUE-0941388. (Received September 22, 2011)

1077-D5-2828 **Margaret L. Morrow*** (`morrowml@plattsburgh.edu`). *From Dilation to Similarity - an Exploration Using Geometer's Sketchpad.*

Similar figures can be defined in terms of the transformation dilation. We will share a sketchpad worksheet that guides students through an exploration of some interesting properties of dilation. En route students are introduced to similarity of geometric figures, and develop some strong intuitions about similar figures. We use this worksheet in an introductory level College Geometry class. (Received September 22, 2011)

1077-D5-2854 **Tibor Marcinek*** (marci1t@cmich.edu), Central Michigan University, Department of Mathematics, Pearce Hall 117, Mount Pleasant, MI 48858. *Motions and Rates: Using GeoGebra to Analyze Video Recordings.*

Moving objects are often used to illustrate applications of mathematics and derive important mathematical models. However, students' first-hand experience with these phenomena is problematic and textbooks heavily rely on rather abstract descriptions. Although stroboscopic images and their analysis may provide some experience, video recordings offer greater flexibility and potential to bring hands-on explorations of real motions into the classroom.

In the presentation, we will briefly explain how GeoGebra can be turned into a simple video player with play & pause button and a seek bar, and how its mathematical tools can be utilized to analyze recorded motions. We will share ready-to-use applets and ggb files with videos that represent typical mathematical models (free fall, projectile motion) as well as some phenomena recorded using special techniques (candle burning rate recorded in a time-lapse mode). (Received September 22, 2011)

History of Mathematics and its Uses in the Classroom

1077-E1-441 **Cynthia J. Woodburn*** (cwoodbur@pittstate.edu), Mathematics Department, Pittsburg State University, 1701 S. Broadway, Pittsburg, KS 66762. *Mayan Geometry in the Classroom.* Preliminary report.

When the mathematics of the Mayan civilization is studied, it is typical to include a look at their elegant numerical system and their elaborate calendar systems, but often Mayan geometry is overlooked. It has recently been discovered by archaeologist Dr. Christopher Powell, that instead of using a standard unit of measure in the geometry related to construction, the Mayans used certain standard proportions (including the golden ratio) that continue to be used by modern Maya shamans today. We'll take a look at Dr. Powell's findings and discuss how his results can be used as a hands-on activity with students in a variety of classes. (Received September 01, 2011)

1077-E1-562 **Amy Shell-Gellasch*** (shella@beloit.edu) and **Pedro Freitas**. *When a Number System Loses Uniqueness: The Case of the Maya.* Preliminary report.

The Maya of Central America had a very complex number system which is a modified base-20 system. It evolved out of their astronomical observations of Venus and their calendrics. The interesting consequence of this modified system is that is loses uniqueness. In this talk we will give a short overview of the Mayan number system and explain in what cases it does not express numbers uniquely. This material is interesting from a mathematical point of view and can also be used in a number of math and math history courses. (Received September 07, 2011)

1077-E1-592 **Toke L Knudsen*** (toke.knudsen@oneonta.edu). *Astronomical Instruments Between Theory and Practice.*

As a historian of mathematics with a strong interest in mathematical astronomy, I developed a course centered around the design and construction of astronomical instruments. The course, *Ancient Mathematical Astronomy*, was offered for the first time at SUNY Oneonta as a special topics course in Fall 2010. The central idea for the course was that pairs of students would utilize the theory presented in the course to design an astronomical instrument of their choice, which would later be constructed by the Science Technician. In turn, the process of designing the instrument and subsequently using it, including the inevitable problems that arise along the way, would reinforce the theory. Instruments designed during the course included the astrolabe, the armillary sphere, the plane sundial, the armillary sundial, and the sextant. The talk will detail the technical and historical contents of the course, and the role of the instruments in its execution. (Received September 08, 2011)

1077-E1-627 **David J. Pengelley*** (davidp@nmsu.edu), Mathematics, 3MB, New Mexico State University, Las Cruces, NM 88003. *Number theory à la Sophie Germain: a course of guided discovery from her research manuscripts on Fermat's Last Theorem.*

I have taught a first number theory course primarily through guided discovery studying Sophie Germain's early nineteenth century research manuscripts on Fermat's Last Theorem. Students learned almost every topic of a standard course by fathoming these original sources. I will discuss the content, the student response, and how the original sources enhanced guided discovery and just-in-time pedagogy. The course became a detective story, with students learning mathematics as needed to follow Germain's mystery trail to prove Fermat's Last Theorem.

Germain's handwritten manuscripts have only recently revealed that she had an extensive program to prove all of Fermat's Last Theorem. Her manuscripts require knowing precisely the topics in a first number theory course, e.g., unique factorization, Pythagorean triples, modular arithmetic, Fermat's Little Theorem, Lagrange's Theorem and modular roots of unity, primitive roots modulo a prime, orders of powers, etc. The goal was to have students learn all these topics by wrestling with Germain's writings (in English translation), supplemented with ancillary sources by Euler, Gauss, and Eisenstein on the quadratic reciprocity law. The course assumed only that students were capable at writing proofs. (Received September 08, 2011)

1077-E1-707 **Martin E Flashman*** (flashman@humboldt.edu), Department of Mathematics, Humboldt State University, Arcata, CA 95521. *Newton Estimates the Natural Logarithm of 2: A History Lesson for Calculus II.* Preliminary report.

The second semester of a calculus course has many mathematical themes including transcendental functions, estimation, integration, and infinite series. The author will illustrate the power of using original sources to show the interrelated nature of these themes with Isaac Newton's 16 decimal place estimate for the natural logarithm of 2 which appeared in "The method of fluxions and infinite series" [1671/1736]. (Received September 10, 2011)

1077-E1-1053 **Jim Fulmer***, jrfulmer@ualr.edu, and **Tom McMillan**, tcmcmillan@ualr.edu. *Exploring Prime Numbers in Classes with Preservice and Inservice Teachers.*

Prime numbers can be framed into a very interesting dialogue in classes for preservice and inservice teachers. Prime numbers have been studied for a long time. This session will focus on several topics about prime numbers: the prime number triangle, mirror primes, palidromic primes, Mersenne primes, Fermat primes, finding prime numbers by the sieve of Eratosthenes, Euler's formula for primes, counting primes, Sophie Germaine primes, largest-known prime, prime testing, and Goldbach's Conjecture. In addition, we shall discuss the question: Historically, is one a prime number or not a prime number? Some history of prime numbers will be included. The objectives of the presentation are: 1) To acquaint participants with the prime triangle, 2) To discover various patterns in the prime triangle, 3) To discuss a brief history of prime numbers, 4) To explore various types of prime numbers, and 5) To look at formulas to generate prime numbers. (Received September 15, 2011)

1077-E1-1174 **Scott B. Guthery*** (scott@docentpress.com), 2400 Beacon #208, Chestnut Hill, MA 02467. *Google Books and the Long Tail of Mathematics.*

A theorem proven by Lagrange in 1779 is just as true and and just as useful today as it was the day after he proved it. This is the long tail of mathematics. Google Books in cooperation with research libraries around the world is making a vast store of long-tail, "shoulders of giants" mathematics readily available to today's student, teacher, and independent scholar. This talk describes case studies in using open-access mathematics literature in the classroom and for independent study. Tips for using these resources are included. (Received September 17, 2011)

1077-E1-2008 **Dick Jardine*** (rjardine@keene.edu), Mathematics Department, Keene State College, 229 Main Street MS2010, Keene, NH 03435-2010. *A President, A. Partridge, and Practical Mathematics.* Preliminary report.

One of our founding fathers, who was also one of our young nation's significant scientists, carried on a mathematical correspondence about the calculation of the elevation of mountains. The exchange between two men actively engaged in "practical mathematics" during the Jeffersonian era includes application of geometry, trigonometry, and calculus. Included in the presentation is how this content has been included in undergraduate calculus and history of mathematics courses. (Received September 21, 2011)

1077-E1-2108 **H. Smith Risser*** (hrisser@mtech.edu). *Putting Mathematics Education Controversies in Historical Context.*

Many current controversies in mathematics education have deep historical roots. During a one semester history of mathematics course, students learned about the historical roots of several educational controversies using historical mathematical documents, commentaries on historical documents, and opinions from both educators and mathematicians. In this talk, three specific educational controversies presented in the course will be discussed: whether computational tools or computational algorithms are superior, whether abstract mathematics is less valuable than mathematics employed for a practical purpose, and whether symbolic representation should play a role in the introduction of mathematical concepts. The historical roots of each controversy will be presented along with bibliographies of the resources used for each topic. Although the presentation will focus on a history of mathematics course, the materials presented could be used in a wide range of courses including methods courses for preservice mathematics teachers and liberal arts mathematics courses. (Received September 21, 2011)

1077-E1-2233 **Steven R Benson*** (sbenson@lesley.edu), Division of Natural Science and Mathematics, Lesley University, 29 Everett Street, Cambridge, MA 02138. *Could they have known it generalized? Giving credit where credit is (probably) due.* Preliminary report.

There is not much written evidence of ancient Babylonian mathematics, but what has been found provides fascinating examples of intricate algorithms used to solve specific numerical problems (which we would now classify as quadratic equations). Some historians have claimed these ancient mathematicians could not have possibly understood whether their algorithms generalized to other problems since these generalizations would require more sophisticated mathematical understanding. I will provide arguments, developed with students in an undergraduate history of mathematics course, that show a feasible scenario for justifying the generality of these algorithms using mathematical tools available to mathematicians of the time. (Received September 22, 2011)

1077-E1-2271 **Dominic W Klyve*** (klyved@cwu.edu), 400 E University Way, Ellensburg, WA 98926. *Euler's "Letters to a German Princess": Translation and Betrayal.*

The "Letters to a German Princess" is the best-selling book that Euler ever wrote. Containing the most complete statement Euler ever wrote about his views on physics, optics, logic, religion, and philosophy, it was translated into eight languages, and remained in print for over a century. It influenced scientists, philosophers, and teachers, and has been hailed as an excellent example of a top scientist turning his attention to a wider audience. What is not well known is that most editions of Euler's work, including the only English translation, have been deliberated altered from Euler originally intended. As often as not, the editors and translations made no mention of these changes, leaving readers ignorant of the fact that they were not actually reading Euler's sentiments. This talk will examine Euler's work, some of the changes which have been made to it, and outline a path to making the original text available again to a wide audience. (Received September 22, 2011)

1077-E1-2390 **Maureen T. Carroll*** (carrollm1@scranton.edu), **Steven Dougherty** and **David Perkins**. *Torricelli and Robinson play Gabriel's Trumpet.* Preliminary report.

Every calculus student is familiar with the improper integral that shows Gabriel's trumpet to have finite volume. What they don't often see is the clever solution by indivisibles that Torricelli used to find this volume. In this talk we discuss his solution as well as the 17th century objections to this non-rigorous but highly intuitive technique. After briefly reviewing the fundamentals of infinitesimal calculus and its rigorous footing provided by Robinson in the 1960s, we are able to revisit this 17th century solution. In changing to an infinitesimal-based argument, we manage to salvage Torricelli's beautiful intuition. (Received September 22, 2011)

1077-E1-2668 **Duane K Farnsworth*** (dfarnsworth@clarion.edu), Department of Mathematics, Clarion University of Pennsylvania, 840 Wood Street, Clarion, PA 16214. *Bringing Sixteenth Century Mathematics into the Twenty-First Century Calculus Classroom.* Preliminary report.

In 1593, working nearly a century before the time of Newton and Leibniz, François Viète became the first person to find an infinite product representation for π. In this talk, I will discuss how the presentation of this eye catching result and its history can fit naturally into almost any calculus course. (Received September 22, 2011)

1077-E1-2677 **Charlie L Smith*** (charlie.smith@park.edu), 8700 NW River Park Drive, # 30, Parkville, MO 64152. *The History of Irrational and Transcendental Numbers; Classroom Benefits.*

This talk is the result of an independent study course which I taught in the Spring Semester of 2011. In that course I used Ivan Niven's classic "Irrational Numbers to study beautiful proofs about irrationality and transcendence which are accessible to undergraduate students.

Since then, I have been studying the history of irrational and transcendental numbers, using the abundant resources of the Linda Hall Library in Kansas City, Missouri. The research has not been exhaustive, but I have been able to identify the major players in the game. I will highlight the contributions of Liouville, Hermite, Lindemann, Weierstrass, Hurwitz, Gelfond, Niven and others.

The proofs of Hermite (e is transcendental) and Lindemann (π is transcendental) are quite long and fiendishly complicated. The ensuing years witnessed the discovery of new techniques and specific refinements which resulted in shorter, clearer proofs. The process seems to culminate in Niven, who published both a one-page proof of the irrationality of π and a 2.5 page proof of the transcendence of π.

The modern proofs of Niven are understandable to students and teachers, thus making it not only possible but convenient to teach and learn this subject matter. We are the beneficiaries of the historical process. (Received September 22, 2011)

1077-E1-2857 **Patricia Williams*** (pwilliams1101@lions.piedmont.edu) and **Elizabeth C. Rogers** (brogers@piedmont.edu). *A Partial Examination of the Evolution of Structural Design.*

The fields of mathematics, science and engineering are all different portals into the task of building a large structure. Science develops basic equations about the nature of our world, mathematics gives us the language to write these equations, and engineering takes them and turns them into concrete (or steel or wood) realities. Put another way, the scientist ponders "Why?";the mathematician gives us the "What?"; and the engineer devises the "How?". Entering through the mathematics portal, this paper will describe the historical development of four types of structures – cathedrals, bridges, skyscrapers and some ancient structures still in place today. How can we build a light and airy cathedral? How can we cross a river? How tall can we build a building? How did ancient engineers create structures that are still in place today? The evolution of the mathematics involved in the designs is featured. Some successes and some failures are presented since unfortunately some of the most enlightening lessons come from the process called trial and error. (Received September 22, 2011)

1077-E1-2935 **Charles F. Rocca*** (roccac@wcsu.edu), Western Connecticut State University, Dept. of Mathematics, 181 White Street, Danbury, CT 06776. *James Hamblin Smith's Euclid.*

"To preserve Euclid's order, to supply omissions, to remove defects, to give short notes of explanation and simpler methods of proof in cases of acknowledged difficulty - such are the main objects of this Edition of the Elements." - James Hamblin Smith

For over a thousand years Euclid was a gold standard for how geometry and arguably mathematics was to be done. Starting in the 17^{th} the field began to see not just minor grumblings but major changes. These came in waves with the rise of analytic geometry, followed by non-Euclidean geometries, the development of firmer ideas about axiomatic systems and Hilbert's axioms for Euclidean geometry. In the late 19^{th} century J.H. Smith prepared his edition of the Elements. While largely faithful to the design of Euclid, within Smith's text we see many references to necessary change to address the difficulties in Euclid. In this talk we will discuss some of the changes that Smith made and how his text can be used in an introductory course in Euclidean geometry to help students appreciate the geometry and its history. (Received September 23, 2011)

Innovations in Teaching Statistics in the New Decade

1077-E5-72 **Jeff A Suzuki*** (jeff_suzuki@yahoo.com), 39 Derrenbacher St., Kingston, NY 12401. *Mathematics and the Law: How Big Should a Jury Be, and How Should It Render Its Decision?*

The standard American jury consists of 12 persons who must render a unanimous verdict, though the Supreme Court has ruled that other sizes and quotas are permissible. We'll show how statistics on conviction and reversal rates, combined with stochastic models of how juries make decisions, can shed light on the wisdom of changing the size of a jury or the means by which it renders a decision. The resulting problems are suitable for inclusion in a broad range of courses, from the most elementary of statistics courses to independent study and graduate courses. (Received July 18, 2011)

1077-E5-741 **Judith E Canner*** (jcanner@csumb.edu), 100 Campus Center, Seaside, CA 93933, and **Jon Detka**. *Using R in an Undergraduate Statistics Course.*

The mention of utilizing R programming in an undergraduate statistics course is often met with trepidation from both students and professors. We believe that the introductory nature of an undergraduate statistics course provides an excellent venue for demonstrating the usefulness of the R language in statistical analysis. We will discuss how we have successfully incorporated R into an Applied Statistics course at Cal State, Monterey Bay. We will discuss our approach to designing lecture materials and weekly lab investigations that carefully scaffold concepts from Statistics with introductory R programming as a means of encouraging students to apply R programming techniques to statistical problem solving. We will discuss our approaches to equipping students with troubleshooting techniques and prepare students for their individualized take-home R practical exams. The use of open source freeware is not devoid of challenges. Installation issues and bugs can detract from student's learning of statistical concepts. In addition, students may struggle with vector concepts or deciphering coding errors and shift their efforts towards completing an assignment without interpreting errors and annotating code. We will present our strategies for helping students overcoming these obstacles. (Received September 12, 2011)

1077-E5-907 **David G Taylor*** (taylor@roanoke.edu), Roanoke College, Department of Mathematics, CS, and Physics, 221 College Lane, Salem, VA 24153, and **Adam F Childers** (childers@roanoke.edu), Roanoke College, Department of Mathematics, CS, and Physics, 221 College Lane, Salem, VA 24153. *Introductory Statistics with a Central Theme: "Statistical Reasoning" Courses That Interest Students.*

In its new general education curriculum, Roanoke College replaced the traditional optional "Introductory Statistics" course with a required core curriculum course called "Statistical Reasoning." These courses combine the traditional topics associated with an introductory course with overarching natural questions about a central theme that students explore throughout the semester. Rather than introduce statistical topics and use those to motivate examples, we introduce a question regarding the central theme and develop the statistical theory and methods to answer those questions. Example courses developed have included Statistics and the Weather, the Statistics of Sports, Statistics and Botany, and Here's to Your Health. We will talk about some of these courses, the positive benefits of this course design, and comparisons between our old model and new model for introductory statistics courses. (Received September 14, 2011)

1077-E5-1234 **Katarzyna Kowal*** (kkowal@ramapo.edu), School of TAS, Ramapo College of New Jersey, 505 Ramapo Valley Road, Mahwah, NJ 07430. *Teaching an effective multi-section elementary statistics course.* Preliminary report.

This paper presents a series of innovations that the author implements into teaching the elementary statistics course at Ramapo College. The innovations are based on the author's 8 years of experience of teaching the course and being the coordinator of all 5-9 sections of the course that have a common syllabus and a common final exam. The author will describe some effective usage of technology and of certain ancillary materials in the course's lectures, assignments as well as in individual and group projects. The author will present how it is possible to include in the course syllabus and to thoroughly cover the important for the new decade topic of hypothesis testing, having it preceded by all the proper and necessary background. Some alternative formulas and teaching methods that the author believes can be omitted by the course will be reviewed. Ramapo's Course Enrichment Component and some methods of how this course can fulfill such component will be discussed. One of such methods that will be presented involves assigning group projects that implement SENCER (Science Education for New Civic Engagements and Responsibilities) ideals into the course (the author applied for and received a SENCER-NSF 4-semester grant for implementing such ideals to her course). (Received September 18, 2011)

1077-E5-1341 **Kimberly J Presser*** (kjpres@ship.edu), Shippensburg University, Department of Mathematics, MCT 274, Shippensburg, PA 17257. *A Statistical Odyssey: Modernizing the Discussion Board to Enhance Student Engagement.* Preliminary report.

Odysseys2Sense is an online site that encourages student discussion through a virtual game. This presentation will focus on the experiences I have had using this platform in both a general education statistics course and a statistics class for mathematics majors. This system modernizes the concept of the discussion board in a number of ways, including requiring students to post a response before revealing other student responses and giving students anonymity in the discussions. I will discuss the pros and cons of using such a system from the instructor's perspective, as well as student feedback. (Received September 19, 2011)

1077-E5-1353 **Christina Erbacher*** (ceerbach@ncsu.edu), 2108 SAS Hall, Box 8205, Raleigh, NC 27695, and **Hollylynne Stohl Lee**. *Engaging Students in Reasoning About the Logic of Hypothesis Testing.*

Given the opportunity to introduce a class of undergraduate introductory statistics students to hypothesis testing, we sought a strategy that focused on developing the conceptual understanding of "p-values" and their role in hypothesis testing, rather than leaning on formulas and computations. Our paper [submitted to *Mathematics Teacher*] shares an adaptation of a teaching technique by Peter Howley (2008) used to introduce hypothesis testing. The lesson intends to help students articulate the logic of a hypothesis test by reasoning through a context and using graphs to indicate a rejection region before any formal terminology or processes are introduced. We will share the lesson, sample student responses, and a task to extend the lesson. Our approach to introducing hypothesis testing can be used to prompt a discussion in the group about the value of hypothesis testing in the curriculum and to hear approaches by others that promote meaningful understanding of this formal technique. (Received September 19, 2011)

1077-E5-1653 **Shonda Kuiper*** (kuipers@grinnell.edu), Department of Mathematics and Statistics, 1116 8th Ave, Grinnell, IA 50112. *Playing Games with a Purpose.*

This talk presents multiple strategies for using games in undergraduate statistics courses. Traditionally, we think of games as a distraction, just something that we do for fun. However, other disciplines have shown that well-designed games can dramatically impact learning by: (1) having a low threat of failure early on, but provide a challenging environment that grows with the students' abilities; (2) fostering a sense of engagement; (3) representing realistic but simplified models of current research in a variety of disciplines; and (4) providing an intrinsic motivation for students to want to learn. In addition to developing basic skills and understanding of material, games can encourage personal interest and social investments that lead students to take charge of their own learning. By making students grapple with intriguing simulations of real-world problems that demonstrate the intellectual content and broad applicability of statistics as a discipline, games can encourage students to incorporate statistical thinking into any field they are interested in. (Received September 20, 2011)

1077-E5-1660 **Julie Beier*** (beier_jc@mercer.edu), Mercer University, Department of Mathematics, 1400 Coleman Ave., Macon, GA 31201. *Statistics Scrapbooks in Elementary Statistics.*

When teaching Elementary Statistics we often desire to create students who are both consumers and producers of statistics. A project called a "Statistics Scrapbook" is an attempt to allow students an opportunity to do just that throughout the semester. Students are required to create entries that either examine and evaluate statistics they encounter in the world, or that collect data and use statistics to make an informed decision about a question of interest. We will discuss the implementation of this project including objectives, activities leading into this course project, how the project has matured, and evaluation. Additionally, we will present some samples of student entries. (Received September 20, 2011)

1077-E5-1824 **Kevin F. Cummiskey*** (kevin.cummiskey@usma.edu), MADN-MATH, 6406 Swift Road, West Point, NY 10996, and **William H. Kaczynski**. *Playing Games with a Purpose: Initial Lessons from the Classroom.* Preliminary report.

"Playing Games with a Purpose" is a National Science Foundation funded program to develop, implement, and evaluate Web-based games and corresponding investigative labs. Each game-based lab presents a research question in the context of a case study and encourages students to follow through a complete process of statistical analysis. *Tangrams*, based on the ancient Chinese puzzle game, is the first of these interactive games-labs to be implemented and tested in the classroom. *Tangrams* was developed by graduate students at Grinnell College under Dr. Shonda Kuiper and Dr. Sam Rebelsky. The associated lab was developed by Dr. William Kaczynski and Kevin Cummiskey of the United States Military Academy. In this presentation, I discuss my observations and lessons learned from its use in my calculus-based, introductory probability and statistics course taken by all students at the United States Military Academy. While this initial test occurred in an introductory course, *Tangrams* is easily adapted to more advanced undergraduate and graduate statistics courses. (Received September 21, 2011)

1077-E5-1849 **Lisa Carnell*** (lcarnell@highpoint.edu). *Using an Online Homework System in an Introductory Statistics Course: Instructor and Student Perspectives.* Preliminary report.

In this talk I will share my experiences using an online homework system in an introductory statistics course. I will discuss how implementing the system has impacted my own teaching and students' learning in the course. In addition, I will present survey results on students' attitudes toward this method of assigning and assessing homework. (Received September 21, 2011)

1077-E5-2007 **Christopher John Malone*** (cmalone@winona.edu), PO Box 5838, Winona, MN 55987, and **Tisha Hooks** and **April Kerby**. *Using Alternative Forced Choice Models to Introduce the Concepts of Statistical Inference.*

Cobb (2007) argues that the introduction of statistical inference is needlessly complicated because of its reliance on normal-based methods. As a result, several authors (e.g. Tintle (2011), Rossman, Chance, Holcomb (2010)) have advocated for introducing the concepts of statistical inference through simulations. These advances have resulted in the development of new curriculums which place more emphasis on the null model and the concept of a p-value. The authors have found that Alternative Forced Choice (AFC) scenarios are a natural way of introducing such concepts. These AFC scenarios are intuitive and interesting to students, and applications exist in several disciplines. The authors will share examples of AFC scenarios that appeal to a wide variety of students and are well aligned with recent developments in the teaching of statistical inference through simulations. (Received September 21, 2011)

1077-E5-2074 **Magdalena Luca***, 179 Longwood Avenue, Boston, MA 02115. *New Trends in Teaching an Introductory Biostatistics Course.*

This presentation will address innovative teaching methods used in an introductory biostatistics course for students enrolled in pharmacy and health sciences programs. In all the programs offered at the college, statistical literacy is absolutely essential in our students' understanding of drug development and administration, appropriate use of statistical methods in research literature, and in everyday life. Newly introduced teaching methods include the extensive use of "statistical applications" on TI84 calculators; "clickers" for assessing students' understanding and knowledge of newly introduced topics, but, more importantly, for stimulating discussion and communication in class; "scientific writing" for developing students' communication skills. While presenting these techniques, I will clearly identify the statistical topics that are eliminated from the course in order to be able to emphasize topics that are very important in making our course successful. (Received September 21, 2011)

1077-E5-2100 **Jennifer L. Green*** (jgreen11@unl.edu) and **Erin E. Blankenship** (eblankenship2@unl.edu). *Cutting Through the Theory: Emphasizing Statistical Thinking in Mathematical Statistics.*

The two-semester calculus-based undergraduate mathematical statistics sequence is typically a traditional, lecture-heavy course. Students leave the sequence with a set of skills that revolve around mathematics, but with little understanding about how the theoretical concepts they have learned connect to real statistical practice. At the University of Nebraska-Lincoln, we recently revised a long-standing undergraduate math stat sequence to focus more on conceptual understanding while still including the theoretical content of probability and inference students need to be successful in subsequent statistics or actuarial science courses. Through the use of non-traditional classroom activities, as well as newly developed assignments, we were able to promote student understanding and problem solving, as opposed to mere memorization and calculation. These non-traditional materials, in conjunction with more traditional assessments, allowed us to gain a more holistic picture of student understanding. In this presentation, we will provide examples of the activities and assignments used in two different iterations of the undergraduate math stat sequence, as well as discuss our personal experiences with their implementation. (Received September 21, 2011)

1077-E5-2317 **Patricia B Humphrey*** (phumphre@georgiasouthern.edu). *Statistics and the (Post-) Millennial Student.*

Students today are very different from when we, their professors and instructors were students. They Facebook, Google, text and Tweet (unfortunately, sometimes during class). Interaction with others has been boiled down to "soundbites" of 140 characters or less. They grew up with video games and SpongeBob (recently shown to be detrimental to attention and higher order intellect). We believe they are "tech savvy," but this is often not the case. We understand that GAISE encourages us to use real data in teaching, but are the examples we select interesting and attention-grabbing to them? How can we overcome these problems? We, their instructors are most likely programmed to teach in the same manner we were taught: a lecture followed by homework, quiz, etc. One possibility is to reorganize our teaching into smaller "bites." Another is to take advantage of social media. I'll discuss strategies I've used: their pluses and minuses as well. (Received September 22, 2011)

1077-E5-2338 **Todd Swanson*** (swansont@hope.edu), Hope College Mathematics Dept., 27 Graves Place, Holland, MI 49422-9000, and **Jill VanderStoep** (vanderstoepj@hope.edu), Hope College Mathematics Dept., 27 Graves Place, Holland, MI 49422-9000. *Introducing Statistical Inference using Randomization Methods.* Preliminary report.

For the past two and a half years, we have been using randomization based methods to introduce statistical inference. We have discarded topics from our traditional course and have reordered the remaining topics a number of times. Using randomization methods allows us to use the intuition students bring to class to introduce inferential statistics. This means from the first day of the course students begin to understand the structure of a test of significance, what a sampling distribution is, and what a p-value means. This early introduction to statistical inference allows us to build on this knowledge for the whole semester. Our students now develop a deeper understanding of the entire statistical process. We have also moved from a mainly lecture based class to one that is driven by group work, self-discovery, active-learning and tactile demonstrations using case studies, projects, and research articles. Our paper will include an overview of our curriculum, changes we have made to it along the way, an example we use in class, a class activity, and some assessment results. (Received September 22, 2011)

1077-E5-2429 **Chris Oehrlein*** (cdoehrlein@gmail.com). *Introducing Sampling Distributions and Hypothesis Testing using Hands-On Simulations and Student Response Technology.*

While computer applications can generate results and graphs representing thousands of trials of a simulated study, students can be left without a sense of ownership of the concept of a sampling distribution and how it is used in hypothesis testing. Trusting that the application and its representations were programmed accurately, they can learn from watching the sampling distribution grow, and it's mean and standard deviation change as the number of trials increases, but they are still not completely active participants and learners if they are doing no more than pressing keys or selecting options on a screen. Before this computer-simulated example can solidify the statistical concepts, students need to have a more concrete experience that includes predicting some expected value that a random process might generate, actually performing or simulating the trials themselves, and deciding if the actual data is a rare or common occurrence based on their outcomes as a class. Collecting this data from a class or groups of students can be a daunting task. Student response technology (clickers) used with a statistical analysis package can generate tabular and graphical representations of the partial sampling distributions quickly in a format that can be easily analyzed. (Received September 22, 2011)

1077-E5-2468 **Sean D Simpson*** (sean.simpson@sunywcc.edu), **Stacey Hancock**, **Jennifer Noll** and **Aaron Weinberg**. *From Tactile to Computer Simulation: An Intermediate Activity to Increase Understanding of Sampling Distributions.* Preliminary report.

Sampling distributions are foundational to introductory statistics curricula. Research has documented students' difficulties with this concept, indicating that students often confuse distributions of samples with distributions of sample statistics, apply the properties of the population distribution to the sampling distribution, and experience difficulty making sense of the variability of sample statistics and how this knowledge can be useful in statistical inference (Chance et al., 2004; Lipson, 2003; Saldanha & Thompson, 2007). We hypothesize that this difficulty arises due to students not fully understanding the process of repeated sampling and how this process is used to construct sampling distributions. To address this, we propose an "intermediate" stage between sampling activities and sampling- distribution activities in which students describe models for the repeated-sampling process and write instructions for carrying out the resulting simulation.

In this talk, we will describe this "model & simulation-describing" stage, provide an example of "bridging activities" between hands-on and computer-simulation methods that support this stage, and discuss results from our own classroom experiences. (Received September 22, 2011)

1077-E5-2503 **Milo Schield*** (Schield@Augsburg.edu), Augsburg College, Minneapolis, MN 55454. *Teaching Statistical Literacy Entirely Online: 2011.* Preliminary report.

Statistical Literacy is a catalog-approved course at Augsburg College. In 2011, this innovative full-semester course for students in non-quantitative majors was taught totally on-line in an accelerated six week format for the second time. The course used Moodle exercises and Odysseys2sense(TM): a revolutionary web forum that promotes civil discourse via anonymous peer review. Participants used Odyssey to discuss their analyses of statistics in graphs and short essays. This was an intense course. During the 6 weeks they completed 73 Moodle exercises averaging 10 questions each, they analyzed 14 news stories and they gave weekly feedback on the course. These exercises included calculating the influence of different definitions on the size of a statistic, calculating the change in an association after taking into account the influence of a binary confounder and calculating the number of cases attributed to a given factor. Student evaluations of the textbook, the Moodle exercises, the use of "Odyssey" and the online course are analyzed. This course demonstrates how critical thinking about statistics in the everyday media can be taught on-line at an accelerated pace in a way that encourages reflective dialog, is scalable for large classes and is manageable for the teacher. (Received September 22, 2011)

1077-E5-2547 **Kumer Das*** (kumer.das@lamar.edu), 200 G Lucas Engineering Building, PO Box 10047, Lamar University, Beaumont, TX 77710. *Value and Relevance of an Engineering Statistics Course.*

Students in engineering statistics courses are usually skeptical, especially at the beginning of the course, of the value and relevance of the subject matter. In fact, engineers usually do not consider statistical literacy as a compulsory component of their career. In this study, several approaches (for example, the use of good real examples and exercises, Moore method teaching, a short and personal interview/chat at the beginning of the semester) have been practiced to turn those students on to statistics. In this presentation, the pros and cons of these approaches will be discussed and few recommendations will be made. (Received September 22, 2011)

1077-E5-2567 **Michael D. Miner*** (jcmhs77@aol.com), 65 Edenbrook Drive, Hampton, VA 23666.
Engaging Adult Learners in the Application of Statistical Processes to Solve Real World Problems.

The non-traditional learning environment primarily involves adult learners who have for various reasons returned to or initiated studies in higher education to be more competitive in a highly competitive job market. To that end, the preponderance of these adult learners seek comparable degrees relevant to career fields. The majority of the programs available to them involve a business statistics course or a related research course that introduces research and statistics used in business decision making. A key practice that is highly effective in reaching course objectives and enabling students' understanding and success is to have students research current and relevant issues associated with their work environments, collect data on key variables, apply statistical processes, and provide a detailed report on findings along with the impact on the managerial decision making structure. This presentation will show the effectiveness of incorporating current and relevant real world problems that spans the statistics course. Two sample projects will be presented to show how students were successful in implementing changes in work environments as a result of completing the class long project. (Received September 22, 2011)

1077-E5-2631 **Heather Hulett*** (hhulett@uwlax.edu), Department of Mathematics, University of Wisconsin-La Crosse, La Crosse, WI 54601, and **Barbara Bennie** (bbennie@uwlax.edu), Department of Mathematics, University of Wisconsin-La Crosse, La Crosse, WI 54601.
Read and Reflect: Making Statistics Real.

In a general education statistics course, the applications of topics to the real world can be lost on students. Textbook problems rarely look like the statistics students encounter in their own field or in popular media, even if the text uses "real world" data. To overcome this deficit and to make statistical ideas more relevant to students, we incorporate current media articles into our Elementary Statistics course. Our "Read & Reflect" assignments allow students to see how the vocabulary and concepts being studied are used daily in both popular and professional journalism. Current articles are chosen that reflect the "just-in-time" learning of ideas just covered in class and also ideas from earlier in the semester, reinforcing basic principles that sometimes get forgotten as new material is covered. We will share some examples of our Read and Reflect activities and present an assessment of their impact on student attitudes and student learning. (Received September 22, 2011)

1077-E5-2763 **John D. McKenzie***, Math/Science Division, Babson College, 231 Forest Street, Babson Park, MA 02457-0310. *Teaching by the Test.*

This presentation examines how one may teach students by constructing some non-standard questions for mid-semester examinations. These questions build upon the class examples and assigned paper and electronic exercises that the students are expected to have mastered. Although this approach is not new, it is rarely used today for a number of reasons such as the benefits of "teaching to the test". The presentation describes in detail two examples of such questions used in an introductory, applied statistics course for undergraduates. The first addresses the question, "Why there are two criteria (via z-scores and boxplots) for determining outliers?". It uses a data set in which the two criteria yield different results. "What is a triangular distribution?" is the second question considered. This is a distribution that the students have not seen before but will definitely see in advanced applied quantitative courses. The presentation concludes the pros and cons of using such questions. (Received September 22, 2011)

1077-E5-2770 **Annela R Kelly*** (annela.kelly@bridgew.edu), 10 Stanley Avenue, Barrington, RI 02806. *Probability Density Functions from Real-World Applications.*

The talk will introduce motivating examples of probability density functions from actuarial science for more advanced statistics course. These applicational examples illustrate the concept of discrete and continuous probability density functions, and how to calculate expected value, standard deviation and covariance. First, this approach, introduces the students to the well-regarded actuary profession and to the actuarial science exams. Second, the use of these problems will reinforce the understanding of density functions the expected value; the standard deviation and the covariance. (Received September 22, 2011)

1077-E5-2782 **Charles Bergeron*** (chbergeron@gmail.com) and **David Clarke** (David.Clarke@acphs.edu). *Descent into 'The Abyss' of Least-Squares Linear Regression.* Preliminary report.

We teach a freshman course Introduction to Lab Data to freshman science students. Our emphasis is on developing an appreciation for harnessing the power of mathematics when doing science. In this paper, we present an activity on linear regression. We wanted to create an activity based on an engaging and interesting application while keeping the data collection process fast and simple. Our activity is based on a 7-minute clip from the James Cameron film The Abyss. In this clip, oil driller Bud descends into an undersea trench with depths reported by the other characters. Time is recorded from the video player. The time-depth relation is roughly linear. Using their data, students can produce a scatter plot, estimate linear model parameters, assess the goodness-of-fit, physically interpret the slope as Bud's speed and answer questions based on interpolation and extrapolation. The activity also reinforces the use of spreadsheet software to summarize and manipulate data. We found that audiovisual nature of the application appealed to our students. We think that this activity would be suitable for any linear algebra or statistics course that covers linear regression. We also present a similar activity based on a shorter clip from the same film. (Received September 22, 2011)

1077-E5-2901 **Alexander G. Atwood*** (atwooda@sunysuffolk.edu), SUNY Suffolk County Community College, Department of Mathematics, 533 College Road, Selden, NY 11784. *How the Analysis of Current Economic Growth, Income and Employment Can Be Used in Teaching an Introductory Statistics Course that Speaks to Students.* Preliminary report.

The statistical analysis of economic growth, of changes in income and of changes in employment opportunities provides a powerful way to motivate students to study Statistics in an introductory course. From the years 2000 to 2010, changes in several economic indicators serve to highlight what is happening in the USA. Although US economic output grew significantly in the last ten years, with per-capita Gross Domestic Product increasing by 8%, the average worker did not reap the benefits of this economic growth, with median household income decreasing by 4%. Furthermore, a dramatic increase in the productivity of workers from 2000 to 2010 of 32%, due to automation, computerization and increased efficiency, has led to a steep decline in the number of workers needed to power the growing economy, with 10% less workers needed to power the economy in 2010 compared to 2000, while the total population of the USA has increased by 10%. While we are living in a time of increasing economic prosperity, the average worker is seeing a decline in their standard of living and is chasing after vanishing employment opportunities. What does this mean to students in our Statistics classes, and what enlightened and innovative economic policies might be created to solve these problems? (Received September 22, 2011)

Innovative and Effective Ways to Teach Linear Algebra

1077-F1-274 **Donna A. Dietz*** (dietzd@seas.upenn.edu), Donna Dietz, Levine 572, 3330 Walnut Street, Philadelphia, PA 19104. *Combinatorial Scheduling: a way to motivate matrix multiplication and other important concepts.*

Combinatorial Scheduling (Ronald Graham, 1978) is an underused problem type which can be used to effectively teach a variety of Linear Algebra concepts. Students are encouraged to use matrices to model prerequisite graphs (posets), which leads directly to matrix multiplication as an obvious step in the solution. They also learn how to remove transitivity and loops from matrices (graphs). Scheduling problems can be easily adjusted to nearly every level of student, making them extremely versatile. Simple examples can be done easily by hand (for a Liberal Arts course), but more complex situations are also well-suited for programming exercises (particularly with MATLAB) for advanced students. (Received August 17, 2011)

1077-F1-421 **C. Ray Rosentrater*** (rosentr@westmont.edu), Westmont College, 955 La Paz Rd., Santa Barbara, CA 90108. *Connecting Linear Algebra Concepts.*

Commonly, students find that an intuitive or computational understanding of mathematical concepts suffices for success in mathematics courses taken prior to Linear Algebra. Consequently, students often are uncomfortable with the increased amount of mathematical vocabulary, the more technical nature of the ideas, and the greater use of theorems and proofs to connect concepts they encounter in Linear Algebra. I will present an interactive classroom review activity that I have found useful in helping students focus on clearly articulating Linear Algebra definitions and identifying conceptual connections. (Received August 30, 2011)

1077-F1-711 **Edward Early*** (edwarde@stedwards.edu), St. Edward's University, Austin, TX 78704. *Discrete Dynamical Fibonacci.*

Discrete dynamical systems provide a powerful application of eigenvalues and eigenvectors to a plethora of modeling problems. They also provide an elegant way of deriving the explicit formula for Fibonacci numbers. Come see how beautifully it works when set up properly (and how one small misstep can sabotage the lesson plan!). (Received September 11, 2011)

1077-F1-828 **Dragu Atanasiu*** (Dragu.Atanasiu@hb.se) and **Piotr Mikusinski**. *Teaching geometry using linear algebra.* Preliminary report.

Our goal is to draw attention to the fact that basic ideas from elementary linear algebra in $\mathbb{R}^2$ provide powerful tools for solving nontrivial problems in plane geometry. To prove our point we present solutions of four geometry problems from four consecutive International Olympiads (2007-2010) using linear algebra. Standard preparation of students participating in mathematics competitions emphasizes classical geometric methods while neglecting linear algebra. This is true also for every student in a College Geometry course. Concepts of linear algebra are present in practically all areas of mathematics. Using linear algebra when practicing solving geometry problems students will use their creativity with ideas they are most likely use in the future. On the other hand, while classical geometry is beautiful, it has a rather limited area of usefulness. Moreover, geometric proofs often require quite ingenious ideas and thus are prohibitively difficult for many students. Since the proofs based on linear algebra are more straightforward, the same problems become accessible to a larger number of students. (Received September 13, 2011)

1077-F1-872 **Tanya Berezovski** (tberezov@sju.edu), St. Joseph's University, Department of Mathematics, Philadelphia, PA 19131, and **Tyler Gaspich*** (tg450283@sju.edu). *Using Dynamic Geometry Software to Foster Students' Understanding of Vectors.*

Fundamental linear algebra concepts such as scalar multiplication and vector addition require students to have strong computational skills and the ability to visualize. While computational algorithms are more accessible, visual representations prove to be rather difficult to many freshmen. In this study we investigate the impact of using The Geometer's Sketchpad on students' understanding of fundamental concepts of linear algebra. The intervention consists of a set of dynamic geometry activities. These activities range from simple tasks on the definition of a vector to conceptually challenging tasks on multiple representations or vectors, targeting students' understanding of vectors. Pre/post-tests were administered to measure the change in participants' knowledge. It is found that the designed dynamic geometry tasks provided students with experimental and modeling tools, and allowed them to deepen their conceptual knowledge. Several specific activities and their benefits, including instructional and assessment, will be presented. (Received September 13, 2011)

1077-F1-879 **Michael Josephy*** (michael.josephy@ucr.ac.cr). *Linear Algebra Projects for Computer Science Majors in Costa Rica.* Preliminary report.

For the last several years we have been coordinating the linear algebra course required of Computer Science majors at the Universidad de Costa Rica. Students must submit two or three group projects during the semester, following an outline of some six questions distributed online. The project obliges the students to look more deeply into an advanced topic in linear algebra, using internet resources, mathematical software, and their own analysis. Each term the project is different. Recent subjects have included Hilbert matrices, Möbius transformations, Moore-Penrose inverses, Sudoku matrices, rank one matrices and the LU-decomposition. (Received September 13, 2011)

1077-F1-920 **Nathan M Wodarz*** (nwodarz@uwsp.edu), Department of Mathematical Sciences, University of Wisconsin - Stevens Point, 2100 Main Street, Stevens Point, WI 54481. *Reinforcing Basic Linear Algebra Skills Using Computer Animation.*

My department offers two linear algebra courses. The first is the standard sophomore level course, and the second is taken after completing a proofs course. In practice, instructors find little retention from the sophomore level course to the upper level one.

In an attempt to make the review of the first class more exciting for the class, I decided to modify a project involving computer animation that I had previously used in a sophomore level course. Students were expected to first construct a model using vectors in *Mathematica* and then to manipulate the model in progressively more sophisticated ways. In this way, students were exposed to review material involving vectors and linear transformation in a more gentle fashion than I had previously been able to accomplish. The project also exposed students to related concepts which don't usually fall into the curriculum, such as homogeneous coordinates and affine transformations.

Example projects will be presented, as well as qualitative and quantitative data comparing student achievement on prerequisite material. (Received September 14, 2011)

1077-F1-1022 **Daniel A. Ramras*** (ramras@nmsu.edu). *The Wronskian as a method for introducing vector spaces.*

One challenge in most linear algebra classes is the jump from R^n to the general notion of a vector space. I'll discuss a method for introducing vector spaces that focuses on the example of real-valued function spaces. These are different enough from R^n to be new and interesting, yet concrete and familiar enough for students to explore on their own with the proper guidance. I'll describe a method helping students discover various ideas like linear combinations, linear independence, and linear transformations in the context of function spaces, culminating in Wronskian matrix and its application to independence of functions. (Received September 15, 2011)

1077-F1-1071 **Don Spickler***, Salisbury University, 1101 Camden Ave., Salisbury, MD 21801. *Linear: Maxima Edition.*

The Linear project is an ongoing software development project at Salisbury University that was started in 2007 with the goal of developing an easy to use teaching and exploration tool for undergraduate linear algebra courses. The package was designed, written and is maintained by both faculty and students at Salisbury University. Our latest addition to the package is the incorporation of the Maxima computer algebra system as a back-end calculation engine, giving Linear the capability of a full CAS while still remaining easy to use, cross platform, and free. In addition to adding many options, as a result of the use of Maxima, we incorporated a LaTeX parsing engine into the display system for textbook-like displays of matrices and expressions. In this talk we will demonstrate some of the advances made to the latest version of the program and showcase some of its more pedagogical features. (Received September 16, 2011)

1077-F1-1193 **William O. Martin*** (`william.martin@ndsu.edu`), **Jeff Suzuki** (`jeff_suzuki@yahoo.com`), **Draga Vidakovic** (`dvidakovic@gsu.edu`), **Sergio Loch** (`sloch@grandview.edu`), **Laurel A Cooley** (`lcooley@brooklyn.cuny.edu`), **Catalin Ciuperca** (`catalin.ciuperca@ndsu.edu`) and **Scott Dexter** (`sdexter@brooklyn.cuny.edu`). *LINE (Linear Algebra in New Environments): Using Learning Theories to Design Linear Algebra Modules.* Preliminary report.

A group of mathematicians and mathematics education researchers have been investigating ways to incorporate research on the teaching and learning of mathematics to shape instruction in upper division undergraduate linear algebra courses. In this session we will provide an assignment on linear maps that was designed with attention to learning theories. The assignment culminated with the problem: Prove that if $W \subseteq U, V$, all vector spaces, and $T : W \to V$ is a linear map, then there exists $S : U \to V$, a linear map such that $S(\alpha) = T(\alpha)$ for all $\alpha \in W$. The module was used in an advanced linear algebra course at a Midwestern land grant university. We will describe the development of the module and share our analysis of student thinking processes in terms of a learning theory. We also will discuss how the interaction of mathematics education researchers and mathematicians has influenced the thinking of both about the teaching and learning of undergraduate mathematics. The work was supported in part by NSF DUE-0837050 (Received September 17, 2011)

1077-F1-1242 **Sukanya Basu*** (`basus@gvsu.edu`), Department of Mathematics, A-2-178 Mackinac Hall, 1 Campus Drive, Allendale, MI 49401-6495. *A Comparison of Different Pedagogical Approaches to Linear Algebra.*

In this talk, we will explore the four key ideas of linear combination, span, linear independence and basis in Linear Algebra from three different viewpoints, namely, algebraic (formula-oriented), geometric (visualization-oriented) and numerical (matrix-oriented). We will also compare pros and cons of using each viewpoint over the other when introducing these ideas in the classroom. Finally, we will explore connections between these key ideas from Linear Algebra and other areas of mathematics such as Multivariable Calculus and Differential Equations. (Received September 18, 2011)

1077-F1-1437 **Tim Chartier*** (`tichartier@davidson.edu`), Department of Mathematics, Davidson College, P.O. Box 6908, Davidson, NC 28035. *Muggle Magic with Matrix Arithmetic.*

Matrix arithmetic is a powerful tool in part due to its speed of computation. This talk will illustrate the usefulness of these tools by casting spells as if linear algebra were our wand. Matrix addition will enable Harry Potter to disappear in the halls of Hogwarts. Multiplication with permutation matrices will cast a levicorpus spell, flipping a person on the spot. We will also pull a spell from outside arithmetic and visit the diagonal as we transition down Diagon Alley. (Received September 19, 2011)

1077-F1-1585 **Jeff R. Knisley*** (`knisleyj@etsu.edu`). *On Generating Large Dimensional, Hand-Calculable Exercises and Applications.*

One of the challenges in Linear Algebra is in developing problems, projects, and exercises that are both larger dimensional and student-accessible. Indeed, round-off error, computational complexity, difficulty factoring characteristic polynomials of degree 3 or higher, and similar aspects often mean that any problems or applications of rank 3 or higher are approached solely via technology.

However, that same technology can be used to create student-accessible problems and applications of ranks 4 or 5 or even higher, even allowing the creation – if desired – of a technology-free course featuring only hand-calculable problems. In this presentation, we present a freely downloadable Maple worksheet that produces these types of problems. Moreover, it can be used to create hand-calculable applications of arbitrarily large rank involving stochastic matrices, eigenvalues and eigenvectors, Leslie matrix models, the simplex method, and several others. Options include the ability to restrict to integer arithmetic and limits on the number of operations required. (Received September 20, 2011)

1077-F1-1698 **Paul E. Becker*** (peb8@psu.edu) and **Mark Medwid**. *Group Theory in the Linear Algebra Classroom.* Preliminary report.

Computer algebra systems are now widely available in college classrooms. In this environment, Cayley's theorem becomes a unifying concept across abstract algebra, linear algebra, geometry, and other courses. We discuss the representation of small groups by concise block-diagonal binary matrices. We then discuss Maple lab experiences which simultaneously develop fundamental concepts in group theory and linear algebra. We concentrate on a recent senior-level linear algebra course, in which group theory provided an introduction to some of the standard topics. (Received September 22, 2011)

1077-F1-1720 **Martha Ellen Waggoner***, 701 N C Street, Indianola, IA 50125. *Discovery learning in linear algebra using dynamical geometry software.*

I have developed several Geometers Sketchpad sketches that students can use to help them understand transformations, eigenvalues, eigenvectors and a geometrical interpretation of the determinant. These dynamic sketches are used in discovery learning exercises in a computer classroom. In this talk I will demonstrate a couple of sketches, explain how they are used in the classroom and report on student feedback. (Received September 20, 2011)

1077-F1-1812 **Sang-Gu Lee** (sglee@skku.edu), Dept. of Mathematics, Sunkyunkwan University, 300 Cheoncheon-dong, Jangan-gu, Suwon, Gyeonggi 440-746, South Korea, and **Kyung-Won Kim*** (kwkim@skku.edu), Dept. of Mathematics, Sunkyunkwan University, 300 Cheoncheon-dong, Jangan-gu, Suwon, Gyeonggi 440-746, South Korea. *Full Sage Contents of Introductory Linear Algebra.*

Sage-Math has proved to be an efficient tool that can handle most standard exercises in linear algebra. Since after we realized it, we have done an extensive experimental research, and developed approximately one hundred basic commands in Sage-Math for most of the concepts and computational needs of an introductory linear algebra course. These tools can be found on our website on contemporary linear algebra with Sage: http://matrix.skku.ac.kr/2011-sage/sage-la. In this talk, we introduce the contents and discuss how to utilize it for an effective teaching of linear algebra. (Received September 21, 2011)

1077-F1-1813 **Sang-Gu Lee*** (sglee@skku.edu), Dept. of Mathematics, Sungkyunkwan University, 300 Cheoncheon-dong, Jangan-gu, Suwon, Gyeonggi 440-746, South Korea. *Mobile Math Applications for the Second Course of Linear Algebra.*

We show that the Smartphone and Sage-Math have features that can be effectively used for learning of the second course of linear algebra. We provide mobile contents, which contain lecture notes, video lectures, solutions of problems, computational tools and social networking features for the second course of linear algebra. Now students can have a whole process of learning mathematics in their hand. This has the potential to change in an innovative and effective manner the teaching of linear algebra. In this talk, we present this new application and contents. Further, we discuss how those changes may affect the students' future learning of the second course of linear algebra. (Received September 21, 2011)

1077-F1-2328 **Megan Wawro*** (mwawro@vt.edu), Virginia Tech, Mathematics Department, 460 McBryde Hall, Blacksburg, VA 24061-0123, and **Christine Larson** (christine.j.larson@vanderbilt.edu). *A Hypothetical Learning Trajectory for Conceptualizing Matrices as Linear Transformations.*

A hypothetical learning trajectory is a plausible storyline about teaching and learning that details learning goals, instructional tasks, students' learning progression, and the role of the teacher. In this presentation, we articulate a hypothetical learning trajectory (HLT) designed to support students' development and elaboration of a transformation view of matrix multiplication. The major learning goals of this HLT are (a) conceptualizing a matrix as a mathematical object that transforms input vectors to output vectors, (b) interpreting matrix multiplication as the composition of linear transformations, and (c) developing the imagery of an inverse as "undoing" the original transformation. Furthermore, the instructional tasks are designed to support students in coming to view matrices as objects that geometrically transform a space. Within this HLT, we aim to extend students' conceptualization of the "matrix acting on a vector" view of a matrix times a vector to a more global view of a matrix transforming an entire space, as opposed to the localized view wherein matrices are conceived transforming one vector at a time. (Received September 22, 2011)

1077-F1-2686 **Jeffrey M Hokanson*** (jeffreyh@rice.edu), Rice University, 6100 Main Street - MS 134, Houston, TX 77005, and **Steven J Cox** and **Mark Embree**. *A Physical Laboratory for Linear Algebra.*

Although numerical experiments provide convenient demonstrations of linear algebra concepts, students often find physical experiments more compelling. In 2007, we introduced an optional physical lab component to accompany Rice's introductory matrix analysis class. This lab invites students to replicate examples from the course, e.g., linear systems modeling resistor networks and trusses, using custom physical hardware. Students recreate Daniel Bernoulli's multiple pendulum experiment by displacing the pendulum in its eigenvectors; video capture technology confirms that generic solutions are a superposition of eigenvectors. Three inverse problems challenge students to extend their capabilities: discrete electrical impedance tomography, parameter recovery in a spring network via least squares, and an inverse eigenvalue problem on a beaded string. This lab course unites theory, computation, and experiment. (Received September 22, 2011)

1077-F1-2689 **Stephen Hilbert*** (hilbert@ithaca.edu). *Using N-dimensional Geometry as a Thread to Increase Geometric and Abstract Reasoning in Linear Algebra.* Preliminary report.

I use the idea of n dimensional (with n >3) geometry as a continuing thread in my sophomore level linear algebra course. This enables the course to strengthen the students' geometrical intuition and also to increase their skill at abstraction. The only prerequisite for this course is Calculus 2 and the majority of students are not math majors. Since computing solutions to linear systems of n equations and finding eigenvalues for n dimensional matrices is simple with technology, the course emphasizes how to use computations to expand geometric ideas to higher dimensions. One of the basic ideas is to use 2 and 3 dimensions as "labs" where we can see the geometry and then extend the geometric ideas to higher dimensions by using computational analogies. I will present examples of this technique as well as ways to add a geometric component to test questions and in class examples. The presentation will also include some examples to convince the students that learning about problems that are more than 3 dimensional is useful and interesting. (Received September 22, 2011)

1077-F1-2712 **Tom Edgar*** (edgartj@plu.edu), Department of Mathematics, Pacific Lutheran University, Tacoma, WA 98447. *Web 2.0 for Linear Algebra Classes.*

We discuss utilizing a few techniques involved in the Web 2.0 movement for teaching Linear Algebra at liberal arts colleges. We focus on the use of a course wiki as a place to involve students in the understanding of important definitions and provide avenues of communication for our students. Additionally, we present the idea of using online video tutorials about computer algebra software to enhance the course experience. By using relatively new screen-capturing software, we can teach students how to use software packages (in particular Sage) to do routine computations required throughout the course. We describe our experience with these techniques and mention the benefits of using tools like these, including increased student involvement and increased use of relevant technology without wasting precious in-class time. (Received September 22, 2011)

Mathematical Preparation of Teachers: The Impact of the Common Core State Standards Initiative

1077-F5-222 **Teresa D Magnus*** (tmagnus@rivier.edu), Department of Mathematics and Comp Sci, Rivier College, 420 S. Main St., Nashua, NH 03060, and **Ann Gaffney**. *Uncovering and Discovering: CCSS Mathematical Process Standards in a Mathematics Course for Middle School Teachers.*

Offered for the first time in summer 2011, this intensive one-week team-taught course engaged current and prospective teachers in developing a deeper understanding of middle school mathematical content through co-operative problem solving activities. Content included most of those listed in the CCSS standards such as operations on whole numbers, rational numbers, integers, and algebraic expressions, as well as measurement, geometric formulas and relationships, proportional reasoning, rational number representations, indeterminates, sequences, functions, quantitative literacy, percents, and probability. While the content itself was a review for the participants, the experience of rediscovering and further uncovering these concepts through active learning and problem solving was a rich, enlightening experience for all participants. They made sense of problems, developed conjectures, observed the different approaches that others took, discussed the importance of moving from concrete to abstract understanding, and critiqued and taught each other. Participants regularly expressed that they had not only gained a better understanding of the mathematics they might teach, but also that they developed an appreciation for cultivating mathematical habits of mind in their students. (Received August 25, 2011)

1077-F5-795 **Davida D Fischman*** (fischman@csusb.edu), 5500 University Pkwy., CSUSB Department of Mathematics, San Bernardino, CA 92407. *Early Implementation of CCSS via Standards for Mathematical Practice.*

In considering changes in preparation of teachers, it can be useful to learn from work with in-service teachers. We have been using the CCSS Standards for Mathematical Practice (SMPs) as a bridge connecting current standards and teaching approaches to the content and approaches intended by the CCSS. I will discuss what we have done to gain the support of administrators and the interest of teachers, how this work is progressing in several districts in our service area, and how we are modifying the CSUSB teacher preparation program based on preliminary conclusions from this work.

Few teachers or local administrators in the US have much understanding of the CCSS: the fundamental changes in approach to teaching mathematics, or of the changes in the content of the standards. We have found that an effective way to address this issue is to introduce the SMPs, and to advocate for their use as support for current content standards while preparing for the future. Through this lens teachers and administrators have become excited about the CCSS, and teachers have willingly participated in professional development that assists them in understanding and implementing the SMPs; they have developed an interest also in learning about changes in content standards. (Received September 12, 2011)

1077-F5-859 **Tanya Berezovski*** (tberezov@sju.edu), St. Joseph's University, Department of Mathematics, Philadelphia, PA 19131. *Developing Teachers' Flexibility in Geometry: Addressing the CCSS Mathematics Objectives.*

The Common Core Standards place greater emphasis on high school students' understanding of geometric concepts, particularly through study of both synthetic and analytic approaches. In our study we investigate teachers' preparedness to integrate multiple-solution tasks into their teaching practice. In this talk we will discuss a geometry course that was designed for practicing high school teachers. One of the primary goals of this course was to make teachers aware of how to use multiple-solution tasks effectively in their instruction, as well as to impact teachers' own flexibility in geometry. We will also present our analysis of teachers' experiences that suggests that teachers began to expand their instructional repertoire, integrating multiple-solution tasks. (Received September 13, 2011)

1077-F5-979 **Leigh M. Harrell Williams*** (leighh@vt.edu), **Teri J. Murphy**, **M. Alejandra Sorto**, **Rebecca L. Pierce** and **Lawrence M. Lesser**. *Aligning the Self-Efficacy to Teach Statistics (SETS) Instrument to the Common Core State Standards for Mathematics.*

Research in mathematics and science education has shown that teacher knowledge and beliefs affect teachers' effectiveness in a classroom. We have developed the Self-Efficacy to Teach Statistics (SETS) instrument, based both on states' mathematics standards for students and teachers and on the Guidelines for Assessment and Instruction in Statistics Education (GAISE) Pre-K-12 Report (ASA, 2007). The SETS is designed to measure pre-service middle school teachers' self-efficacy to teach topics at levels A and B of the GAISE framework. The items on the SETS instrument ask teachers to rate their self-efficacy on a scale of 1 (not confident at all) to 6 (completely confident). We conducted a validation study on the instrument which resulted in a Cronbach's alpha estimate of reliability of .958 (Harrell, Pierce, Sorto, Murphy, Lesser, & Enders, 2009; Sorto, Harrell, Pierce, Murphy, Enders, & Lesser, 2010). In this presentation, we will show the degree of alignment of the instrument to the Common Core State Standards for Mathematics (www.corestandards.org) regarding statistical skills and knowledge. We will also discuss current as well as potential uses of the SETS instrument for assessment of teacher preparation, program evaluation, and professional development for in-service teachers. (Received September 15, 2011)

1077-F5-1012 **Elizabeth A. Burroughs*** (burroughs@math.montana.edu), Department of Mathematical Sciences, PO Box 172400, Bozeman, MT 59717. *Professional Development for Grades K-8 Mathematics Coaches.*

This paper describes aspects of a 45-hour professional development course in coaching knowledge for practicing K-8 mathematics instructional coaches that address the Common Core State Standards mathematical practices.

The professional development course is part of a research project investigating knowledge that contributes to successful K-8 mathematics instructional coaching. A coach can be broadly defined as a person who works collaboratively with a teacher to improve that teacher's practice and content knowledge, with the ultimate goal of affecting student achievement. In seeking to contribute to a comprehensive understanding of the effectiveness of mathematics instructional coaching, this research project offers two types of professional development courses: one in mathematics content knowledge, and one in coaching knowledge. Because of the widespread adoption of the CCSS that has occurred since the research study began, the project has had the opportunity to scrutinize its definition of standards-based instruction for coaches. This paper describes changes to the curriculum of both courses in response to CCSS standards and assessments. (Received September 15, 2011)

1077-F5-1533 **Barbara Henriques** (bhenriques@sjc.edu) and **Ekaterina Lioutikova*** (elioutikova@sjc.edu). *Integrating content, pedagogy, and cognitive coaching: a professional development model.* Preliminary report.

Acceptance of the Common Core Mathematics Standards by the majority of states leads to a renewed need for professional development efforts to support practicing teachers of mathematics. In this talk, we describe the Innovative Mathematics Academy Advancing Learning and Leadership ($\mathrm{IMA}^2\mathrm{L}^2$), a content-based program for teacher leaders developed at Saint Joseph College in partnership with the Consolidated School District of New Britain, CT. The program, supported by a state MSP grant, is currently in its second year. Learning activities are designed to emphasize careful mathematical reasoning and to help K-8 teachers develop the habits of mind of mathematical thinkers, which directly relates to the demands of CCSS. Program participants also develop Cognitive Coaching skills as to promote teacher mentoring, educational collaborations and continued professional development in schools. (Received September 20, 2011)

1077-F5-2050 **Tommy Smith*** (tsmith@uab.edu), School of Education - UAB, Birmingham, AL 35294-1250, **John C Mayer** (mayer@math.uab.edu), Dept. of Math - UAB, Birmingham, AL 35294-1170, and **Donna Ware** (wared@uab.edu), Dept. of Math - UAB, Birmingham, AL 35294-1170. *Inquiry-Based Courses at UAB for Prospective Elementary and Middle School Teachers Modeling the Standards for Mathematical Practice.*

A series of inquiry-based mathematics courses were developed and are being implemented at UAB. These courses are a part of a mathematics track aimed primarily at preparing middle school mathematics teachers, with two of the courses having a majority enrollment of elementary education majors. This presentation will share experiences from these two courses, MA 313, Patterns, Functions, and Algebraic Reasoning, and MA 314, Geometric and Proportional Reasoning. The inquiry-based focus of these courses uses pedagogy which models many of the Common Core Standards for Mathematical Practice. Students regularly engage in group problem solving tasks that often involve hands-on investigations. The courses emphasize reasoning and sense making and seek to develop in students productive dispositions such as perseverance in problem solving. A key feature developed in the process is communicating mathematics to others in written and oral form. Students lead group and whole class discussions of problems. In group and individual problem solving tasks, students learn to represent problems numerically, using words, using graphs, algebraically, and using physical models. The ultimate goal of these courses is to develop mathematically proficient students who will be teachers. (Received September 21, 2011)

1077-F5-2087 **Yating Liu*** (liu.891@buckeyemail.osu.edu). *Enhancing the content knowledge of pre-service secondary mathematics teachers: Understanding connections.*

The Common Core Standards propose development of understanding regarding two aspects of mathematics learning: 1. How the content is connected to each other as components of the subject; and 2. How forms and representations of concepts evolve from informal to more formal levels. These two goals demand that the teachers possess a deep understanding of content trajectory, which is often missing from their own mathematics coursework. This gap motivated the development of a new graduate course at the Ohio State University. Using the NCTM Curriculum Focal Points, Crossroads in Mathematics Standards, and CCS as framing models for curriculum and instructional design, the course content is organized to engage participants in examinations of key ideas of Arithmetic, Algebra, Pre-calculus and Calculus, Number Theory, Linear Algebra, Abstract Algebra, Geometry, and Probability in K-16 in order to trace the trajectory of specific concepts. The participants study secondary curriculum materials and evaluate their utility for meeting the suggested standards. They design tasks that focus on identifying connections among various mathematical concepts and hence to create lessons that nurture conceptual understanding. We will share the course syllabus as well as illustrative examples of tasks. (Received September 21, 2011)

1077-F5-2581 **Bernadette Mullins*** (bmullins@bsc.edu), Department of Mathematics, Birmingham-Southern College, Birmingham, AL 35254, **Faye Clark**, AL, **Ann Dominick**, AL , and **Sherry Parrish**, AL. *The Standards for Mathematical Practice: Principles Guiding Pre-service Preparation and In-service Professional Development.* Preliminary report.

A professional development institute for in-service teachers (36 contact hours) has been developed to illustrate the Common Core Standards for Mathematical Practice. Experienced teachers who have had the opportunity to read and discuss the Practice Standards with peers expressed the need to better understand them. During this institute, teachers engage with inquiry-based mathematical tasks that allow them to see each of the eight Practice Standards in action. Between sessions, teachers intentionally focus on one of the standards and reflect on the extent to which their students show evidence of the practice. A course to be offered to pre-service teachers will also incorporate these tasks and discussions. The content standards addressed by this course are Number and Operations Fractions, The Number System, and Ratios and Proportional Relationships. Both in-service and pre-service offerings were developed by the NSF-funded Greater Birmingham Mathematics Partnership. (Received September 22, 2011)

1077-F5-2643 **Gregory D Foley*** (foleyg@ohio.edu), 117 McCracken Hall, Athens, OH 45701. *Advanced Teacher Capacity in Mathematics and the Common Core.*

The Advanced Teacher Capacity (ATC) project develops technological, pedagogical, and content knowledge among teachers in Grades 11-12 via two yearlong courses: Quantifying Uncertainty and Analyzing Numerical Trends (QUANT) and Modeling and Spatial Reasoning (Modspar). QUANT focuses on data analysis, probability, and statistical reasoning; selecting and enacting cognitively demanding instructional tasks; and using data collection devices, spreadsheets, and interactive statistical software. Modspar addresses discrete, continuous, and geometric modeling and spatial reasoning; creating and implementing cognitively demanding student assessments; and using graphing and geometry applications, including spherical and three-dimensional interactive geometry software. This session will describe these courses and their relationship to the Common Core State Standards for Mathematics and will present the results of the related research since 2007. The session will explain how the standards for mathematical practice are integrated into QUANT and Modspar and how these courses could be adapted to preservice teacher preparation. (Received September 22, 2011)

1077-F5-2746 **Juliana V. Belding***, jbelding@math.harvard.edu. *Designing Professional Development around the CCSS Standards for Mathematical Practice: A Mathematician-Teacher Collaboration.*

The Common Core State Standards, launched in 2010 and now adopted by forty-four states, include a set of standards for mathematical practice which may seem second nature to mathematicians. We will talk about how these provide a unique opportunity for mathematicians and educators to design professional development around the standards, i.e. to create mathematical experiences in which the standards arise naturally. In particular, we will discuss an example of a four-day seminar on geometric transformation and complex arithmetic for 7-12 grade in-service teachers which was designed and led by a team of middle and high school teachers and university mathematicians from the Focus on Math Math-Science Partnership in Boston. (Received September 22, 2011)

1077-F5-2908 **Elizabeth C. Rogers*** (brogers@piedmont.edu), 165 Central Ave., Demorest, GA 30535. *Using Experience from the Past to Move Forward to the Common Core State Standards.*

As most states ponder the impact of the Common Core State Standards Initiative, Georgia reflects on the successes and failures of a very similar set of standards. After study and review by educators and other stakeholders, most feel the Georgia Performance Standards (GPS) in Mathematics will need only minor revision to conform to the CCSS model. This presentation will reflect on the changes that have been implemented by a private liberal arts college in the preparation of elementary, middle grades and secondary mathematics teachers at the four-year, masters, six-year and doctoral degree levels. With experience based on the past eight years, we will discuss the changes in vision, outlook and mathematics curricula that have accompanied the GPS. This presentation will also explore options and initiatives that are being considered for teacher preparation programs as we merge into the transitional phase of the CCSS. Finally, long term goals for adapting assessments to be consistent with the CCSS and to provide continuing resources for teachers currently in the classroom will be considered. (Received September 22, 2011)

1077-F5-2914 **Taliesin Sutton*** (tsutton@email.arizona.edu) and **Nicole Kersting**. *Using Video Excerpts from Authentic Mathematics Classrooms to Demonstrate the Mathematical Practices at Various Grade Levels.* Preliminary report.

The Standards for Mathematical Practices provide a decomposition of the habits, dispositions, and identities of critical thinkers and adaptive problem solvers. As such, they represent not just an important part of students' mathematics education but a vital part of their general education. Of course, teaching students how to enact these practices while covering the content standards is a daunting task for any teacher. So, as the Common Core Standards are adopted by more and more states, the question arises: How do we prepare teachers to instruct their students on how to enact these practices? Teaching the math practices through modeling them in teachers' content courses or professional development workshops has its limitations. Relying on this type of training would place a lot of responsibility on pre-service teachers to transfer how the practices are enacted in a room full of adults to how those same practices will manifest in a k-12 classroom. I will discuss using video from actual classrooms as a means to prepare pre-service teachers' to enact the mathematical practices in K-12 classrooms. I will play a video clip, discuss the potential for using video clips in this manner, and examine possible curriculum that implements video to teach the math practices. (Received September 23, 2011)

1077-F5-2955 **William McCallum*** (wmc@math.arizona.edu). *Updating the CBMS report on the mathematical education of teachers and the Common Core.*

10 years after the influential report on the Mathematical Education of Teachers,, CBMS is coming out with an update. The original report made recommendations about teacher preparation; the updated report will include recommendations for mathematics departments about teacher professional development as well. It will also consider the implications of the Common Core State Standards in Mathematics for both preparation and professional development. In this report we will discuss some of these recommendations and conduct an audience discussion about them. (Received September 23, 2011)

Mathematics and Sports

1077-G1-60 **stanley rothman*** (stanley.rothman@quinnipiac.edu), Mount Carmel Ave., Hamden, CT 06518. *Streaking: Finding the probability for various batting streaks.*

In baseball,a player can gain instant fame by duplicating or exceeding one of the fabled types of batting streaks. The most well known is Joe DiMaggio's 1941)streak of getting at least one hit in 56 consecutive games. There are also other batting streaks such as Ted Williams'(1949)84-game consecutive on-base streak, Joe Sewell's (1929) 115-game streak of not striking-out in a game, and the 8-game streak of hitting at least one home run in each game, held by three players (Ken Griffey Jr.,Don Mattingly, and Dale Long). Other streaks include most consecutive plate appearances with a hit the record is 12 held by Walt Dropo (1952)), most consecutive plate appearances getting on-base (the record is 16 held by Ted Williams (1957). In this paper, we present two functions to calculate the probability of a player duplicating a hitting streak. One is recursive; the other is a new piecewise function that calculates the probability directly. These functions are used to compare types of streaks with respect to their difficulty of duplicating. In particular, the 56-game consecutive hitting streak is compared to the 84-game consecutive on-base streak. (Received July 14, 2011)

1077-G1-607 **Sheldon H. Jacobson*** (shj@illinois.edu), **Alexander G. Nikolaev**, **Douglas M. King** and **Adrian J. Lee**. *Seed Distributions for the NCAA Mens Basketball Tournament: Why it May Not Matter Who Plays Whom.*

Bracketology, the art of successfully picking all the winners in the NCAA annual Mens Division I college basketball championship tournament, has become a favorite national activity. In spite of the challenges and uncertainty faced in this endeavor, patterns exist in how the seeds appear in each round, particularly in the later rounds. This paper statistically analyzes tournaments from 1985 to 2011, finding that the distribution of seeds that win in the rounds beyond the Sweet Sixteen can be modeled as a truncated geometric random variable. This model allows one to consider any set of seeds in each tournament round and compute the probability that these seeds would win in that round; this methodology can evaluate the likelihood of each seed combination in each tournament round, based on past tournament history. Finally, each tournament from 1985 through 2011 is analyzed using this model to assess its likelihood and measure the probability of its occurrence. The resulting model was implemented in the website, bracketodds.cs.illinois.edu, prior to the 2011 NCAA Tournament. The key implication of the model is that the teams in the tournament and who they play is far less important than where they are seeded, to determine their likelihood of advancing deep into the tournament. (Received September 08, 2011)

1077-G1-618 **Robert Franzosa*** (robert_franzosa@umit.maine.edu). *The Baseball Simulator: Accurately Simulating Major League Baseball Games with a Minimum Number of Statistics.* Preliminary report.

We will present a model (The Baseball Simulator) for simulating major league baseball games and seasons based on team (rather than individual) statistics. The model was motivated by the desire to create an accurate simulation model that employs as few statistics as possible. We will present a statistical overview comparing Baseball Simulator results and actual major league results for the seasons 1901 - 1993. We will also present results of a Baseball Simulator Ultimate Baseball League season where every major league from 1901 to 1993 plays every other team from the same timespan to determine an overall best Baseball Simulator major league team. Finally, we will share a related classroom activity where students employ probability concepts in the design of their own teams that compete in dice-roll baseball games. (Received September 08, 2011)

1077-G1-738 **Paul P. Britton*** (pabritton@davidson.edu), Davidson, NC 28036, and **Carl R. Yerger** (cayerger@davidson.edu), Davidson, NC 28036. *Boxing in Basketball: A Round-By-Round Analysis of the College Game.*

In the last two decades, basketball coaches have increasingly relied on statistical analysis to determine teaching points for their teams. Davidson College men's basketball coach Bob McKillop divides each game into ten "rounds", with a round ending at each media timeout and at halftime, and gives his team several "round" goals for every game. Two particular goals are winning both rounds five and ten, and winning several rounds overall. We tested McKillop's "rounds" concept by recording the round-by-round score for every conference game in the ACC and Southern Conference over the 2009-2010 and 2010-2011 seasons, for a total of 453 games. Using a logistic regression method, we found that over the entire sample, each round is a significant predictor of the game outcome at a p-value of less than .001. While certain rounds had smaller p-values than others, no rounds, including rounds five and ten, were significantly better predictors than each other round. We also found a team winning at least seven rounds won over 99% of games played, and teams winning 5.5 or more rounds won nearly 90% of games. Bob McKillop's rounds concept is highly predictive of game outcomes, and a focus on "one round at a time" is a salient coaching strategy for any college basketball team. (Received September 11, 2011)

1077-G1-1091 **Mike Weimerskirch*** (weimer17@gmail.com), Minneapolis, MN 55407. *An Adjustment to the Colley Matrix Method.*

The Colley Matrix Method is one of six computer ranking systems used by the NCAA Bowl Championship Series (BCS) to help determine which two college football teams should play for the National Championship. The Colley Matrix relies on some basic linear algebra and produces good results, yet has its shortcomings. Most notably is the assumed transitivity of team strength, that if Team A beats Team B, and Team B beats Team C, then Team A will beat Team C. An adjustment to the Colley Matrix, allowing for upsets, using some simple probability theory is discussed. (Received September 16, 2011)

1077-G1-1114 **Jeffrey W. Heath*** (jeffrey.heath@centre.edu), 600 W. Walnut, Danville, KY 40422, and **Ian M. Powell** (ian.powell@centre.edu), 600 W. Walnut St., Danville, KY 40422. *What is the True Probability of Getting a Hit?*

How accurately does batting average represent the probability of getting a hit in any given at-bat? Other situational variables contribute to this probability, and we examine two of those variables: hitting streaks and pitcher matchups. We analyze MLB data over the past 20 seasons, incorporating hitting streaks and pitcher matchups to help find the true probability of getting a hit. This information would allow teams to improve strategic decision-making in baseball such as in lineup optimization and/or substitution patterns. (Received September 16, 2011)

1077-G1-1194 **Chris M. Jones*** (cjones@stmarys-ca.edu), 1928 Saint Mary's Road, Moraga, CA 94575. *Using sports to inspire and teach math to the non-major.*

Most liberal arts colleges require introductory or general education math courses for the humanities major. This talk will first provide an overview of a general education math course and text, which uses sports as a means to teach probability and statistics along with some game theory and elementary linear algebra.

I will then discuss the benefits of sports themed courses in reaching an ever-decreasing and an increasingly at-risk population of male students at liberal arts institutions. (Received September 17, 2011)

1077-G1-1197 **Charles T Zahn*** (candszahn@sbcglobal.net), 5208 Renaissance Avenue, San Diego, CA 921225602. *Individual player productivity in baseball and basketball can be measured in a Mathematically coherent fashion using play-by-play data.* Preliminary report.

Productivity is a ratio of good results to resources consumed. In baseball, the Official Records do not count each player's consumption of resources (Outs made), but this important count can be determined from modern play-by-play data. The same is true for the good results (Net Base Advances). The detailed play-by-play data now allows us to correctly and completely calculate what Barry Codell called the Base Out Percentage over thirty years ago. Furthermore, this productivity measure can be broken down into several multiplicative factors to analyze a player's performance in more depth. In basketball, the good results are points scored which are precisely recorded, but each player's use of possessions (the resource) is not carefully recorded. Once again, the details of play-by-play allow an accurate calculation of possessions used, which involves field goals attempted, free throw groups attempted, turnovers, and offensive rebounds. As in baseball, the productivity ratio (points per possession) can be viewed as a product of several factors. (Received September 17, 2011)

1077-G1-1361 **Alan Levine*** (alan.levine@fandm.edu). *A Century of Baseball Statistics.* Preliminary report.

It is well-known that the number of homeruns hit in major-league baseball took a sharp upward turn in the 1990's and early 2000's. In this talk, we'll look at trends in a number of offensive baseball statistics from the beginning of the 20th century until today. We'll see that some statistics have increased over time, some have decreased, and others show less definitive patterns. We'll also propose some possible explanations for the observations. (Received September 19, 2011)

1077-G1-1417 **Andrew Larsen*** (andy@andylarsen.com) and **Kali Wickens**. *Beyond Regression: Using Learning Machines to Predict NBA Performance.*

Each year, NBA teams make million-dollar invest- ments by drafting collegiate and international prospects in the NBA draft; it is therefore critical to be able to predict the future performance of those players. While current prediction models rely on regression and other basic statistical techniques to make these predictions, the use of arti cial intelligence has not been explored in this context. Learning machines, a branch of arti cial intelligence, have shown marked improvement over their counterparts in making predictions in other elds, such as handwriting recognition, spam lters, and even movie ratings. To make predictions on the future success of NBA players, we utilize two types of learning ma- chines: support vector machines and decision trees. We train both the support vector machines and learning trees on collected data of past collegiate basketball players to create models which can then classify new players coming into the model. These machines make better predictions of player performance (Received September 19, 2011)

1077-G1-1467 **Andrew D. Blaikie*** (ablaikie13@wooster.edu), **Gabriel J. Abud**, **John A. David** and **R. Drew Pasteur**. *Pursuing an optimal statistically-based model for NFL prediction.*

Artificial neural networks are used to create models that predict the outcome of NFL professional football games. The model is based purely on statistics and uses a committee of machines approach for greater consistency. Many statistics are gathered for six seasons, including passing yards, rushing yards, fumbles, etc. Data analysis is performed to identify the most predictive statistics. Some techniques applied include derivative based analysis, principal component analysis, and computing correlations with game outcomes. Ultimately, the technique that produced the best predictive model found the optimal set of statistics using linear regression models with different combinations of statistics. When compared to a group of other computational predictive models over several seasons, our NFL model consistently ranks among the top half in mean absolute error, the difference between predicted and actual game results. (Received September 19, 2011)

1077-G1-2049 **T. S. Michael*** (tsm@usna.edu). *Paradoxes in Colley Matrix Sports Rankings.*

The Colley method ranks sports teams by solving a certain linear system $Cx = b$, where the matrix C encodes the games played between pairs of teams, and the vector b summarizes the outcomes of the games. The i-th component of the vector x is the rating of the i-th team. The Colley method is well motivated and one of the computer rankings used in the Bowl Championship Series (BCS) to select collegiate football teams for post-season bowl games. We construct examples where the Colley method behaves paradoxically. This is joint work with Thomas Quint. (Received September 21, 2011)

1077-G1-2098 **Paul von Dohlen*** (vondohlenp@wpunj.edu). *The Quarterback Passer Rating: Analyzing and Tweaking the QBPR.*

In this talk we will consider rating systems of NFL quarterbacks, focusing primarily on the NFL Quarterback Passer Rating (QBPR). We will analyze the components of the QBPR, consider possible deficiencies in the rating and propose a couple of modifications. In doing so we will also address common criticisms of the rating system, based both on perception and calculation. The work presented is a simple and straightforward modification of the rating aimed at addressing what the author believes to be the two main deficiencies of its calculation. The primary features of the current quarterback passer rating system will be preserved, while the modifications produce desirable results based on calculation and historical perspectives. Furthermore, we will also consider the relevance and impact of ESPNś new Total Quarterback Rating. (Received September 21, 2011)

1077-G1-2364 **Roland Minton*** (minton@roanoke.edu). *Hot Hands on the PGA Tour.* Preliminary report.

The PGA Tour's ShotLink system records detailed information about every shot taken on the Tour. This new wealth of data allows an investigation into the issue of whether golfers get "hot" or "cold" and have streaks of good or bad play. This talk gives preliminary results from tests of streakiness in putting. A variety of golfers are analyzed in a variety of ways over different time scales. A primary metric of putting efficiency is the Strokes Gained statistics that compares the putting results of a given golfer to the Tour's average performance from the distances faced by that golfer. (Received September 22, 2011)

1077-G1-2508 **Tina Hartley*** (tina.hartley@usma.edu). *Modeling a Baseball Defense as a Network.*

Baseball uses many different measures to rate a player's offensive abilities. However, defensive abilities are much more difficult to measure. One area that is often overlooked is how the team as a whole functions in defense, as opposeed to recording statistics for individuals. In this paper, I will examine baseball defense from the perspective of a network, where the individual players are the nodes, with the ball traveling on various paths between the nodes. With this approach, we can look at performance in several different aspects: Which nodes are most valuable to a team, and does that vary for different teams? Which paths generate outs most frequently? Are different positions more critical against certain teams and with certain pitchers? In addition, by comparing performance across teams, we can compare individual performance of players in the same positions. (Received September 22, 2011)

1077-G1-2571 **Reza D Noubary*** (rnoubary@bloomu.edu), Dept. of Mathematics, Bloomsburg University, Bloomsburg, PA 17815. *Rule of Tangent for Win-By-Two Games.*

We introduce a trigonometric interpretation of the odds of winning points and games in tennis when serving from deuce. We place this result in the more general setting of a gambler's ruin problem and also propose a performance measure to quantify the serving and receiving skill of one player relative to another. Then we extend the analysis to table tennis and volleyball. These latter games are similar to tennis in that the winner must obtain a certain minimum score while leading by two points, but they differ in their determination of which player serves a given rally and in whether a point is awarded to the receiver for winning a rally. We quantify the impact of these differences on the outcomes of games, assuming that the probability for a player to win a single point does not change during a game (Received September 22, 2011)

1077-G1-2685 **Chuck Wessell*** (cwessell@gettysburg.edu), PA. *Using Sports Ranking in a Numerical Linear Algebra Course.*

In the spring of 2011, an undergraduate special topics course, The Mathematics of Ranking and Clustering, was offered for the first time at North Carolina State University. Although the course was a great success, the professor learned many lessons while confronting the challenge of presenting this material to an audience with a wide range of linear algebra and programming abilities. This talk will focus on the sports ranking part of the course and recount those lessons learned. The author will also share a suggested syllabus, classroom activities, project assignments, and strategies for recruiting students (including non-math majors). (Received September 22, 2011)

1077-G1-2837 **Jacob Erb*** (jacob_erb@taylor.edu), Morris Hall Room 315, Taylor University, 236 W Reade Ave, Upland, IN 46989. *A Connection Between Cross Country Scoring and Election Tallying.* Preliminary report.

The analysis of voting structures is a study which has been motivated by the appearance of discrepancies in the outcomes of various intuitive voting procedures when those outcomes are given the same set of candidate rankings. For instance, both the Condorcet Winner and the plurality winner are used as standard procedures to measure and select a populace's preference from a group of alternatives. Situations involving more than two candidates where the two are in disagreement are easy to find.

Cross country scoring has similar paradoxes. In the same three-way meet, team A could defeat team B, B could beat C, and C could beat A in head to head scoring.

Because of the many parallels between elections and other competitive ranking procedures, the analysis done in social choice theory has implications for a realm much broader than that of voters and politicians. More specifically, this project sought to apply this analysis to cross country race outcomes, asking the simple question "How do we turn runners into voters?" (Received September 22, 2011)

1077-G1-2844 **Nicholas Gorgievski*** (nick.gorgievski@nichols.edu), Nichols College, Center Road, PO Box 5000, Dudley, MA 01571, and **Thomas C. DeFranco** (tom.defranco@uconn.edu), University of Connecticut, 249 Glenbrook Road, Unit 2064C, Storrs, CT 06269. *A Logistic Regression Analysis of the NFL Overtime.*

Over the past few years, football fans, sportscasters, writers, as well as mathematicians have all weighed in on whether the NFL overtime rule is fair to both teams. Some football enthusiasts have offered alternatives to this rule. As a result of all of the controversy, the NFL owners accepted a proposal to alter the overtime rule for postseason games beginning in the 2010-2011 football season. However, the old rule was left in place for games that go into overtime during the regular season. Hence, we pose the question; does the NFL regular season overtime rule give the winner of the coin toss an unfair advantage? In this session, we use logistic regression to examine the coin toss and its effect on the outcome of a regular season overtime game. Additionally, we describe how the NFL kickoff rule change, initiated at the beginning of the 2011-2012 NFL season, may have an impact on regular season overtime games. (Received September 22, 2011)

1077-G1-2858 **Yousuf George*** (cgeorge0@naz.edu), 4245 East Ave., Rochester, NY 14618. *Pythagorean Prognostication.*

In the 1980s, Bill James suggested a relationship between the runs scored and runs allowed by a team and the team's number of wins. This relationship, known as the Pythagorean Formula, is given by

$$\text{Winning Percentage} \approx \frac{(\text{Runs Scored})^2}{(\text{Runs Scored})^2 + (\text{Runs Allowed})^2},$$

which has been found to be a very good approximation of actual winning percentage. Combined with the great deal of statistical research in baseball that has focused on the number of runs that individual players generate on offense and prevent on defense, this formula can determine approximately how many wins any given player contributes to a team's overall record.

Further research has focused on applying this formula to other sports, and modifying the formula to increase accuracy in approximating winning percentage. However, we will investigate the use of this formula as a natural measure of team strength, and as a predictor of playoff success. (Received September 22, 2011)

1077-G1-2930 **Brian A. Macdonald*** (bmac@jhu.edu). *An introduction to quantitative analysis in hockey.*

We will give an introduction to analyzing team and player performance in hockey. We'll discuss problems with using goals alone to measure team performance and discuss other statistics that are better than goals at predicting future goals. We'll talk about plus-minus, problems with plus-minus, and ways to adjust plus-minus in an attempt to correct these problems. Finally, we'll discuss how weighted shots can be used to analyze goalies, skaters, and teams. (Received September 23, 2011)

Mathematics Experiences in Business, Industry, and Government

1077-G5-324 **James H. Fife*** (jfife@ets.org), Mail Stop 13-E, Educational Testing Service, Rosedale Road, Princeton, NJ 08541. *Cubic Splines, Local Extrema, and the Harmonic Mean: An Application to Graph Editors.*

A graph editor is an applet that, when inserted in an Internet-delivered test question, allows the examinee to enter a graph as a response. One way in which a graph editor can capture the graph of a smooth function is for the student to click on a series of points that lie on the graph. The editor then connects the points with a smooth curve; e.g., a cubic spline. If it is desired that the curve has a local extremum at a certain point, the derivative of the spline can be constrained to be zero at that point. But while the condition that the derivative equal zero is certainly necessary for the curve to have a local extremum, it is well known not to be sufficient. In

2003 Kruger claimed that a sufficient additional condition is to constrain the derivative at non-extreme points to be the harmonic mean of the adjacent secant lines. At least, he claimed that that constraint "works well". In this talk, we prove Kruger's claim. We also investigate the effect of constraints that use the arithmetic mean or the geometric mean. Finally, we unify our results through the power mean. (Received August 22, 2011)

1077-G5-520 **William P Fox*** (wpfox@nps.edu), 2977 Sloat Road, Pebble Beach, CA 93953. *New Metrics to Detect Suicide Bombers.*

We examined the use of radar to detect humans at a stand off distance of approximately two to eight meters wearing detonation wires as part of a suicide bombing vest. We used the GunnPlexer Doppler radar at 12.5 GHz to collect experiment data of humans without wires, with wires, and wires with a simulated vest. We performed experiments with the subjects walking and collected data on the radar cross section backscatter. We examined the data as well as both the horizontal and the vertical polarization (HH and VV). We developed several simple metrics using the polarization data from this data that could be used in building models to more accurately detect subjects wearing wires. Through more analysis, we discovered additional information about the data and created more useful metrics and combinations of metrics that could be used to increase the detection probability. We used Monte Carlo simulation to test our theories. To date through modeling, we have a success rate over 98% and a false positive rate of under approximately 2%. This research and the results encourage one to think that suicide bombers can be found prior to their detonation of their bombs at a safe range. (Received September 06, 2011)

1077-G5-775 **Ananthnarayan Hariharan** (ahariharan2@unl.edu), 203 Avery Hall, Lincoln, NE 68588, and **Lauren Keough*** (s-lkeough1@math.unl.edu), 203 Avery Hall, Lincoln, NE 68588. *Math in the City.*

Math in the City is an interdisciplinary course in which students engage in a hands-on learning experience using mathematical modeling to understand 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. In this talk I will focus on three student projects that focused on investing and budgeting problems for the City of Lincoln, NE. (Received September 12, 2011)

1077-G5-1378 **Ellina V. Grigorieva*** (egrigorieva@twu.edu), 8800 Sagebrush Trail, Aubrey, TX 76227, and **Evgenii N. Khailov** and **Andrei Korobeinikov**. *Reduction of the operation cost via optimal control of an industrial wastewater biotreatment process.*

A model of an industrial wastewater bio-treatment by means of autothermal thermophilic aerobic digestion (ATAD) is created and investigated. The model is described by a nonlinear system of three differential equations with one bounded control, the aeration rate. An optimal control problem of minimizing energy consumption on the given time interval is stated and solved analytically with the use of Pontryagin Maximum Principle. Dependence of the optimal solution on the initial conditions and model parameters are established. Results of this study can be immediately applied to practical ATAD reaction design. . (Received September 19, 2011)

1077-G5-1922 **Thomas Höft*** (thomas.hoft@tufts.edu). *Optimization in Fourier imaging for laser remote sensing.*

We describe an imaging modality, digital holography, used in industry for laser-based long-range remote sensing. The Fourier transform is central to computational image formation. An optimization problem arises when compensating for the blur caused by imaging through a turbulent atmosphere. Results from computer simulations and field-collected data will be presented. (Received September 21, 2011)

1077-G5-2112 **Joseph J. Rushanan*** (jjr@mitre.org), 202 Burlington Road, Bedford, MA 01730. *Modeling GPS Interference.*

One important aspect to satellite navigation performance, such as GPS, is the interference caused by signals in the same system. A common model for this interference is to replace the superposition of the interfering signals with a single non-repeating white noise random signal, the so-called long-code approximation. This approach fails notably in the case of interference from several GPS C/A signals on a desired GPS C/A signal. We model this C/A on C/A interference with a single time-domain equation for the output of the GPS receiver correlator. The equation takes into account the Doppler difference between the signals along with the relative difference in ranges (quantified by when potential bit transitions occur). Using 1 ms correlation sums, one can express the correlator output equation as a single Gaussian quadratic form. Standard analysis techniques can then be applied to the quadratic form to yield the distribution of outputs as a weighted sum of Chi-squared variables. We show why variations larger than those from the long-code approximation are to be expected and how often they will occur on average based on the specific satellite constellation. These predictions are validated via simulations that reproduce much of the functionality found in a GPS receiver. (Received September 21, 2011)

1077-G5-2293 **William S. Barfield*** (wsbarfield@cox.net), 5010 Portsmouth Rd., Fairfax, VA 22032. *Using Regression to Determine Cost Estimating Relationships for Costing of FAA Software.*

Estimating the development cost for expensive large-scale software is difficult and may employ analogous actual costs, parametric modeling, and inferential statistics on regression of relevant financial data. Cost Estimating Relationships (CERs) are regression equations that typically use normalized actual costs of prior analogous software development. CERs were determined for nine essential Federal Aviation Administration (FAA) Work Breakdown Structure (WBS) elements pertaining to software development and related life cycles activities. The CERs are based on the largest set of well-maintained cost data available within the FAA. Depending on hypothesis for each type of CER, its source data set is derived from 52 to 83 FAA programs of less than 1 million dollars to greater than 500 million dollars life cycle cost. We show the methodology, regression results and statistical accuracy of the new CERs. The determination of these CERs from using inferences about the data variables may be considered, from a purely mathematics perspective, as a regularized ill-posed and ill-conditioned inverse modeling problem in calculating the values of the CER parameters obtained from the budget data. This is an excellent example of using applied statistics in business, industry, and government. (Received September 22, 2011)

1077-G5-2397 **Michael Dorff*** (mdorff@math.byu.edu). *"Careers in Mathematics" speakers series.*

For the past four years, we have been organizing a series of lectures titled "Careers in Mathematics" at Brigham Young University. Each year we invite 5-7 speakers who have received a degree in mathematics and then went into a career in business, industry, or government. The idea of the series is to show students that there are a myriad of careers for mathematics majors. We have had speakers from such places as the Pentagon, Lawrence Livermore Labs, Raytheon, Goldman Sachs, the Center for Disease Control, General Dynamics, the National Security Agency, Sandia National Labs, the Hartford, the U.S. Navy, and Pixar Animation. The speakers talk about mathematics in such careers as operations research, financial analysis, law, medical research, business, engineering, actuarial sciences, programming, and movie production. In connection with this, we recently created a strong program for internships for math majors and this fall had a panel presentation by 5 majors who did summer internships so they could talk about their experience to other students. Typically we have about 150 students in the audience. We started out being supported by local funds but now are supported by an NSF grant. In this presentation, we will talk about the "Careers in Mathematics" speaker series. (Received September 22, 2011)

1077-G5-2674 **Emilie Hogan*** (emilie.hogan@pnnl.gov) and **Cliff Joslyn**. *Visualizing semantic data through the use of partially ordered sets.* Preliminary report.

A major challenge in business, industry, and government is making use of large amounts of collected data. A common type is semantic data, data that is organized as objects and labeled relationships between them. "Ontologies" are used to keep track of the meaning of the labels, and are hierarchical structures, e.g., WordNet. Displaying an ontology to an analyst is an important part of making use of the data. Our approach is to model the ontology as a finite, bounded, partially ordered set (poset), and focus on the vertical layout of the poset. For a graded poset this is not difficult. However, the posets resulting from ontologies tend to be ungraded. We introduce a concept called interval rank where the location of each element in the poset, in relation to the top and bottom, is described by an integer interval. The intervals can then be partially ordered.

We show that interval rank, R, is an order preserving map, and prove that repeated application of the interval rank function yields a privileged total preorder on the data. This pushes us towards a preferred vertical layout. We also show that the height, width, and dimension of the poset change monotonically through repeated application of R. Finally we investigate possible "measures of gradedness" for posets. (Received September 22, 2011)

1077-G5-2780 **John R Ramsay*** (jramsay@wooster.edu), Dept of Mathematics and Computer Science, The College of Wooster, 1189 Beall Ave, Wooster, OH 44691. *Tires, Insurance and Clutches: Applications of Undergraduate Consulting.* Preliminary report.

Most consulting opportunities for academics in business, industry and government occur at the professional or graduate student level of academia. There are, in fact, many opportunities for undergraduate mathematics students to do important consultant work for clients as well. The College of Wooster Applied Mathematics Research

Experience(AMRE) is a summer program that employs students to work as consultants in the surrounding region. Students generally work in teams of three with a mathematics or computer science faculty member acting as advisor. Clients of the program come from business, industry, government agencies, and service organizations. This paper will outline the AMRE program and present the details of the following three representative projects completed by the undergraduate teams in the program:

(1) Development of a tool for the analysis of the cross sectional geometry of complex steel cord structures.

(2) Development of a market competitiveness metric to be used in analyzing insurance pricing elasticity.

(3) Customizing an economic order quantity model in an automotive industry component part lot-sizing problem.

(Received September 22, 2011)

Mathematics of Sudoku and Other Pencil Puzzles

1077-H1-148 **Gregory P. B. Dresden*** (dresdeng@wlu.edu), Dept. of Math., Robinson Hall, Washington & Lee University, Lexington, VA 24450. *Finding closed knight's tours on annular chessboards.* Preliminary report.

The problem of finding a closed knight's tour on the standard (8x8) chessboard is well over a thousand years old, and was studied (and solved) by Euler, among others. Recently, the problem for all (not-necessarily-square) rectangular boards has been solved, but not that for annular boards. In this presentation we give results of our work to classify all such annular boards that admit a solution. (Received August 02, 2011)

1077-H1-367 **Robert W. Vallin*** (robert.vallin@sru.edu), Department of Mathematics, 200 Vincent Science Center, Slippery Rock, PA 16057. *Counting on KenKen Puzzles.* Preliminary report.

KenKen (or KenDoku) Puzzles first appeared in 2004, invented by Tetusya Miyamoto. These puzzles are like Sudoku puzzles, using an $n \times n$ grid and filling each row and column with the digits $1, 2, \ldots, n$, but with an extra, arithmetic, twist. An obvious question, with a non-obvious answer, is, "For n fixed, how many different KenKen Puzzles are there?" We will introduce these puzzles, look at their complexity, and make some assumptions to reduce the question to something answerable. (Received August 26, 2011)

1077-H1-426 **Kenneth L Price*** (pricek@uwosh.edu), Department of Mathematics, University of Wisconsin Oshkosh, 800 Algoma Boulevard, Oshkosh, WI 54901. *Arrowgrams.*

An arrowgram is a type of puzzle based on the transitive relation, directed graphs, and groups. To solve the puzzle a group element is assigned to each arrow of a directed graph. This is called a grading and the group element assigned to an arrow is called its grade.

Grades for some arrows are given. The rest of the arrows are assigned grades using a rule which is based on transitivity. Arrowgrams also contain secret messages. The words are formed by pairs of letters which stand for the arrows. The puzzle is solved when every arrow is graded and the secret message is revealed.

To describe the transitivity rule we say vertices X, Y, and Z form a transitive triple if there are arrows from X to Y, from Y to Z, and from X to Z. The arrow from X to Z is the hypotenuse. The arrows from X to Y and from Y to Z are the legs. We use additive notation for the group operation and require the sum of the grades of the legs to equal the grade of the hypotenuse in every transitive triple.

This talk will cover answers to some mathematical questions related to the construction of arrowgrams. How many arrows have to be given grades? Which arrows can be used? Can the same set of arrows be used for different groups? Examples of arrowgrams will also be provided. (Received August 31, 2011)

1077-H1-505 **John Lorch*** (jlorch@bsu.edu), Department of Mathematical Sciences, Ball State University, Muncie, IN 47304. *Magic Squares and Sudoku.*

We introduce a family of magic squares, called linear magic squares, and show that any parallel linear sudoku solution of sufficiently large order can be relabeled so that all of its subsquares are linear magic. As a consequence we show that if $q > 3$ is a prime power then there exists a complete family of mutually orthogonal magic sudoku solutions of order q^2. We also discuss applications to orthogonal magic sudoku solutions of arbitrary square order. (Received September 06, 2011)

1077-H1-844 **Nate L. Coursey*** (ncoursey@students.kennesaw.edu). *Mutually Orthogonal Sudoku Latin Squares.* Preliminary report.

A Latin square of order n is an $n \times n$ matrix where each row and column is a permutation of the integers $1, 2, ..., n$. Two Latin squares A and B, both of order n, are orthogonal if all n^2 ordered pairs formed by juxtaposing the two matrices are unique. It is well known that there exists a pair of orthogonal Latin squares of order n for every positive integer $n \neq 2, 6$. A family of mutually orthogonal Latin squares (MOLS) of order n is a collection of Latin squares of order n such that each Latin square in the collection is orthogonal to every other Latin square in the collection. It is relatively easy to show that the maximum size of a collection of MOLS of order n is $n-1$.

A gerechte design is a an $n \times n$ matrix where the matrix is partitioned in n regions $S_1, S_2, ..., S_n$ where each row, column and region is a permutation of the integers $1, 2, ..., n$. The popular puzzle Sudoku is an example of a gerechte design.

Results about mutually orthogonal Sudoku Latin squares of order $n = k^2$ are beginning to appear in journals. This talk discusses the adjustments that must be made when n is not a perfect square and the size of critical sets (clues) of mutually orthogonal Sudoku Latin squares. (Received September 13, 2011)

1077-H1-850 **Serge C. Ballif*** (ballif@math.psu.edu). *Orthogonal Graph Colorings.*

A *latin square* of order n is an $n \times n$ array filled with n symbols such that each symbol occurs once in each row and column. Two latin squares are said to be *orthogonal* if, when they are superimposed, every ordered pair of symbols occurs exactly once. Latin squares are examples of a proper coloring of a graph. We define two n-colorings of a graph to be *orthogonal* if no ordered pair of colors occurs more than once when the two colorings of each vertex are listed as an ordered pair. We show that the usual bounds on the maximum size of a certain set of orthogonal latin structures such as latin squares, row latin squares, equi-n squares, single diagonal latin squares, double diagonal latin squares, and sudoku squares are a special cases of bounds on orthogonal colorings of graphs. We also show that the problem of finding a transversal in a latin square of order n is equivalent to finding an n-clique in a particular graph. (Received September 23, 2011)

1077-H1-1036 **Andrew J Simoson*** (ajsimoso@king.edu), King College, Mathematics Department, 1350 King College Road, Bristol, TN 37620, and **Ilhan M Izmirli**. *Al-Maghribi meets Sudoku.*

The sixteenth century Algerian mathematician Al-Maghribi posed what he called the *Mecca problem* in the appendix to his book on algorithms and algebra. A landowner $\mathcal{L}$ has 81 trees numbered 1 through 81; tree-i produces i baskets of fruit each season. How can $\mathcal{L}$ partition the 81 trees among his 9 sons so that each one receives 9 trees and an equal number of baskets of fruit each seaon from those trees? We show how Al-Maghribi may have generated his solution, and demonstrate that the underlying structure is a completed Sudoku puzzle. Furthermore, any completed Sodoku puzzle gives rise to a solution to the Mecca problem (so called because it was a puzzle to do while on pilgrimage to Mecca). (Received September 15, 2011)

1077-H1-1408 **John K McSweeney***, john.mcsweeney80@gmail.com. *Quantitative Analysis of Crossword Puzzle Difficulty.*

What distinguishes a crossword puzzle from a simple list of trivia questions is the interlocking nature of the answers in the grid – one solution can promote further ones in a cascading fashion. To model this mathematically, we build a network object from a puzzle: answers in the puzzle are nodes in the network, and nodes are linked via an edge if the corresponding answers cross. Each node also has a state, "solved" or "unsolved", and a node x becomes solved if the proportion of its neighbors that are solved exceeds some given threshold φ_x; we take the φ_x to be independent and identically distributed random variables. Motivated by analogous issues which arise in epidemiological analyses of structured populations, we consider the following general questions: what features of the distribution of the difficulties φ_x of the clues, and of the topology of the crossword network, determine whether a puzzle can be fully (or nearly fully) solved? Are impediments to full solution typically due to puzzle structure or clue difficulty? We will present rigorous results for certain puzzles with a high degree of symmetry, as well as simulation-based analyses of "real-world" puzzles from the Sunday New York Times. (Received September 19, 2011)

1077-H1-1423 **Daniel J Katz*** (katzd@guilford.edu), Guilford College, 5800 W Friendly Ave, Greensboro, NC 27410. *Critical sets in Futoshiki squares.* Preliminary report.

Of the mathematical questions inspired by the popularity of Sudoku, one of the most intriguing is the question of how many givens (initially provided entries) a Sudoku requires to be uniquely solvable. It is commonly accepted that the required number is 17, but as of this writing, no proof of this lower bound has been found. In a sense, the minimal-entry Sudoku problem is an offshoot of the study of critical sets in Latin squares (minimal subsets that uniquely complete to a Latin square), but the additional subsquare constraint in a Sudoku complicates things considerably.

Futoshiki, a puzzle which comes from Japan and has recently gained popularity in the United Kingdom, is another puzzle type that adds a constraint to the Latin Square; in this case, the new constraint is the introduction of "greater than" clues between certain pairs of adjacent cells. Thus, the Futoshiki has two types of givens, numbers and comparisons, and the family of Futoshiki-critical sets is a generalization of the critical sets in Latin squares. I will discuss some open problems concerning these Futoshiki-critical sets, compare to what is known about Latin squares, and present some preliminary results. (Received September 20, 2011)

1077-H1-1603 **Julian F Fleron*** (`jfleron@westfield.ma.edu`), **Volker Ecke**, **Christine von Renesse** and **Philip K Hotchkiss**. *Radon-Kaczmarz Puzzles: CAT Scans Meet Sudoku.*

In this talk we introduce a family of Sudoku-like puzzles which we call Radon-Kaczmarz puzzles. Solution strategies for these puzzles are directly related to the mathematics behind CAT scans and other forms of medical imaging. We describe these connections and state interesting open questions about this family of puzzles. We describe comprehensive classroom materials on these, and related, puzzles that we have developed and share our students' reactions to this material. In closing we will provide surprising connections between mathematical solution strategies for puzzles such as this, compelling history, and the development of sophisticated medical imaging. (Received September 20, 2011)

1077-H1-2003 **Agnes M. Rash*** (`arash@sju.edu`), Mathematics Department, 5600 City Avenue, Philadelphia, PA 19131. *MultiSudoku: A Game of Divisors and Multiples.*

Many students who are preservice elementary school teachers have difficulty with basic number facts, mental arithmetic and logic. Studies about math anxiety suggest that intervention is needed to reduce the anxiety that some student exhibit and that games are an appropriate approach to alleviate these problems.

This presentation discusses how to design Sudoku puzzles that ask students to complete the 9 by 9 grid with numbers that all share a greatest common divisor, or are all multiples of a common number. Construction of several examples given one basic grid is explained. (Received September 21, 2011)

1077-H1-2053 **Jason Rosenhouse*** (`rosenhjd@jmu.edu`) and **Laura Taalman** (`laurataalman@gmail.com`). *A Sampler of Sudoku Studies.*

If you peruse the puzzle page of a typical in-flight magazine or local newspaper, there are two things you are likely to see. One is a Sudoku puzzle. The other is a message to the reader, no doubt meant to be comforting, that solving a Sudoku puzzle does not require any mathematics. That message notwithstanding, mathematicians have certainly found much of interest in Sudoku puzzles. A substantial research literature of Sudoku studies now exists. In this talk we give an overview of a few highlights from this literature. We also suggest ways in which Sudoku studies can be used for pedagogical purposes. Many topics introduced in higher-level mathematics classes arise naturally from a consideration of Sudoku-related questions. (Received September 21, 2011)

1077-H1-2330 **Darrah P. Chavey*** (`chavey@beloit.edu`), Beloit College, 700 College St., Beloit, WI 53511. *Clue-Symmetric Sudoku.*

The traditional Sudoku puzzle begins with a rotationally symmetric set of cells already filled in. Of course the puzzle-solver is not expected to keep it symmetric while filling in the remaining cells. However, a determined puzzler could try to do this to make an easy puzzle more challenging, but this would depend heavily on the skills of the puzzler. We define the category of "Clue-Symmetric Sudoku" as Sudoku puzzles where a clue to fill in position (i, j) in the puzzle implies an equivalent clue to fill in position (j, i). This means that anyone who could complete the puzzle could also complete the puzzle so that after every other entry the completed cells will form a rotationally symmetric set, and this claim would be true regardless of the skill level of the puzzler. We show a fairly broad class of clue-symmetric Sudoku puzzles and how to generate them. (Received September 22, 2011)

1077-H1-2639 **Philip Cobb*** (`phcobb@prodigy.net`), 41-31 210 Street, Bayside, NY 11361. *Minimal* 6×6 *Ken Ken puzzles.*

An open Sudoku question asks for the minimum number of given digits needed to yield a unique solution. While this remains unknown, we saw during the puzzle session last January that Ken Ken may be solvable with a single given number. Continuing last year's study of 4×4 Ken Kens, we will see what types of 6×6 Ken Ken puzzles can be constructed with only two regions. In addition, the completed puzzle may be interpreted as the Cayley table of a group. (Received September 22, 2011)

1077-H1-2665 **Brant Jones*** (jones3bc@jmu.edu), **Laura Taalman** and **Anthony Tongen**. *Solitaire mancala games as pencil puzzles.* Preliminary report.

Mancala games are played by sowing stones among pits on a game board. Because all of the stones in a given pit must be removed and then sown on each turn, the analysis of game play leads naturally to the study of number theoretic properties of the game board.

As a player, one of the strategic goals in the game is to set up a single chain of moves that allows the capture of all available stones. In this talk, we consider the question of when it is possible to construct such a "slam" board given only partial information about the number of stones on the board. (Received September 22, 2011)

1077-H1-2861 **Rebecca E Field*** (fieldre@math.jmu.edu), MSC 1911, James Madison University, Harrisonburg, VA 22807, and **Beth Arnold**, **Steve Lucas** and **Laura Taalman**. *Minimal connected Shidoku symmetry groups.*

There are two basic ways to rearrange a Sudoku board to produce another Sudoku board which is essentially the same as the initial board. The first way is by using physical symmetries such as rotating a board 180 degrees or switching the bottom two rows. The second is by relabeling the entries, such as turning all of the ones into twos and vice versa. We will discuss the ways that these two types of Sudoku symmetries interact for the special case of Shidoku, the four by four equivalent of Sudoku. We will also discuss how these are used, along with Burnside's lemma, to count the number of essentially different Sudoku/Shidoku boards. (Received September 22, 2011)

Mathematics of Sustainability

1077-H5-696 **Martin E. Walter*** (martin.walter@colorado.edu), Department of Mathematics Campus Box 395, University of Colorado, Boulder, CO 80309. *Nineteen Years Teaching Environmental Numeracy and Logic: Mathematics for the Environment.* Preliminary report.

I have been teaching a class, Mathematics for the Environment, for the past nineteen years. We study climate change, financial crises, media literacy, the synthetic chemical soup in which we all marinate, food production, energy (solar and others), populations, surveillance and identity theft, ecological economics and thermodynamics, the kinship relations of Australian aborigines and much more. Besides the "usual" mathematical analysis, we study the underlying logic of our society–where Nature indicates that this logic is not sustainable, and what might be changed to make it so. My classroom materials are now available in book form, and I am working on other possible formats. (Received September 10, 2011)

1077-H5-2000 **Irina Kareva**, **Benjamin Morin** and **Georgy Karev***, karev@ncbi.nlm.nih.gov. *Preventing the tragedy of the commons through punishment of over-consumers and encouragement of under-consumers.*

The conditions that can lead to the tragedy of the commons, i.e., to the situation when a shared resource is depleted due to overexploitation, can be reformulated as a game of prisoner's dilemma: while preserving the common resource is in the best interest of the group as a whole, over-consumption is in the interest of each particular individual at any given point in time. One way to try and prevent the tragedy of the commons is through infliction of punishment for over-consumption, thus selecting against over-consumers. The effectiveness of various punishment functions in an evolving consumer-resource system is evaluated within a framework of an infinitely-dimensional system of ODEs. Conditions leading to the possibility of sustainable coexistence with the common resource for a subset of cases are identified analytically using adaptive dynamics; the effects of punishment on heterogeneous populations with different initial composition are evaluated using the Reduction theorem for replicator equations. (Received September 21, 2011)

1077-H5-2138 **Peter T Otto*** (potto@willamette.edu), Department of Mathematics, Willamette University, Salem, OR 97301. *Sustainability Project for Calculus I.*

Based on the model developed by Thomas Pfaff at Ithaca College, in each of the past two semesters, I have incorporated a Sustainability Project in the Calculus I sections I have taught at Willamette University. In this project, pairs of students choose a sustainability topic of interest, gather data, fit a curve to the data, and then answer short calculus related questions about their fitted functions. Once completed, the students are asked to make brief presentations of their findings to the class. This project is partly motivated by a sustainability across the curriculum initiative the university is considering to include in its general education requirements. (Received September 21, 2011)

1077-H5-2455 **Michael Ian Friedrich** (mifriedr@unca.edu), Asheville, NC 28804, and **Halcyon Annette Garrett*** (hagarret@unca.edu), Asheville, NC 28804. *What's for Dinner: Linear Analysis of Nutritional Data and an Application to Community Health.*

One misconception regarding food in America is that eating well is more expensive than eating highly-processed foods of relatively low nutritional quality. However, this mistaken belief can be disproved by analyzing dietary requirements mathematically.

George J. Stigler was the first to use linear algebraic techniques to analyze the nutritional content of various foods. In 1945, he published "The Cost of Subsistence" in which he determined the most nutrient-rich diet possible with a limited number of foodstuffs and a pre-established budget. Since that time, similar studies have analyzed foods available in developing countries in order to provide optimal nutrition to populations living beneath the poverty line. This method is extremely useful as it can be applied to any demographic with a set of food items, given nutritional and budgetary constraints.

In our study we generate a list of foods that are inexpensive, nutrient-dense, and widely-available through local supermarkets. We then present several diets which meet the recommended daily allowances (RDAs) of key nutrients as established by the FDA. These meal plans can be integrated into a local program which promotes health awareness and financial literacy within the Buncombe County community in North Carolina. (Received September 22, 2011)

1077-H5-2830 **M. Anne Dow*** (adow@mum.edu), Department of Mathematics, Maharishi University of Management, Fairfield, IA 52557. *A Mathematics Course for Majors in Sustainable Living at the Level of Intermediate Algebra.*

For four years I have been developing and teaching a 4-credit course for Majors in Sustainable Living at Maharishi University of Management. The Major in Sustainable Living aims at an entrepeneurial rather than a technical goal: to create graduates who are prepared to design, build, and maintain sustainable communities. Students are expected to be able to understand and use technical reports, but not necessarily able to create the technology. Thus only a minimum level of mathematical training is required. Every mathematical topic is introduced in the context of a problem in Sustainable Living. For example, I introduce trigonometry by the problem of where to place awnings on a house for maximum passive solar effect. Then I cover the relevant mathematics in its own right, show how it solves the problem, and finally show how the same mathematics solves lots of other problems in Sustainable Communities. Parabolas are introduced in the context of gathering energy, and so on. The final project is to create a design for a sustainable community with 5 houses that gathers its own energy and water. (Received September 22, 2011)

1077-H5-2896 **Ben Fusaro*** (fusaro@math.fsu.edu), Dept of Mathematics, Florida State University, Tallahassee, FL 32306-4510. *Embodied Energy, Energy Return on Investment, and Sustainability.*

The embodied energy of a unit of energy is the number of units of solar energy that it took to produce that unit of energy. For example, the embodied energy in a Cal(orie) of wood, coal, crude oil is about 20K, 40K, 55K solar Cal, resp. The embodied energy in one Cal of electricity produced by a coal-fired power plant is about 150K Cal. (Since these are ratios, any physical unit – BTU, kilowatt-hour, etc. may be used.) Embodied energy introduces the concept of ecological quality of energy to input/output processes. This concept will be used to generalize the ROI of business to Energy ROI. Embodied energy and EROI will be used to get a realistic estimate of the feasibility of replacing fossil fuels by sources of energy such as wood, palm oil and wind. (Received September 22, 2011)

Modeling Across the Mathematics Curriculum

1077-I1-300 **Paul R Bouthellier*** (pbouthe@pitt.edu), 504 East Main Street, Titusville, PA 16354. *Teaching 3D Mathematical Modeling.*

Creating mathematical models of 3-dimensional objects has many applications. One application is in manufacturing. An example of this is the creation of car parts-for which Bezier curves were created. In this presentation the computer packages Poser, 3D Studio Max, Maya, Swift 3D, and Carrara will be used to illustrate the mathematical models created for a chess game and a (space) flight simulator. The purpose is to teach students how to break a complex modeling problem into a series of simpler ones-which are much easier to model. From the chess game the following will be modeled: the 6 pieces, the board, and a chess clock. To model and animate these objects we will use: Bezier curves, rotation matrices, Boolean additions and subtractions, trigonometry, texture mappings, geometric deformations, and inverse kinematics. For the flight simulator we will model: several space ships, planets, and a galaxy. These will be modeled and animated using: Bezier curves, Boolean additions and subtractions, texture mappings, spherical coordinates, parametric equations, rotation matrices, quaternions, and local and global coordinate systems. (Received August 19, 2011)

1077-I1-780 **Rebekah Isaak*** (isaak009@umn.edu), Dept. of Educational Psychology, U Minnesota, 192 Educational Sciences Building, 56 East River Road, Minneapolis, MN 55455, **Daniel T Kaplan** (kaplan@macalester.edu), 55116, and **Joan Garfield** (jbg@umn.edu) and **Andrew Zieffler** (zief0002@umn.edu). *Developing a Modeling Concept Inventory.*

Modeling is a vague term that has diverse meanings across the fields in which it is used. There is not a generally accepted "syllabus" or set of topics that students need to learn about modeling. As part of the work on the NSF-funded project MOSAIC, we have separated concepts of modeling into a set of identifiable components that are consistent across fields (e.g. they apply to both mathematics and statistics) and used those components to build a Modeling Concept Inventory. We will share the development of this inventory, the framework that we have used to organize the modeling process for teaching and evaluating students, and discuss inventory's intended use in a variety of courses that teach aspects of modeling. (Received September 12, 2011)

1077-I1-867 **Alex Capaldi*** (alex.capaldi@valpo.edu). *Using Infectious Disease Models in Calculus and Differential Equations Courses.*

Infectious diseases fill the media. Avian flu and swine flu have graced the news in recent years while pop culture has seen the new Hollywood movie "Contagion" and countless examples of zombie apocalypses in movies and games. Because of this high level of exposure to the topic, students are likely to appreciate seeing this application to the content taught in their mathematics courses. We will present multiple examples and projects drawn from the field of epidemiology that could be used in calculus and differential equations courses. (Received September 13, 2011)

1077-I1-981 **Jana Gevertz*** (gevertz@tcnj.edu), **Julie Beier** and **Keith Howard**. *Using Mathematical Cancer Models in an Introductory Differential Equations Course.* Preliminary report.

Many incarnations of the Introductory Differential Equations course aim to teach students analytical, qualitative and numerical methods for gaining insight into the behavior of ODE solutions. Using mathematical models to keep this material in context allows students to gain a greater appreciation of the mathematical techniques typically taught. We discuss several variants of an ODE modeling project (utilized at two different institutions) in which students explore the behavior of cancer growth and treatment through existing mathematical models. The exploration includes both understanding the mathematical workings of the models and their limitations. We will discuss the mathematical, affective, and writing goals, contexts and outcomes of the projects, and how they differed for the two institutions. (Received September 15, 2011)

1077-I1-1440 **Paul C Fonstad*** (pfonstad@gmail.com). *The Volume and Surface Area of a Toy Train.*

While discussing the formulas for volume and surface area of different basic solids, students rarely get a chance to see situations where the formulas can be applied to a more complicated, real world scenario. This talk will focus on a lesson plan created for use in a Geometry for P-8 Teachers class that uses the idea of modeling a toy train to show students real world applications of volume and surface area formulas. To encourage higher level thinking, the activity requires the students to discover first-hand the limitations of the formulas and to come up with creative ways to apply their prior math knowledge in problem solving. (Received September 19, 2011)

1077-I1-1445 **Dexter C. Whittinghill*** (whittinghill@rowan.edu), Department of Mathematics, Rowan University, Glassboro, NJ 08028. *Modeling the Gummy Bear Launcher as a Simple Computer Experiment.*

We describe the Cobb gummy bear launcher, found in Activity Based Statistics, by Scheaffer, Watkins, Gnanadesikan and Witmer (Wiley, 2008). Long used as a hands-on manipulative to create experimental data that can be used to motivate regression and the analysis of variance, we present a mathematical use of the launcher. The machine that is the launcher, and the physical process of launching a gummy bear, can be modeled mathematically with fairly simple functions–trigonometry, polynomials and the classic projectile path from calculus–though in a complicated composition. Unlike results from a physical, launcher experiment, the output of "runs" of this model are deterministic data: the same input always gives the same output. The science of analyzing the output from such a "computer experiment" inspired a new branch of statistics in the late 20th Century. (For instance, running a climate model is a computer experiment.) Finally, we present an analysis of the gummy bear model. (Received September 19, 2011)

1077-I1-1537 **Veera Holdai**, **Brian Hill**, **Steven Hetzler** and **Kathleen Shannon*** (kmshannon@salisbury.edu), Mathematics and Computer Science, Salisbury University, 1101 Camden Ave, Salisbury, MD 21801. *The Center for Applied Mathematics and Science at Salisbury University.* Preliminary report.

The Center for Applied Mathematics and Science (CAMS) at Salisbury University has as its centerpiece a four credit undergraduate course: Directed Consulting. This "course" provides students with the opportunity to work on a real problem, not just a realistic problem, in a team setting similar to that in which professionals work. While providing this educational experience for STEM students, CAMS helps businesses, industries and educational agencies solve problems in strategic ways. The directed consulting course is a team of students with different backgrounds working under the direction of two faculty members. The team studies a particular problem, builds appropriate mathematical and statistical models and produces a report. In this paper we will discuss the operation of the course, including the selection of faculty leaders; the process of finding projects to work on; and funding, as well as the benefits to students and the faculty involved. The last two projects involved Salisbury University mathematics placement and developing an economic index to indicate the strength of the economy of the Eastern Shore of Maryland. (Received September 20, 2011)

1077-I1-1649 **Carla D Martin*** (martincd@jmu.edu) and **Anthony Tongen** (tongenal@jmu.edu). *Research Experiences for All Learners.*

To encourage independent thought and inquiry, we have designed many in-class projects for several courses that involve various levels of mathematical modeling. Most courses with this modeling-based approach have been applied mathematics courses, but we have also implemented them in a more theoretical course as well. In this talk we share some of these projects and their successful implementation.

The projects are designed to reinforce material covered in class, show real-life applications in a variety of fields, and are research-like in nature. In particular, the answers are not readily available, have not been thoroughly investigated, or present open-ended questions whose answers may lead students down different paths of discovery. Each project can also serve as a starting point for an undergraduate research project. We highlight many real-world applications that do not involve high-level mathematical theory and are accessible to students at many levels.

This modeling-based approach has had very positive results. Student project groups have gone on to present posters at local and regional conferences. Several students have won awards and many have changed their major to mathematics or changed their track within mathematics as a result of these projects. (Received September 20, 2011)

1077-I1-1650 **Nagaraj S Rao*** (nrao@mercy.edu), 555 Broadway, Dobbs Ferry, NY 10522, and **Sanju Vaidya**. *Why Mathematics?*

"Why Mathematics?" is a very frequent question asked by students at all levels of education. We answer this question through mathematical modeling. "Mathematical Modeling at Mercy College" (M3C) Young Scholars program started in 1994 with the support of NSF for high school students. The goal of M3C is to attract capable students, especially women and minorities, into mathematics and science by engaging them as participants in a series of activities designed to highlight mathematics and science as the exciting, challenging, and rewarding fields of study. Real-world problems from the sciences are used to introduce the young scholars to the mathematical modeling process. Classroom instruction and hands-on activities in the computer and science laboratories are supplemented by weekly visits to research centers. Math concepts are introduced as a tool to solve real-world problems. Students work in groups on their final projects, based on Ordinary Differential Equations, and present these projects in the program Banquet. The program has served more than 250 students over 15 years. The outcome has been extremely encouraging: the program has been effective in building confidence in students to take challenging math and science courses. These concepts are used across the curriculum. (Received September 20, 2011)

1077-I1-2195 **Anand L Pardhanani*** (pardhan@earlham.edu), Mathematics Department, Earlham College, Richmond, IN 47374. *Social justice modeling contexts for teaching calculus and higher level math courses.*

The idea of integrating mathematics with social justice is motivated by two complementary goals: (i) to utilize mathematics for understanding and seeking solutions to social problems, and (ii) to learn and develop new mathematics through application to social justice needs. Interest in this area has been growing in recent years, as evidenced by presentations and sessions on these topics at conferences, and in the growth of related publications.

These and other similar efforts have resulted in the availability of some modest literature on social justice applications of mathematics. However, a common impediment to using ideas from such literature, particularly for college level math courses, is that the mathematical content is often elementary and frequently involves topics from only statistics.

In this presentation I will discuss some alternate ways to bring social justice contexts into teaching college level courses beyond elementary statistics, via a modeling framework. I will give examples of application models that would work well for calculus sequence courses, differential equations and more. The presentation will include pointers on how to find sources for social justice applications, and how to integrate them into a mathematical modeling framework. (Received September 21, 2011)

1077-I1-2273 **Michael A. Jones*** (maj@ams.org), Mathematical Reviews, 416 Fourth Street, Ann Arbor, MI 48104, and **Rabab Abi-Hanna** and **Kenneth Krott**. *The Optimal Placement of Range Lights.*

Range lights are pairs of lighthouses on bays, rivers and other waterways that guide boats safely along a linear path, called the range line. To limit the expenses of building, operating, and maintaining the lighthouses, fewer lighthouses, and hence longer range lines, should be used. To keep a boat in a channel bounded by curves $y = f(x)$ and $y = f(x) + h$, optimally long range lines are secant and/or tangent lines to the two curves. Their placement depends on concavity and applies the Mean Value Theorem. I'll describe a project based on the optimal placement of range lights that has been used in a Calculus I class. (Received September 22, 2011)

1077-I1-2500 **Therese L Bennett** (bennettt1@southernct.edu), Southern CT State University, Department of Mathematics, 501 Crescent Street, New Haven, 06515, **Ray Mugno*** (mugnor1@southernct.edu), Southern CT State University, Department of Mathematics, 501 Crescent St, New Haven, CT 06515, and **James Tait** (taitj1@southernct.edu), Southern CT State University, Department of Environmental Studies, 501 Crescent St, New Haven, CT 06515. *Learning Mathematics in the Context of Environmental Issues.*

Faculty from the Mathematics Department and the Environmental Science Department co-teach a course for the Honors College called "Mathematics and the Environment". The purpose of the course is to teach mathematics in the context of addressing real-world environmental problems. Students use the mathematics that they learn to construct models of global climate change at the local level, using data from Connecticut and the New England region. Project topics include river flow, temperature change, precipitation levels and sea level change. In this presentation, we will give an overview of the structure and content of the course, a description of some of the student projects and their results, and samples of student feedback. (Received September 22, 2011)

1077-I1-2612 **Sheldon Lee*** (shlee@viterbo.edu), 900 Viterbo Drive, La Crosse, WI 54601. *Integrating modeling into an introductory programming course.*

Many colleges with small math programs cannot afford to offer courses in numerical analysis, computer science, and modeling. In this talk, I outline a new course that attempts to address all three of these topics in order to fill this gap in the curriculum. In this course, students are introduced to procedural programming in the context of solving mathematical problems, with an emphasis on real-life problems. Students build their repertoire of modeling tools by learning about topics such as matrix algebra and its applications, probability theory, and Monte Carlo simulation. I will discuss some of the challenges of assigning meaningful mathematical modeling projects that are accessible to students with basic programming skills and a Calculus II background. (Received September 22, 2011)

1077-I1-2658 **Marian F Anton*** (marianfanton9@gmail.com). *A modeling project on sensor networks.* Preliminary report.

Imagine that a bunch of sensors are spread inside a forest, for fire protection purposes, and each sensor covers a small area. Unfortunately we have no idea where these sensors land, but we know which sensors are near each other and which are near the boundary of the forest. Can we determine if the sensors cover the forest? I will answer this question using only high school geometry and indicate how this solution introduces students to combinatorial topology, linear algebra, and computer science. (Received September 22, 2011)

1077-I1-2667 **William Dean Stone***, 801 Leroy Place, Dept of Math, New Mexico Tech, Socorro, NM 87801. *Pack size vs. Prey Density in the Mexican wolf.* Preliminary report.

Pack size vs. Prey Density in the Mexican wolf The best known populations of grey wolves (canis lupus) are probably the Northern packs such as in Yellowstone and on Isle Royale. These packs are generally 5 to 8 wolves, sometimes as many as 14. The Mexican Lobo, subspecies (canis lupus baileyi), recently re-introduced in New Mexico currently form packs of only 2 adults plus juvenile pups. Historically, lobo packs seem to have been larger. We explore the relationship between prey density and hunting effort, and the effect on pack size. The mathematics involved are suitable for use in a systems of ODEs class. (Received September 22, 2011)

1077-I1-2853 **Joyati Debnath*** (jdebnath@winona.edu), Dept. of Mathematics and Statistics, Winona State University, Winona, MN 55987. *Mathematical Thinking as a gateway to Undergraduate Research.*

Mathematics modeling should be an integral part of all mathematics courses as students are more motivated when they experience a real-life problem in their course work. Along the same line, an undergraduate research gives students to create their own model and address the problem in hand. The speaker will discuss how an upper division mathematics course was created and implemented to address the 2004 MAA CUPM Curriculum Guide recommendation regarding "analysis of real-life situations and construct appropriate mathematical models" at Winona State University. (Received September 22, 2011)

Motivating Statistical and Quantitative Learning through Social Engagement

1077-J1-143 **Bonnie J Shulman*** (bshulman@bates.edu), Bates College, Dept. Mathematics, 3 Andrews Road, Lewiston, ME 04240. *Mathematics for a Just World: Teaching Quantitative Literacy Through Social Justice Issues and Service Learning.*

In Fall 2010, over 150 students signed up for 40 seats in my new course, Mathematics for a Just World. Clearly I struck a chord in the catalog description: "Do you want to change the world and make it a better place? Do you see mathematics as a collection of disconnected, arbitrary rules that you memorize for a test and then promptly forget? This course teaches quantitative literacy, critical thinking and problem solving skills in a socially relevant context. We use mathematics as a powerful analytic framework for understanding and developing realistic solutions to issues of social, political and economic injustice. At the end of this course, you should be able to answer for yourself the question: why do I have to know this?" The course includes a service learning requirement, tutoring math at an after-school program. Topics covered include: the wealth gap; unemployment; cost-benefit analysis; the relationship between poverty and school achievement; racial profiling; and tax cuts. In this paper I share sample lesson plans, tips on integrating the service learning component, successes and challenges in teaching the course, and a list of resources for others to use. (Received August 01, 2011)

1077-J1-161 **Mike Daven** (mike.daven@msmc.edu) and **Lee Fothergill*** (lee.fothergill@msmc.edu), Mount Saint Mary College, Newburgh, NY 12550. *Math Trails in Undergraduate Mathematics.*

Math Trails have gained popularity with K-12 teachers to emphasize to their students that mathematics is everywhere. A Math Trail is an activity where participants encounter examples of mathematics in their community. These activities support nationally recognized curriculum standards, helping to make connections and improve communication and problem-solving skills while discovering and learning about mathematics in the local neighborhood. In this talk we will describe an ongoing service-learning project in which mathematics majors are creating a math trail on our campus, accessible to a range of local K-12 students and other members of the community. (Received August 03, 2011)

1077-J1-169 **Morteza Shafii-Mousavi*** (mshafii@iusb.edu), Mathematical Sciences, PO BOX 7111, South Bend, IN 46634, and **Paul Kochanowski** (pkochano@iusb.edu), PO BOX 7111, South Bend, IN 46634. *Service-Learning Projects and Activities that Engage Liberal Arts Mathematics Students: Implementation and Assessments.*

We will present how the use of service-learning projects helps students in liberal arts courses gain greater understanding of math, as well as to improve their understanding of math language, ability to communicate solutions, and write recommendations to clients. Student teams complete client driven projects which emphasize discrete math. Given a project, a team meets its client organization; defines the problem; formulates the model; and writes research issues. A team focuses on data needs, statistical measures, and technological skills necessary to solve its problem. They write journals and communicate their ideas. In the classroom, students learn core math concepts. Finally, teams write reports and make presentations. We use rubrics to evaluate students' learning consisting of exams, projects, reports, presentations, and recording course work in student portfolios. We will discuss a completed project; the learning environment; how the activities were conducted and evaluated; how projects fit into the course; the technology; the students' reactions, and the effect of the project on the students' attitudes. We will provide handouts including rubrics used to assess student learning and the list of completed projects pursued in our interdisciplinary course Mathematics in Action. (Received August 05, 2011)

1077-J1-768 **Zeynep Teymuroglu***, Rollins College, Department of Mathematics and CS, Winter Park, FL 32789. *Service Learning Project in a First-Year Seminar.* Preliminary report.
Service learning has a long tradition at Rollins College. Recently, first-year students in an introductory level statistics course had an opportunity to collaborate with the on-campus Child Development Center(CDC). The goal of the project was to measure the kids' snack time calorie intake and study their eating behaviors. Childhood obesity is recognized as an important public health problem. In this project, students not only gained experience in conducting observational research related to this fast-growing problem, but also fostered relationships with a community organization. This talk will discuss the impact of service learning on student learning and dynamics of teamwork. (Received September 12, 2011)

1077-J1-784 **Angela Vierling-Claassen*** (avierlin@lesley.edu) and **Dorea Vierling-Claassen**.
How Does Acceptance of Lesbian and Gay Men Spread in a Social Network?
According to a 2006 study by the Pew Research Council, acceptance of lesbians and gay men is rising dramatically. How does this kind of societal change come about? Can individuals or advocacy organizations do anything to increase acceptance levels in specific communities? Mathematics can be part of the answer to these questions through studying this change by modeling a social network with a random graph and using a dynamic process to alter opinions and rewire social connections. This model can then be assessed by students for how well it predicts current social changes, and the parameters of the model can be altered to determine how changes in the attributes of people (nodes) and edges (social ties) impact the acceptance level over time. Such a project can involve students at a wide variety of skill levels, creating opportunities for discussion and cooperation between students in introductory and advanced courses. I will discuss a classroom activity that can be used to model the spread of acceptance of gays and lesbians and the use of computer scripts to explore a more sophisticated model (code for R will be posted online). (Received September 20, 2011)

1077-J1-1973 **Maria G Fung*** (mfung@worcester.edu), Mathematics Department, 486 Chandler Street, Worcester State University, Worcester, MA 01602. *Quantitative Literacy in a First-Year Seminar Course.* Preliminary report.
Worcester State University's new liberal arts curriculum involves a yearly themester choice, and currently it is "Worcester in the World." In support of this initiative, a first year seminar course on "Disturbing Times in Worcester and the World" was developed. This course focuses on quantitative learning, through explorations of both global and local data around poverty, education, health, population growth, and environmental issues. Students complete a final project centered on making a positive change on campus or in the community to ameliorate some of serious existing problems. (Received September 21, 2011)

1077-J1-2467 **Alicia Sevilla***, sevillaa@moravian.edu, and **Kay Somers**, somersk@moravian.edu.
Quantitative Reasoning and Informed Citizenship: Building Students' Awareness of Social Issues.
Our course, Quantitative Reasoning and Informed Citizenship, seeks to develop in students the reasoning skills needed to interpret and assess numerical arguments, with emphasis on issues relevant for informed and effective citizenship. Students engage in numerical, logical, and statistical reasoning, while analyzing current issues using real data. Because an important part of being an informed citizen is understanding how quantitative analysis can give insights into issues of social justice, most topics include examples, exercises, activities, or projects addressing such issues. One project in particular links to our college's year-long "In Focus" program on poverty and inequality. "In Focus" themes for future years are sustainability, health care, and war and peace, all of which lend themselves to quantitative reasoning activities related to social justice. We will discuss the course and how we keep it current; we will also give concrete examples of ways we actively engage students in the analysis of social justice issues. (Received September 22, 2011)

My Most Successful Math Club Activity

1077-J5-658 **Jacqueline A. Jensen-Vallin*** (jacqueline.jensen@sru.edu), 1 Morrow Way, Slippery Rock University, 200A Vincent Science Center, Slippery Rock, PA 16057. *Math Club Bingo.*
In Spring 2011, the Slippery Rock University Math Club hosted the game "Math Bingo" during one of its regular club meetings. Each student in attendance was given a (distinct) bingo board. Problems were displayed on the document camera and students were to mark off the slots on their board corresponding to the solution of the problem. As is usual for bingo, the first student to get a certain arrangement of spots on their board marked won

a prize. We will provide examples of the problems and boards used, and discuss ways of providing appropriate prizes. (Received September 09, 2011)

1077-J5-732 **Daniel M. Look*** (dlook@stlawu.edu), St. Lawrence University, Department of Mathematics, 23 Romoda Drive, Canton, NY 01915. *Celebrating Pi-Day with a Piathlon!*

As a biathlon involves completing two activities and a triathlon involves completing three activities, a piathlon involves completing pi activities. Events are scored out of either 1 or 100 points, with 100 points indicating a completed activity. Teams attempt to complete as close to pi events as possible; so they are aiming for 314.159265..... points. Competing involves calculating exactly how much of certain events a team completes. For example, if a team is working on a tangram puzzle they may stop with the puzzle partially complete to earn fewer than 100 points. Students can choose whether the event is worth 100 points or 1 (the 1 point option is used to get decimal scoring). Further, if a team overshoots pi events, certain activities allow the earning of negative points. This event is held annually at St. Lawrence University in honor of Pi day. At the last competition a team was able to approximate pi to 7 decimal places! (Received September 11, 2011)

1077-J5-755 **Brooke E Buckley*** (buckleyb1@nku.edu), Department of Mathematics and Statistics, Northern Kentucky University, Nunn Dr, Highland Heights, KY 41099, and **Bethany A Noblitt** (noblittb@nku.edu), Department of Mathematics and Statistics, Northern Kentucky University, Nunn Dr, Highland Heights, KY 41099. *The Amazing Mathematical Race.*

This presentation will describe an amazing mathematical race, loosely based on the CBS hit show 'The Amazing Race,' in which participants race to complete challenging mathematical tasks. Teams, pit stops, clues, time limits, fast forwards, challenges and prizes are all components of the CBS show. They are also part of the Amazing Mathematical Race sponsored by the Math and Stat Club at Northern Kentucky University as the culminating club event each April. The event is in celebration of Math Awareness Month, sponsored by the Joint Policy Board for Mathematics with which the Mathematical Association of America is a collaborator. In the race, teams of two compete in a series of ten math-related challenges across campus. The goals of this event are to hold an activity featuring mathematics in a fun and exciting environment and to highlight this fun environment for people who are typically wary of mathematics. This presentation will describe various components of our race, including logistics for the implementation of the race, as well as activities appropriate for a variety of mathematical backgrounds. We hope to spark your interest to plan and implement your very own Amazing Mathematical Race. (Received September 12, 2011)

1077-J5-871 **Monika Kiss** and **Jacci White*** (jacci.white@saintleo.edu). *Math Awareness Week: Students Engaging Students.* Preliminary report.

At Saint Leo University, the Math club coordinates the mathematics awareness week activities for the University. These activities include a Pi eating contest, tetrahedron kite night, math movies, math Jeopardy, math contests and more. These ideas will be shared including the success and problems that have been associated with each one, distribution of responsibilities, coordination of prizes, sponsorship, the pros and cons of pairing with another discipline, and other issues to be aware of. (Received September 13, 2011)

1077-J5-1099 **Kathryn Behrend Andrist*** (kathy.andrist@uvu.edu). *Bringing Down The House?*

As keynote speaker for Utah Valley University's (UVU) Math Week, David Irskine, featured in the New York Times bestseller "Bringing Down the House" and major motion picture "21" shared his experiences as an MIT student turned professional card counter. This event was attended by several hundred students, mostly non-math majors. The Math Club followed up this popular presentation with a casino afternoon. Math Club officers were trained as blackjack dealers. An 'experienced' card counting Math faculty member (whose name shall remain anonymous) coached 30+ students in card counting. Students from many disciplines attended to see if they had what it takes to beat the house. Moans, groans and an occasional wahoo could be heard as they tested their ability to concentrate and focus on the cards. The presenter will discuss how to host such an event and will share UVU's creative solution for funding their Math Club. (Received September 16, 2011)

1077-J5-1386 **Dale K Hathaway*** (hathaway@olivet.edu), One University Avenue, Department of Mathematics, Olivet Nazarene Univesity, Bourbonnais, IL 60914. *Origami for Math Clubs.*

A topic that is included in our math club every year is mathematical origami. Student's love the hands on activity and the fact that they get to take something physical from math club that day, stimulating conversations all across campus. The Pentagon-Hexagon Zig-Zag (PHiZZ) units developed by Tom Hull are a favorite because of the ease of construction and the flexibility of the models that can be constructed. Other origami models with mathematical implications have been used and will be discussed including creating dodecahedrons and using business cards to create fractal sponges. This talk will discuss how to implement this topic along with suggestions for mathematical connections and supplies to use. (Received September 19, 2011)

1077-J5-1397 **Jennifer McLoud-Mann*** (jmcloud@uttyler.edu), 3900 University Blvd., Tyler, TX 75799, and **Christina Graves** (cgraves@uttyler.edu), 3900 University Blvd, Tyler, TX 75799. *Interdisciplinary Lecture Series.*

This talk will focus on forming bonds between faculty and student groups in other disciplines that are complementary to mathematics. In particular we will discuss ideas for creating an Interdisciplinary Lecture Series. Specific examples of suggested lecture topics will be given. (Received September 19, 2011)

1077-J5-1723 **Alicia M Cornelia*** (acorneli@u.rochester.edu), CPU #275184 University of Rochester, Rochester, NY 14627. *University of Rochester's Annual Pi-Day Festival.*

University of Rochester's Annual Pi-Day Festival is a collaboration of both activities and lectures in a tribute to both pi and the elegant subtleties of Mathematics. Consisting of a series of lectures, a "pi" pie throwing fundraiser, a revealing of the numbers of pi, and much, much more; the festival was a success! In addition to an excellent advertising campaign created by both the Society of Undergraduate Mathematics Students (SUMS) and University of Rochester Communications; we were able to attract media from the city–which received us an article in the local newspaper. In attendance were students and staff of the university, along with high school students from the surrounding inner-city school districts. This allowed for the Math department to extend its reach not only to University of Rochester students, but also to students who may not have had the chance to really see the beauty in Mathematics. Overall, this event helped to show off the UR Mathematics Department and to also discuss the fundamental role Mathematics plays in our everyday lives (and to also have fun!) (Received September 20, 2011)

1077-J5-2030 **Jill Bigley Dunham***, 401 Rosemont Ave, Frederick, MD 21701, and **Ann Stewart**. *Solidly Platonic: Hood College's Math Tea Love Affair with Vi Hart.*

Vi Hart, a "recreational mathemusician," has recently become well-known for her series of Web videos, known collectively as Doodling in Math Class. She has also developed a number of fun, colorful, and very hands-on demonstrations on her web site.

With her permission, we will share our experiences using two of her activities in our weekly math tea: creating Platonic-solid balloon animals, and carving Platonic solids out of food. (Received September 21, 2011)

1077-J5-2043 **Kathi Crow*** (kcrow@salemstate.edu). *Art Museum Field Trip.*

While most students are familiar with how math can be applied to fields such as physics and economics, many don't see how it can be connected to the arts. A trip to the local art museum is a great way for the students to bond on an outing and to learn how some basic math can be applied to problems involving art.

My favorite math club activity involves teaching the students how to find the "best" viewpoint for seeing some works of art and then going out to the museum to put the theory into practice. Given a photograph or a painting made with realistic perspective, basic math such as similar triangles can be used to ascertain where to stand so you view it from the same perspective as the artist or camera. The theory can be taught in a quick 15 minute lecture and then we're ready for a day of fun. (Received September 21, 2011)

1077-J5-2111 **H. Smith Risser** (hrisser@mtech.edu), **Casey Clark*** (Cmclark@Mtech.edu), **Jay Rosencrantz**, **JoAnne McAllister**, **Jeff Winter** and **Stuart Fortier**. *The Calculus Bowl: A Fundraising Activity for the Mathematics Club.*

In this presentation, undergraduate mathematics club members and mathematics faculty will describe a fun and engaging Math Club fundraiser which rewarded competitors for the knowledge they gained in their calculus classes: The Calculus Bowl. Montana Tech's First Annual Calculus Bowl had over 200 participants and raised over 1100 for the mathematics club. The format of the Calculus Bowl, incentives used to attract competitors, and lessons learned during the first Calculus Bowl competitions will be described in the presentation. University and high school faculty, as well as student leaders interested in utilizing innovative and exciting math club activities and fundraisers are encouraged to attend this presentation. (Received September 22, 2011)

1077-J5-2267 **Maria Falidas*** (falidasm@acs.gr), Greece. *Beautiful Minds: Getting hooked on Math through Literature.*

It's 3:30pm. The sound of the bell announces the end of this school day and rushes students down the stairs away from the "math floor." On the board an exercise on Newton's approximation stares the last students of the Calculus class murmuring goodbye... Or is it hello? The door opens again, four 10th graders come in for the

Math Literature Club meeting and start talking about the curve. "Miss, isn't that what Archimedes said about the parabola?

If you are looking for ways to inspire students to see Mathematics in a different light, a mathematical fiction reading will give you a spark. This talk will provide a quick tour of resources and guidelines for enrichment tasks associated with novels addressing different levels of student groups. (Received September 22, 2011)

Philosophy of Mathematics and Mathematical Practice

1077-K1-85 **Joshua B. Wilkerson*** (jbwilkerson@tamu.edu), Texas A&M University, College Station, TX. *Beyond Practicality: George Berkeley and the Need for Philosophical Integration in Mathematics.*

"When am I ever going to use this?" As a math teacher, this is the number one question that I hear from students. It is also a wrong question; it isn't the question the student truly intended to ask. The question they are really asking is "Why should I value this?" and they expect a response in terms of how math will solve their problems. But should we study math only because it is useful? Or should we study math simply for its own sake?

It is my contention that valuing mathematical inquiry for its own sake in the general pursuit of truth is a better mindset in which to approach the practice of mathematics, rather than exalting practicality. This paper will demonstrate one unexpected reason to support such a philosophical view: it actually leads to *more* practical applications of mathematical endeavors than would otherwise be discovered.

Support for this theory may be found in the life of George Berkeley. This paper will examine the historic mathematical implications of Berkeley's philosophical convictions: the refinement of real analysis and the development of nonstandard analysis. Berkeley not only answers the question of why we need philosophical integration in mathematics, but also how we approach such integration. I will close by examining the latter. (Received August 09, 2011)

1077-K1-383 **Thomas Drucker*** (druckert@uww.edu), Dept. of Math. and Comp. Sci., University of Wisconsin–Whitewater, 800 West Main Street, Whitewater, WI 53190. *Thought in Mathematical Practice.*

Palle Yourgrau has recently argued that mathematics as currently practiced is a domain from which thought is absent. His claim is that philosophers who have tried to carry mathematical techniques over into metaphysics have fallen short because the questions that arise in philosophical discussions require thought and not just the application of technique. He points to a thread of criticism of mathematics that goes back to Plato. In this paper an attempt will be made to characterize stages in the doing of mathematics that require thought on the part of those performing them. While there are aspects of mathematical practice that are formulaic enough to appear not to require thinking, it is throwing babies out with bathwater to abandon what mathematics has to offer to the practice of metaphysics. (Received August 28, 2011)

1077-K1-800 **Jeff Buechner*** (buechner@rci.rutgers.edu), Dept Philosophy, 432 Conklin Hall, 175 University Ave., Rutgers University, Newark, NJ 07102. *Formal mathematical proof and mathematical practice: a new skeptical problem.* Preliminary report.

There are several problems in the philosophy of mathematics concerning the notion of mathematical proof, at least one of which serves as the primary motivation for experimental mathematics. But there is a new problem which appears to have no easy fix; moreover, it is a skeptical problem. The problem is that one can construct a proof (in some cases by an algorithm) which conforms to the definition of a formal mathematical proof, which no mathematician would regard as a legitimate mathematical proof. Indeed, there are some constructions that even a layman with no knowledge of mathematics would regard as an illegitimate mathematical proof. Appeal to the informal notion of proof used by mathematicians is circular: to justify the formal notion, one needs to appeal to the informal notion, which, in turn, is justified in terms of the formal notion. The skeptical problem is: which proofs are genuine and provide mathematical knowledge, and which do not? It is worthless to appeal to the notion of a formal mathematical proof to resolve the skeptical issue. (Received September 12, 2011)

1077-K1-904 **Ruggero Ferro*** (ruggero.ferro@univr.it), via Gabelli 57, 35121 Padova, Italy. *How Do I (We) Know Mathematics.*

I view the philosophies of knowledge divided into three broad groups. Some of them deduce their position about the process of knowing from general ideas about the nature of humankind, with the difficulty of justifying how do they know the correctness of their views. Some others want to be experimental, observing what other people do during the process of knowing, forgetting that they have to interpret and guess what in happening inside them, since the language is not as transparent as it is often assumed to be. Noting the difficulties faced by the other positions, a third group reverts to a mysterious unborn human capability to know. Knowledge is a personal endeavor: not only with respect to the acquired knowledge, but also the process of coming to know is very personal. Thus a fourth position can be imagined according to which a central role is played by introspection, i.e. I have an idea of what it is to know by analyzing within myself the way I come to know. To support this position one should make explicit what is seen by analyzing the process of knowing within oneself, how it relates to other people knowledge, and one should show how we can reach our actual knowledge (of mathematics in particular) through the detected process. My exposition will develop these points. (Received September 14, 2011)

1077-K1-1196 **Daniel C. Sloughter*** (`dan.sloughter@furman.edu`), Department of Mathematics, Furman University, Greenville, SC 29613. *The Consequences of Drawing Necessary Conclusions.* Preliminary report.

Benjamin Peirce defined mathematics to be "the science which draws necessary conclusions." His son, Charles Peirce, pointed out a significant consequence of this definition: mathematics, out of all the sciences, relies upon no other science. A mathematician seeks out the consequences of given hypothetical relationships. In doing so, he need not concern himself with either the nature of the objects involved, or how it is that we come to know them.

In particular, mathematics is independent of philosophy. Yet this does not lessen the importance of the work of the philosopher of mathematics: an account of the nature of mathematical knowledge is of fundamental importance to our understanding of the nature of human knowledge as a whole. As G. H. Hardy pointed out, anyone "who could give a convincing account of mathematical reality would have solved many of the most difficult problems of metaphysics." In attempting to find this account, philosophers need to pay close attention to exactly what it is that mathematicians do. Although the philosophy of mathematics need not have any influence on mathematical practice, it is a matter of vanity for mathematicians to think that the philosophy of mathematics is worthwhile only if it were to have some such influence. (Received September 17, 2011)

1077-K1-1287 **sarah-marie belcastro*** (`smbelcas@toroidalsnark.net`). *Epistemological Culture and Mathematics.* Preliminary report.

After Evelyn Fox Keller, we define *epistemological culture* to mean the standards used by members of an academic discipline to achieve explanatory satisfaction. As mathematicians, we have a distinct epistemological culture (consider the use of the word "proof" in mathematics vs. its usage in other contexts).

We will argue that the epistemic privilege generally accorded to mathematics is inextricably linked with mathematical practice, and that both mathematical practice and epistemic privilege are intertwined with and inform mathematical epistemological culture. That is, mathematics is viewed as having a more powerful claim to truth than many other fields; our practice as mathematicians contributes substance to this view; and our standards for deciding validity are deeply related to our methods of producing/disseminating knowledge.

The epistemological culture of mathematics differs, in sometimes surprising ways, from the epistemological cultures of laboratory and social sciences. We posit that these differences partially explain vexing phenomena such as the inappropriate usage of mathematics in social science or cultural theory research, and the overgeneralization of feminist critiques of biological and social sciences to the physical sciences and mathematics. (Received September 18, 2011)

1077-K1-1744 **Nathaniel G. Miller*** (`nathaniel.miller@unco.edu`), Campus Box 122, University of Northern Colorado, 501 20th Street, Greeley, CO 80639. *CDEG: Computerized Diagrammatic Euclidean Geometry.*

The use of diagrams in Euclidean geometry is an area in which most informal mathematical practice does not align well with most formal logical and philosophical accounts of geometry. Most people giving informal geometric proofs rely on diagrams as part of their proofs; this tradition, in fact, goes back to Euclid. However, most formal accounts of geometry developed over the last 150 years do not rely on diagrams, and it is often claimed that diagrams have no proper place in rigorous mathematical proofs.

CDEG is a free computer proof system for manipulating and giving proofs with diagrams in Euclidean geometry that seeks to bridge that gap. It is based on a rigorously defined syntax and semantics of Euclidean diagrams. This talk will include a demonstration of CDEG, and a discussion of some of the mathematical, philosophical, and educational implications of such a diagrammatic computer proof system for Euclidean geometry. (Received September 20, 2011)

1077-K1-2002 **Bonnie Gold*** (bgold@monmouth.edu). *Philosophy (but not philosophers) of mathematics does influence mathematical practice.* Preliminary report.

Since most philosophers of mathematics tend to ignore current mathematical practice outside of foundations, it is not surprising that mathematicians tend to ignore current philosophy of mathematics. I will argue, however, that in a deeper sense a mathematician's philosophy of mathematics, even if not coherently articulated, does affect his/her mathematical activities: the types of questions considered, whether (s)he focuses more on individual problems or on mathematical structures, the general direction of mathematical work over a time interval. Further, investigating, rather than suppressing, these underlying motivations can lead to interesting philosophical questions. (Received September 21, 2011)

Preparing College Students for Calculus

1077-K5-903 **Ramanjit K Sahi*** (sahir@apsu.edu). *Making connections with Precalculus.*

Functions are the cornerstone for Precalculus. Exploring various algebraic and trigonometric functions through activities, lectures, and interactive software help students to have a deeper understanding of the topics. In this presentation, I will talk about the strategies and techniques applied in my Precalculus classes that have helped in increasing students proficiency as well prepared them for Calculus. (Received September 14, 2011)

1077-K5-1271 **Alison Ahlgren*** (aahlgren@illinois.edu), Department of Mathematics, 1409 West Green Street, Urbana, IL 61801, and **Marc Harper** (marcharper@ucla.edu). *Identifying Crucial Concepts and Skills, and Preparing College Students for Success in Calculus.* Preliminary report.

The placement program began at the University of Illinois in 2007 and is currently in its 5th year. All students take an online assessment and are offered the opportunity to use the ALEKS technology to remediate prior to course enrollment. Data from three years of placement covering thousands of U of I students on 182 concepts and skills has yielded unprecedented specificity in determining which items are indicative of student preparedness and success in three forms of Calculus. Items are naturally partitioned by statistical analysis into a spectrum from basic to advanced and are traceable throughout the sequence of courses, clearly identifying particularly strong and weak students. Further, it is possible to determine which items correlate most significantly with student performance in Calculus and to see if these items are being adequately addressed in Precalculus. If not, then changes to the Precalculus and summer readiness curriculums can be made to reflect the reality dictated by the data. These results are of use to educators, instructors, and placement program developers. We present examples and vivid visualizations of the results from this study. (Received September 18, 2011)

1077-K5-1565 **Angie Hodge*** (amhodge@unomaha.edu). *Preparing your calculus students: An inquiry-based algebra review.*

For anyone who has taught calculus, it is evident that the issue is not how to teach students the calculus material, but rather how to help each student succeed despite their insufficient background in algebra. That is, the algebra skills of the students is one of the greatest obstacles that inhibits students from doing well on calculus exams even if they seemingly understand the calculus concepts. Recently, I tried something different and began my calculus class with an inquiry-based algebra review that proved to be very successful. In this session, I will discuss the method I used to review algebra in only one week, including details about how I involved the students and did this without lecturing at them. The results of the first exam were astounding with not a single student making any "freshman mistakes" or many algebra errors at all. Rather, they became inquisitive and wanted know more about when they can use algebra and why the rules they memorized years ago actually work. This session is aimed at helping others prepare their calculus students to learn CALCULUS by effectively and efficiently overcoming their algebra deficiency via an inquiry-based learning approach. (Received September 20, 2011)

1077-K5-2684 **Alla Morgulis*** (amorgulis@bmcc.cuny.edu) and **Claire Wyn Wladis**. *Preparing students for proofs and deeper conceptual thinking by implementing collaborative learning projects in Intermediate Algebra and Trigonometry.*

We developed a pilot Intermediate Algebra and Trigonometry course which implemented collaborative learning projects that introduced students to proofs and conceptual thinking. The aim was to prepare students for the higher-order thinking skills that are needed in calculus courses and beyond. The pilot courses in which this new curriculum was implemented had higher student success rates and higher scores on the department final exam, suggesting that the new course structure was effective. We hope that longer term followup with pilot students (currently in progress) will show improved rates of success in higher level mathematics courses.

In this talk we will describe the structure of the pilot course and assignments and talk about how this new way of teaching was implemented. In addition we will discuss challenges and practicalities encountered in actually implementing the new curriculum. (Received September 22, 2011)

1077-K5-2721 **Mairead Greene*** (mairead.greene@rockhurst.edu), 1100 Rockhurst Road, Kansas City, MO 64110, and **Paula Shorter** (paula.shorter@rockhurst.edu). *Mathematical Reasoning in Calculus: Moving Between Representations.*

One form of mathematical thinking that we engage our calculus students in from the beginning is exploring concepts in multiple different representations (graphical, narrative, symbolic, numerical) and connecting an understanding of concepts across representations. To achieve this, students are often asked to develop a concept in one representation and then in turn take the same concept and extend their understanding to a new representation. This strengthens and deepens the students' understanding of concepts and at the same time prepares them to approach problems using multiple representations throughout the course. In addition, we pose typical calculus problems, but in a variety of different representations which forces students to look beyond memorized methods and apply their understanding of the concepts instead. This improves their ability to approach more typical analytical versions of these problems as they can reach for graphical and numerical tools to help them understand the situation. This talk will illustrate situations where students are required to understand concepts in multiple representations and connect this understanding across representations. We will also discuss how we develop this ability in our precalculus and calculus courses at Rockhurst University. (Received September 22, 2011)

1077-K5-2801 **Peter J. Byers*** (pbyers@bu.edu). *Tangent lines: a multifaceted concept.*

Over the last few decades, math education has increasingly emphasized making connections between different topics. Thus, a key part of improving teaching is improving connections and deciding which connections are most important. In a Calculus or Pre-Calculus class, tangent lines can be connected with each of the following topics:

- Tangent lines to circles, as taught in 10th grade Geometry
- High school velocity and rate problems
- Graphing calculators
- Double roots of polynomials
- Continuous functions and limits
- Derivative as a number and as a function
- Exponential functions (including problems in interest, population growth, radioactive decay, etc.)
- Advanced topics such as inverses, linear approximation, and the chain rule for compositions of functions

This presentation will consider what changes can be made in order to teach these connections more effectively, and particularly how tangent lines to exponential functions can be treated with geometric (non-calculus based) techniques like scaling. It will conclude by considering the success of such changes thus far. (Received September 22, 2011)

1077-K5-2880 **Susan L Ganter*** (ganters@ecu.edu) and **Jack Bookman** (bookman@math.duke.edu). *Long-Term National Impact of the Calculus Reform Initiative.* Preliminary report.

From 1988 to 1997, the NSF's Calculus Program awarded over 23 million to 127 institutions and organizations, with a goal of "raising students' conceptual understanding, problem solving skills, analytical and transference skills, while implementing new methods to reduce tedious calculations," with an emphasis on "interactions between different sectors of the mathematical sciences community in the development of model curricula and prototypical instructional materials." Now, after almost 25 years, is the right time to conduct a comprehensive, critical study–enough time has passed to gain some perspective but we are still within the window of institutional memory. This presentation will outline a project in which a set of research studies is being developed to assess this long-term impact. The primary purposes of the project are: 1. to survey the 127 NSF-funded calculus PIs (1988-97), to assess the current status of calculus at their institutions; 2. to assess long-term changes in calculus textbooks as influenced by calculus reform efforts; 3. to conduct six case studies of a broad range of mathematics departments; and 4. to publish and disseminate the volume resulting from the proposed work and a set of previously-developed expository papers. (Received September 22, 2011)

Projects, Demonstrations, and Activities that Engage Liberal Arts Mathematics Students

1077-L1-214 **Stan Perrine*** (sperrine@csuniv.edu), Charleston, SC. *The Real Cost of Home Ownership.*

The past three years has seen the development of a significant project on the cost of home ownership for our Liberal Arts Math Course. This project starts with the basic calculation of a mortgage payment, but then goes on to incorporate the true cost of home ownership - from principal and interest, to insurance and taxes, and then on to furnishing the home. Students use online tools such as are available at yahoo real estate to calculate mortgage payments for different interest rates and loan lengths, and also to shop for and purchase major household appliances. Finally, students are asked to reflect on whether their chosen professions will allow for the ownership of the "home of their dreams." This talk will give examples of student work as well as feedback and comments on the value of the project from students and faculty. (Received August 13, 2011)

1077-L1-282 **Daniel P. Wisniewski*** (Daniel.Wisniewski@desales.edu), Department of Mathematics/Computer Science, DeSales University, 2755 Station Avenue, Center Valley, PA 18034. *Reading, Writing and Discussing Mathematics in a Service-level Undergraduate Course.*

Often, undergraduate liberal arts students taking a mathematics course to satisfy a general education core requirement are "math-phobes." In the service-level course *Survey of Mathematics*, reading, writing, and discussion are successfully integrated into a traditional curriculum of mathematical problem-solving. From a "popular" mathematics book, students read various chapters which combine historical facts with rigorous mathematics and applications. Selected readings support lectures, yet often explore other topics.

Students write reviews which contain a summary of and a personal reaction to the chapter's material, including how the material does or does not relate to other aspects of their life (e.g., other courses, job experiences, family and social life, previous math education). Additionally, students participate in an on-line Discussion Board in response to particular chapters on broader topics (e.g., women in mathematics).

Providing the opportunity for success in math, these chapter reviews receive positive feedback and enable students to shift their impression and experience of math from one of fear and dislike to one of genuine interest and enjoyment. Examples of topics and student work will be given with preliminary data charting student reactions. (Received August 18, 2011)

1077-L1-442 **Robert Edward Lewand*** (robert.lewand@goucher.edu), Dept.of Mathematics and Computer Science, Goucher College, 1021 Dulaney Valley Road, Baltimore, MD 21204. *Final Project in an Elementary Cryptology Course.*

A popular way for liberal arts students to fulfill their mathematical reasoning general education requirement at my institution is by taking an elementary cryptology course. In this presentation I will describe the final project used to assess student learning in that course. The project involves cryptanalysis of three messages whose decipherments rely on the students' ability to determine the nature of the cryptographic scheme as well as the key(s) employed to encipher each. I will describe the learning objectives of the course, the mathematical knowledge that students need to bring to bear on this challenge, the rubric used to appraise the students' level of mastery of the course material, and finally assessment. (Received September 01, 2011)

1077-L1-517 **Emelie A Kenney*** (kenney@siena.edu), Department of Mathematics, Siena College, 515 Loudon Road, Loudonville, NY 12211. *Open Questions in Number Theory for Liberal Arts Students: The Good, the Bad, and the Underwhelming.*

Many institutions offer specially designed "core courses" so that non-science majors can satisfy a quantitative literacy requirement. Although not all faculty are fond of teaching them, such courses can present an opportunity to expose liberal arts students in a dynamic way to the wonder and joys of actually doing mathematics. We describe various ways we have incorporated unsolved problems in number theory and combinatorics into a history of mathematics core course. Sample assignments and in-class exercises are then provided and critiqued. Finally, we discuss favorable outcomes, drawbacks and shortcomings, and possible future refinements of this approach to engaging liberal arts students in their mathematical education within a rich, challenging context. (Received September 06, 2011)

1077-L1-560 **Reva Kasman*** (rkasman@salemstate.edu), 352 Lafayette Street, Salem, MA 01970. *Balancing structure and creativity in projects for liberal arts mathematics.* Preliminary report.

Liberal arts mathematics courses offer students the (often surprising) opportunity to apply mathematical topics to their own life experiences. For instance, every student can recall a dilemma in which voting could have been used to make a group decision, or a situation where scheduling conflicts needed to be avoided. But not every example that a student designs will lead to rich data for analysis or assessment. Ideally, assignments allow for creativity while still being sufficiently structured to ensure that students have a constructive learning experience and instructors can easily grade the finished products. This talk will describe several projects given at the end of units on voting theory and graph theory which have been created with these goals in mind. In each project, students are able to choose their own imaginative context, but a "skeleton" of data is provided, such as a preference schedule with unnamed candidates, which must be incorporated into the chosen thematic scenario. (Received September 07, 2011)

1077-L1-974 **Jeffrey L. Poet*** (poet@missouriwestern.edu), Computer Science, Math, and Physics, 4525 Down Drive, Saint Joseph, MO 64507. *Geometric Constructions in Contemporary Problem Solving.*

Our liberal arts math course consists of four required units - graph theory, descriptive and inferential statistics, voting theory, and the mathematics of finance – all standard units in a liberal arts math text. I include a fifth unit on geometric constructions in which I teach students to "think with their compass and unmarked straightedge." In addition to pulling some historical context into the class, this unit appeals to students in the fine arts and other tactile learners. This unit gives the usual math non-enthusiasts an opportunity to shine. (Received September 15, 2011)

1077-L1-1106 **Theresa Jorgensen***, jorgensen@uta.edu, and **Barbara Shipman**, bshipman@uta.edu. *Try Trisecting by Bisecting.*

We present a guided classroom activity, designed for liberal arts majors, that showcases the classic geometric problem of trisecting an angle. While it is not possible to trisect an arbitrary angle with compass and straightedge, this example explains, in a liberal-arts setting, how this is possible using an infinite sequence of bisections. Considering all of these bisections at once by taking an intersection of appropriately defined geometric objects allows us to trisect the angle. The visual representation of the convergence gives liberal arts students a pictorial context in which they are more comfortable, allowing them to consider the underlying mathematical concepts without becoming entangled in notation. The result shows these students how infinity lends the mathematical power to achieve a feat that by finite methods alone is impossible. (Received September 16, 2011)

1077-L1-1247 **Jackie A Hall*** (hallja@longwood.edu), VA. *"I CAN PROVE IT"– Using Proofs of the Pythagorean Theorem to Bolster Confidence for the math-anxious Liberal Arts Mathematics Students.*

One of the projects in Mathematical Thinking, a Liberal Arts course designed specifically for the "I cannot do math" student, involves proving the Pythagorean theorem. In class we prove the theorem four different ways. Most of the students remember having been taught Pythagoras' theorem in high school; however, very few have ever seen an actual proof of the theorem.

After proving the theorem in class, the students are assigned (worth two quiz grades) to prove Pythagoras' theorem to someone else and to write about the experience. One grade is for the proof itself. It is graded for correctness just as if they were answering a test question "Prove the Pythagorean Theorem." The other quiz grade is given for the story they tell of proving the theorem. How did the proof go? What was the student's experience? What were the reactions of the person hearing the proof? Many students prove the Pythagorean theorem to a parent or sibling or old friend. The experience is generally quite positive. Many report the pleasure of parents or their own excitement and pride in themselves that they are able to prove such a fundamental truth to parents or friends. (Received September 18, 2011)

1077-L1-1256 **Russell D Blyth*** (blythrd@slu.edu), Department of Mathematics & Computer Science, Saint Louis University, 220 N. Grand Blvd., St. Louis, MO 63103. *Do it together to understand it: group activities that help liberal arts students understand mathematical concepts.*

For the past ten years I have been teaching a small "freshman inquiry seminar" class based on the first six chapters of Burger and Starbird's textbook "Heart of Mathematics." The pedagogy is non-traditional; students are assigned to read each text section ahead of class so that class time is spent on discussion, questions and (primarily) group activities. The course material naturally lends itself to some predictable hands-on activities (for example, cutting Möbius bands in halves or thirds), but we will focus our talk on several other activities that help students break through their initial difficulties in understanding some topics. For example, we will discuss using a computer worksheet to assist in encoding and decoding messages using public key cryptography (students exchange messages via email during class and gain a better appreciation for how public key cryptography works), walking paths in an open space of the classroom floor to figure out winding numbers, and attempting to unravel themselves from a ring of held hands to demonstrate equivalence or non-equivalence of a knot to the unknot. At the conclusion of the talk we will discuss two creative projects that students undertake, one on the fourth dimension and one on fractals or chaos. (Received September 18, 2011)

1077-L1-1384 **Yun Lu*** (lu@kutztown.edu), Mathematics Department, Kutztown University of PA, Kutztown, PA 19530. *Using a Jeopardy Game to Engage Students' Learning.*

Jeopardy is a very popular quiz show in American, and it can also be used to engage students' learning in mathematics. In this talk, I will describe how I used the Jeopardy games to help students learning when I taught finite mathematics in my school, and I will also share some students' feedback with the audience. (Received September 19, 2011)

1077-L1-1526 **Erin Smith*** (Erin.Smith@zu.ac.ae). *Survey It! Using Surveys to Answer Student's Questions.*

Many students at a Gulf university enroll in a mathematical modeling course that utilizes real life data to provide opportunities for data analysis and interpretation. This course is designed for students of non-science majors with varying mathematical ability and comfort levels. The course uses Excel as a mathematical tool for learning and includes a project students complete individually. One project designed and used in the course allows students to create, conduct, analyze, interpret and present conclusions to a survey using the statistical and graphing skills learned in the course. The goal of this project is to provide a meaningful mathematical experience using Excel as a tool while students gain a greater understanding of the use and applicability of statistics in their daily life. Additionally, students are able to improve their English writing skills as the project requires a submission of a written paper. Projects are evaluated using a rubric. Throughout the project, students exhibit a heightened level of enthusiasm, which is unseen earlier in the course. (Received September 20, 2011)

1077-L1-1687 **Helmer Aslaksen*** (helmer.aslaksen@gmail.com), Dept. of Math., Univ. of Oslo, Box 1053 Blindern, 0316 Oslo, Norway. *Observing the Motion of the Sun and the Moon.*

At the National University of Singapore I have taught a course called Heavenly Mathematics & Cultural Astronomy. One of the goals of the course is to make the students more conscious of the motion of the Sun and the Moon by doing a homework that requires them to:

(1) Take three pictures showing the change in the setting position of the Sun in the course of the semester.

(2) Take three pictures showing the changes in the shadow cast by a ring.

(3) Determine the day of the first visibility of the lunar crescent, i.e., the first day of the Muslim month.

(4) Estimate the tilt of the Moon when it is a crescent close to the horizon.

(5) Estimate where and when the Sun can be seen from your window in the course of the year.

The astronomical prerequisites boil down to three-dimensional geometry, but given how difficult three-dimensional geometry can be to visualize and how alienated many students are from nature, most students find it both interesting and challenging.

I have students from many different countries in my class, and for the students from the temperate zone it is a real eye-opener to see how the Sun and the Moon move in the tropics. (Received September 20, 2011)

1077-L1-2272 **Alissa S. Crans*** (acrans@lmu.edu), Department of Mathematics, Loyola Marymount University, One LMU Drive, Suite 2700, Los Angeles, CA 90045, and **Robert J. Rovetti**. *Beyond Formulas: A Collaboration Between Liberal Arts Underclassmen and Senior Math Majors.*

"Congratulations! Sony Pictures producers have hired you as a scientific consultant to assist them in producing a remake of the classic film Gone With The Seabreeze, which chronicles the founding of the Westchester campus of Loyola University in 1929. The original film features shots of various old buildings that can still be found across campus today. The producers wish to recreate these shots, but need to know where to position the camera, which they have tasked you with finding."

Thus began a collaborative project between liberal arts underclassmen and senior applied mathematics majors. Six teams of underclassmen, each led by a senior math major, set out to reconstruct an old photograph. Along the way they would run into inaccessible landscapes, blocked views, and busy schedules, but ultimately emerged with a polished product, clearer understanding of what it means to apply a theoretical method to a real-world problem, and a different perception and appreciation of what constitutes the art and practice of mathematics. We will discuss the courses involved, describe the assigned project and its pedagogical goals, and showcase the final product of one group. In addition, we will share various observations and reflections made by both students and instructors. (Received September 22, 2011)

1077-L1-2651 **Ben Galluzzo*** (bjgalluzzo@ship.edu), Shippensburg University, 1871 Old Main Drive, Department of Mathematics, Shippensburg, PA 17257. *Candy Bar Election.*

Accessible mathematics and a (seemingly) non-stop election cycle make voting theory a popular topic for liberal arts focused mathematics courses. While the alternative voting methods (and ballots) make for interesting "what-if" scenarios, the lack of "hands-on" experience leads students to question why such methods even exist. In this talk, we will discuss the Candy Bar Election; during which students caucus, campaign, and vote for their favorite candy bar(s) and voting method(s). The data collected from the vote is analyzed by students allowing them to better understand, and actively experience, how different mathematical approaches to solving the same problem can effect significant change. (Received September 22, 2011)

1077-L1-2835 **Charlotte J. Chell*** (cchell@carthage.edu), Department of Mathematics, Carthage College, 2001 Alford Park Drive, Kenosha, WI 53143. *Visualizing Hyperbolic Geometry in the Liberal Arts.*

Carthage College has a program called Great Ideas, modeled generally on the well-known Great Books curriculum. The program emphasizes close reading of seminal texts of the Western tradition, and two of the requirements of a major or minor in the program are the courses Foundations of Mathematical Thought and Foundations of Scientific Thought. The majority of students who enroll in Foundations of Mathematical Thought have taken at most one college math course (if any), but are accustomed to close reading, a distinct advantage for their study of mathematics. This talk will summarize the early texts students work with, and then discuss and demonstrate the extent to which we can bend the premise of reading original texts in order to use GeoGebra and Geometer's Sketchpad custom tools that we have created for hands-on student activities in Hyperbolic Geometry. (Received September 22, 2011)

1077-L1-2902 **Edward W. Welsh*** (ewelsh@westfield.ma.edu). *Hexiclouds: Graph Theory Meets LEGO Bricks.*

Color the edges of an isometric grid with six different colors so that there are edges of all six colors at each vertex. There are many solutions, and finding them turns out to be an easy enough problem for liberal arts majors to tackle using trial and error. A wide variety of solutions emerge when you consider permutations of a trivial solution, and there is a straightforward connection to Hamiltonian and Eulerian circuits: all concepts readily accessible to our curious nonmathematical colleagues on campus. We will represent solutions using LEGO bricks, and look for symmetries and other subtle patterns in this many-layered, deceptively deep problem. (Received September 22, 2011)

1077-L1-2951 **Ricardo Sanchez*** (risanchez@aii.edu), The Art Institute International, Minneapolis, MN. *Teaching College Mathematics Using Text Messaging.*

Text Messaging, using cell phones, is a very popular way for students to communicate and the terror of professors, specially to control the behavior and possible cheating. In this talk, I follow the popular literature about the use of clicker for the teaching of different courses from physics to statistics but instead I use text messaging from regular cell phones and free websites that allow the processing of answers and the projection in a powerpoint prezi or any presentation. The objective is to teach College Mathematics in a liberal arts college. This is a discussion of the experience with examples and suggestions for improvement. (Received September 23, 2011)

Quantitative Literacy and Decision Making

1077-L5-930 **Paul Taylor*** (pttaylor@ship.edu), Department of Mathematics, Shippensburg University, 1871 Old Main Drive, Shippensburg, PA 17257. *Using MS Excel to Improve Understanding of Financial Mathematics.*

A helpful way motivate students to improve their quantitative literacy is to use examples from personal finance. However, beyond compound interest the mathematics threatens to overwhelm students in a typical general education course. A perfect example is a level payment annuity, such as a mortgage repayment plan. Students appreciate the relevance of the topic but the derivation of the mathematical model is quite complex. In our general education course in financial mathematics, students use Microsoft Excel to reduce the model to simpler components of individual payments and interest charges. When the students can see the structure underlying the model, they achieve a much deeper understanding. This approach helps reduce the mystery behind their bills, making students more likely to consider personal matters of mathematics and finance with confidence rather than fear or avoidance. (Received September 14, 2011)

1077-L5-1058 **R W DeGray*** (rdegray@sjc.edu), Department of Mathematical Sciences, Saint Joseph College, West Hartford, CT 06117-2791. *Complex Systems and K-16 Curricula.*

The study of complex systems, a paradigm in the thinking about some of the intractable issues that we as individuals and societies are facing, and the mathematics associated with complex systems is currently sparse in the K-16 curricula. Quantitative literacy and decision making skills can be taught within the structure of courses or lesson plans about complex systems. An open source on-line interactive syllabus for an undergraduate level complex systems course will be offered as a starting point for collaborating on answers to the open question of the necessary mathematics and for building curricula suitable for K-16 education. We can collaborate, via the New England Complex Systems Institute (NECSI) Wiki, and tie together the teaching and learning materials from resources such as the COMplexity DIGest, TEDTalks, Khan Academy, The Futures Channel and others. (Received September 15, 2011)

1077-L5-1244 **Cinnamon Hillyard*** (chillyard@uwb.edu) and **Pete Nye** (pnye@uwb.edu). *The Financing Choices of American Consumers: The Influence of Quantitative Literacy, Cognitive Disposition and Material Values.*

Some consumers finance discretionary spending at extremely high interest rates. Many carry substantial balances on their credit cards at effective annual interest rates as high as 36%, and some pay annual rates on "pay day" loans in excess of 400%. High interest debt can rapidly cascade into an overwhelming financial burden, threatening the consumer's credit and long-term financial health. While these choices may seem unwise or even irrational, they are widespread. This survey study investigates how quantitative literacy (QL) may promote wiser financial choices. In addition, we examine consumers' willingness to apply their quantitative skills and think through the implications of their financing choices. While QL and consumer education matter, we propose that consumer values and motivations may also be important in explaining risky financial choices. For example, materialism drives many American consumers to take on imprudent levels of high interest debt. In addition to providing survey results, we will discuss how we assessed subjective and objective QL and how the results inform QL education practices. (Received September 18, 2011)

1077-L5-2563 **Eric C Gaze*** (egaze@bowdoin.edu), The Center for Learning and Teaching, Bowdoin College, 6050 College Station, Brunswick, ME 04011. *The Financial Literacy Project at Dartmouth College: Online Classroom Resources and Modules.*

The Financial Literacy Initiative at Dartmouth College, http://www.math.dartmouth.edu/~mqed/FinancialLiteracyProject/ , advocates a quantitative approach to financial literacy for college students, K-12 students, future teachers and adult learners. The initiative supports this approach through contextually rich curriculum modules for classroom use, short video presentations for faculty development or classroom discussion, and case studies. All materials are freely available through online publication. The Mathematics and Quantitative Education (MQED) financial literacy modules are part of this initiative from the Financial Literacy Center at Dartmouth College. Each module is structured as a slide presentation, supported by numerous activities, discussion questions, ideas for writing assignments, and advice to the instructor. Each module includes explicit ties to quantitative reasoning skills. When appropriate, explicit connections are also made to issues confronting future teachers. Financial literacy is an important life skill. We hope these modules will inspire you to use them in mathematics, economics, social science, business, writing, and quantitative reasoning courses. (Received September 22, 2011)

Research on the Teaching and Learning of Undergraduate Mathematics

1077-M1-33 **Eric David Weber*** (ericweber@asu.edu), 125 S Alma School Rd Apt 1065, Chandler, AZ 85224. *Students' Understanding of Two-Variable Functions and Rates of Change.*

In this presentation, I describe an approach to introducing the derivative function called the calculus triangle, which emphasizes the centrality of rate of change of quantities in thinking about the derivative. I describe the role of the calculus triangle in supporting students' ways of thinking about rate of change of one variable functions, and how they generalized this way of thinking to approach rates of change of two-variable functions in the context of a teaching experiment focused on the same. I present two important ways of thinking about functions, covariational reasoning and shape thinking, and how these two constructs help explain the understandings students developed about the calculus triangle as a representation of rate of change. I conclude by discussing the possible implications of covariational and quantitative reasoning for students' thinking about functions of three or more variables. (Received June 17, 2011)

1077-M1-142 **Kevin C. Moore*** (kvcmoore@uga.edu), 105G Aderhold Hall, Dept. of Math and Science Education, Athens, GA 30602, **Kevin R. LaForest** (laforesk@uga.edu), 105 Aderhold Hall, Dept. of Math and Science Education, Athens, GA 30602, and **Hee Jung Kim** (hjk@uga.edu), 105 Aderhold Hall, Dept. of Math and Science Education, Athens, GA 30602. *A circle of radius one: Pre-service teachers' notions of the unit circle.*

This study investigated undergraduate students' (who were enrolled in a pre-service secondary education program) understandings of trigonometric functions with the initial intention of exploring their notions of periodicity. However, the students' conceptions of the unit circle hindered their ability to correctly solve the tasks given during the first teaching experiment session. The students attempted to relate the described problem contexts to the unit circle by executing calculations, but had difficulty determining and justifying their calculations beyond referring to "unit-cancellation." The students' calculations did not stem from reasoning about the radius as a unit of measure. In response, we implemented tasks that asked the students to reason about relationships between the measure of a quantity and the magnitude of the unit used to make the measure. In this presentation, we discuss the students' activity on these tasks and their solutions to subsequent tasks. The students' progress suggests that ideas of measurement play a critical role in coming to understand important concepts of trigonometry, such as the unit circle and angle measure. The findings also reveal the difficult process students face in re-conceptualizing the mathematics that they understand. (Received August 01, 2011)

1077-M1-292 **Michael A. Tallman*** (michael.a.tallman@asu.edu) and **Eric Weber** (ericweber@asu.edu). *Introducing the Concept of Derivative via the Calculus Triangle.*

Typical treatments of derivative do not clearly convey that the derivative function represents the original function's rate of change. In this presentation, we argue that revealing the relationship between a function and its rate of change function for static values of x does not facilitate productive ways of thinking about generating the rate of change function or allow students to anticipate the graphical behavior of the rate of change function through examining a graph of the original function. Accordingly, we propose an approach to introducing derivative that maintains the centrality of rate of change as a conceptual underpinning of derivative. We propose the concept of a calculus triangle to support students in attending explicitly to quantities, and constructing a method for creating and tracking the ratio of changes in quantities to produce a rate of change function. We have found that the calculus triangle allows students to reason flexibly across mathematical domains such as differentiation, accumulation, as well as across graphical representations. (Received August 18, 2011)

1077-M1-796 **Kimberly Cervello Rogers*** (cervello@msu.edu), B2 North Kedzie Lab, East Lansing, MI 48824. *The Proof is in the Practice? Graduate Teaching Assistants and Future Teachers.*

Proof is vital for developing and conveying knowledge, but prospective teachers of elementary grades (PTEs) have limited experiences constructing and using proofs. As one means for addressing this lack of experience, six sections of a Geometry content course specifically designed for PTEs were the setting for my dissertation. I examined how six graduate teaching assistants (TAs) engaged PTEs in reasoning and proving (RP) and how TAs' beliefs about RP illuminate their instructional decisions around RP-tasks. RP-tasks are tasks with potential to engage PTEs in RP-processes (e.g., generating or evaluating conjectures or proofs). I observed 82 RP-tasks implemented during 42 classroom observations from spring 2011 semester and conducting eight interviews with each TA. Findings indicate that TAs engaged PTEs in a range of RP-processes. For a plurality of observed tasks, however, opportunities for PTEs to engage in RP were decreased. A decrease in RP-opportunities typically occurred when TAs provided a conjecture or justification instead of allowing PTEs to generate them. Analyses of the classroom and interview data indicate there are multiple factors that supported or inhibited how TAs implemented RP-tasks, which can inform professional development for college mathematics instructors. (Received September 12, 2011)

1077-M1-805 **Kelly M. Bubp*** (bubp@ohio.edu). *To Prove or Disprove: How Do Undergraduate Students Decide?* Preliminary report.

When given a mathematical statement with the prompt "Prove or Disprove," how do undergraduate students decide what to do? Do they reason about the logical structure of the statement? Do they consider examples? Do they attempt to relate the statement to prior knowledge? Do they simply guess? Preliminary results will be discussed from an exploratory study in which undergraduate students in transition-to-proof courses were given mathematical statements to "Prove or Disprove." The aims of this study were (a) to investigate how high-achieving undergraduate students decide whether to prove or disprove a given mathematical statement, (b) to explore the difficulties that the students have in deciding whether to prove or disprove a statement, and (c) to examine connections between the students' decision procedures and their success in constructing the related proofs and counterexamples. (Received September 13, 2011)

1077-M1-922 **Rebecca A. Dibbs** (rebecca.dibbs@unco.edu), School of Mathematical Sciences, UNCo, Campus Box 122, 501 20th St., Greeley, CO 80639, **David M. Glassmeyer*** (david.glassmeyer@unco.edu), University of Northern Colorado, Greeley, CO 80639, and **Michael C. Oehrtman**. *Authority dynamics in mathematics discussions.* Preliminary report.

We employed grounded theory techniques to examine the evolution and influences of authority relationships in an undergraduate mathematics education research study. Our analysis focused on video data from a five day teaching experiment with two faculty researchers engaging two second-semester calculus students in a guided reinvention of formal limit definitions. We will discuss our model for authority in a mathematical discussion and characterize the patterns, influence and evolution of authority that we identified in the guided reinvention. Finally, we illustrate the need for researchers to be cognizant of authority patterns in group data collection settings, since such patterns can mask individual evidence of knowledge and reasoning. (Received September 22, 2011)

1077-M1-1004 **Douglas A. Lapp*** (lapp1da@cmich.edu), Department of Mathematics, 214 Pearce Hall, Mount Pleasant, MI 48859. *Building Symbolic Meaning Through Dynamically-Connected Representations in Abstract Algebra.*

This session describes the use of technology to promote mathematical exploration in abstract algebra courses. Experiences will be shared from research conducted on students' learning of abstract algebra and approaches for infusing technology into this course to promote mathematical discourse will be discussed.

This talk illustrates a pedagogical shift from a teacher centered classroom toward student-centered environment using technology that integrates a computer algebra system, dynamic geometry system, spreadsheet, data collection, and dynamic statistics system into one device where all representations are dynamically connected. Changes to any created object in any problem page of a document results in real time changes in other connected objects on any page within the same problem. Research shows that it is this ability for the student to interact with multiple representations visible on the same screen and notice aspects of situations that remain invariant across representations that promotes reification of abstract concepts. Preliminary results from an ongoing study of students' learning of abstract algebra and examples of curricular changes that promote this reification within the traditional abstract algebra courses will be shared. (Received September 20, 2011)

1077-M1-1241 **Elise N Lockwood*** (elise314@gmail.com), 1025 West Johnson Street, Suite 695, Madison, WI 53706. *A Model of Students' Combinatorial Thinking.*

The inclusion of combinatorial topics in K-12 and undergraduate curricula has increased in recent decades, and research indicates that students face difficulties when solving counting problems. There is a need to understand the causes of such difficulties and to discover effective ways to present combinatorial concepts in the classroom. To this point, however, the literature has not addressed students' ways of thinking at a level that enables researchers to understand how students conceptualize counting problems. In this talk, a model of students' combinatorial thinking is presented that emphasizes relationships between formulas/expressions, counting processes, and sets of outcomes. The model represents a conceptual analysis of students' thinking and activity related to counting; it not only sheds light on relevant aspects of students' combinatorial thinking, but it also provides language by which to describe and explain aspects of students' counting activity. In this way, the model has practical implications, both for researchers (as a lens through which to examine data on combinatorics education) and for teachers (as an aid to design instruction based student thinking). (Received September 18, 2011)

1077-M1-1407 **Sarah L. Marsh*** (sarah.marsh@okbu.edu), OBU Box 61772, 500 West University, Shawnee, OK 74804. *Faculty Perspectives on the Transition to Graduate School in Mathematics.*

As students make the transition to graduate school in mathematics, they often face academic struggles, work to meet higher expectations, and search for strategies to deal with this new chapter in their academic experience. But, what exactly are these new graduate students experiencing? How do they cope with (or learn to flourish within) this transition? As part of an exploration of these aspects of the transition to graduate school in mathematics from both faculty and student perspectives, thirteen student interviews and eight faculty interviews were conducted. This talk will focus on these faculty members' views on this transition. We will look at themes emerging from faculty interview data, such as the nature of mathematics, students' preparation for graduate work, the importance of community in the graduate experience, and students' struggle to find a professional "place" in mathematics. (Received September 19, 2011)

1077-M1-1586 **Hortensia Soto-Johnson*** (hortensia.soto@unco.edu), Ross Hall 2240C, School of Mathematical Sciences, Greeley, CO 80639, and **Michael Oehrtman**, **Kristin Noblet**, **Lee Roberson** and **Sarah Rozner**. *Experts' Reification of Complex Variables Concepts: The Role of Metaphor.*

Using a conceptual framework of enactivism, we explored how experts (N=6) blended dynamic interpretations of diagrams, gestures, perceptuo-motor activity with metaphors to reason and communicate about complex variables concepts. Using Lakoff & Johnson's (1980) definition of conceptual metaphor, we found that experts who tended to reason at an operational stage failed to bring mathematical objects into being. On the other hand, participants who displayed evidence of reification of a complex variables concept imparted their sense of understanding through dynamic representations blended with metaphors. These metaphors were often invented or reinterpreted, based on personal experiences, and created to convey nuances of the experts' understanding to students. Our research suggests that investigating experts' use of dynamic imagery and metaphor may allow researchers to gain insight into the development of systematically structured conceptual understanding. This insight may support practitioners' efforts to create opportunities for students to reinterpret experts' metaphors into personal meaningful metaphors that both capture important mathematical concepts accurately and align within their own understandings, experiences, and culture. (Received September 20, 2011)

1077-M1-1692 **Soofia Malik*** (soofia.malik@unco.edu), School of Mathematical Sciences, Campus box 122, 501 20th street, Greeley, CO 80639, and **Karen Traxler** (Karen.Traxler@unco.edu), School of Mathematical Sciences, Campus box 122, 501 20th street, Greeley, CO 80639. *Examination and Analysis of Undergraduate Students' Level of Statistics Anxiety with Respect to Gender and College-year.* Preliminary report.

The present study examined undergraduate students' statistics anxiety levels based on gender and college-year. The students were enrolled in an introductory statistics course. The sample consisted of 343 students (Males=123, Females=220) who volunteered to participate and completed a survey. The survey instrument's construct validity was tested through a confirmatory factor analysis. For the purpose of reliability, the consistency of the instrument's items was examined using Cronbach's alpha internal consistency and split-half reliability coefficients.To account for non-normal data (skew=-3.38), which translated into high statistical anxiety levels across gender and college-year, the Mann-Whitney-Wilcoxon, a non-parametric test, was performed in lieu of the parametric t-test. The results revealed that females were significantly more anxious about statistics than males. No significant difference was found between statistical anxiety and college-year. It is suggested that future studies conduct experimental research to examine the differences between anxiety levels based on gender and college-year of math and non-math majors. This presentation will expand upon the above results and discuss potential future directions for this research. (Received September 20, 2011)

1077-M1-1714 **James T Sandefur*** (sandefur@georgetown.edu), **John Mason**, **Gabriel J. Stylianides** and **Anne Watson**. *Reaching for the Familiar: Example Generation in the Proving Process.*

We analyze video-data from 27 university students working in groups on different proving problems. Our aim is to understand the contribution made by example generation to the proving process. We suggest and illustrate four aspects of situations in which example generation has a positive role to play in proving. These aspects integrate qualities of students and of problems: experience of utility of examples in proving; problem formulation; personal example spaces and technical tools; relational necessity. Our analysis is based on integrating three frames from the literature: 1) manipulating-getting-a-sense-articulating, 2) syntactic & referential and 3) conceptual insight & technical handle. (Received September 20, 2011)

1077-M1-2034 **Marina Kogan***, 3100 Marine St, Boulder, CO 80309, and **Sandra Laursen**, 3100 Marine St, Boulder, CO 80309. *Assessing Suitability of Grades and Course-Taking Patterns as Measures of Long-term Student Outcomes following Inquiry-Based Learning Experiences.*

Grades are a traditional and standard way of measuring academic achievement. While instructor standards for assigning grades may differ, grades are still widely seen to hold a stable meaning across institutional contexts. Moreover, grades may reflect long-term changes in achievement, when improved learning habits and analytical thinking carry over to later courses. Students' course choices may also reflect sustained or lost interest in the discipline. However, are grades and course-taking patterns sensitive enough measures to distinguish the effects of a single semester-long intervention?

We will present findings on the student outcomes of the inquiry-based learning (IBL) courses at two universities. Student academic records allow us to analyze long-term student outcomes for patterns in student grades and course- taking choices. We use grades as a longitudinal proxy for academic achievement, and the number of subsequent math courses as a proxy for student interest in mathematics. On average, all students benefited from the IBL methods as compared with non-IBL peers, but various subgroups reaped different benefits. We will draw conclusions about the suitability of grades and course-taking patterns for pinpointing the effects of such a short intervention as one IBL course. (Received September 21, 2011)

1077-M1-2171 **Aladar K Horvath*** (horvat54@msu.edu), A-713 Wells Hall, Michigan State University, East Lansing, MI 48823. *Definitions and Uses of Function Composition in Secondary and Early Collegiate Textbooks.*

There are many studies on students' thinking about functions (e.g., Leinhardt, Zaslavsky, & Stein, 1990; Oehrtman, Carlson, & Thompson, 2008), but only a few studies on students' thinking about the composition of functions and none on the teaching or curricular treatment of the composition concept. This study investigated the ways that composition is defined, explained, and used in the mathematics curriculum from high school algebra through the chain rule lesson in college calculus. The analysis of twelve textbooks revealed that composition is initially defined as a sequence of functions and later as an operation on functions; the algebraic representation was predominately used (more than three-fourths of the time); and first and second degree polynomials were more frequent than any other function type. This analysis also found that the functions used in textbooks' chain rule lessons were more complex and relied more heavily on the compositive structure than previous material. These results suggest that calculus students may not have a strong foundation with the compositive structure of functions prior to studying the chain rule and that they are trying to make sense of both concepts simultaneously. (Received September 21, 2011)

1077-M1-2507 **Moira K Devlin*** (moira.devlin@sju.edu) and **Agnes Rash**. *Mathematics for Nonmath Majors and Mathematics Anxiety.* Preliminary report.

A new curriculum for undergraduates took effect in 2010 at Saint Joseph's University. The change included "mathematics beauty courses," satisfying the mathematics requirement. One of the new courses was designed to introduce number theory and proofs pertaining to elementary concepts. Through implementing a pretest-posttest design in this course on math anxiety and knowledge, we determined if there is an increase in knowledge and an attitudinal change as a result of taking this course. From the literature research, the principal author explored the different relationships between math anxiety and achievement among middle school and high school students, but we focused on that relationship at the college level. Another issue we explored was intervention programs to help decrease math anxiety and increase achievement. This idea is encouraged but has not yet been researched. The presenter will discuss the research and games introduced to mitigate the problems of math anxiety and content knowledge. (Received September 22, 2011)

1077-M1-2546 **Jason Martin*** (jasonm@uca.edu), Department of Mathematics, MCS 234, 201 Donaghey Ave., Conway, AR 72035, and **Michael Oehrtman**, **Craig Swinyard** and **Beth Cory**. *Quantitative Reasoning During Definition Formation: The Case of Absolute Value.*

The purpose of this research was to gain insights into how calculus students might develop an understanding of formal limit definitions. By employing the method of guided reinvention, we have conducted teaching experiments with pairs of students to observe the emergence of formal sequence convergence definitions. This presentation focuses on two different teaching experiments where two pairs of students, neither pair containing students who had received any instruction on formal limit definitions, constructed rigorous definitions for sequence convergence.

A key component of any formal definition of sequence convergence is the use of absolute value to denote the distance between individual sequence terms and the value of the limit. Indeed, one pair of students conceived of absolute value as this measurable attribute of sequence graphs (i.e. a quantity). The other pair of students, however, conceived of the absolute value as a transformation, mapping negative values to positive values. Results revealed the importance of conceiving of absolute value as a quantity as this conception supported the first pair of students in progressing forward in creating their formal definition, while the other pair struggled to formulate their ideas in the context of a transformed sequence. (Received September 22, 2011)

1077-M1-2580 **Claire Wyn Wladis*** (cwladis@gmail.com) and **Alla Morgulis**. *A Controlled Study of Collaborative Learning in Intermediate Algebra.*

This project tested the hypothesis that a change from a traditional lecture-based format to a more student-centered and collaborative one would increase student success in Intermediate Algebra and Trigonometry. Six pilot experimental sections ran each semester, each with a comparable control section with the same instructor offered at a similar day/time and using the same assignments. Pilot instructors underwent training to ensure effective and consistent use of techniques. Student and faculty surveys and interviews, student scores on departmental exams, and data on success rates and retention were also used to assess the intervention's effectiveness. The statistical analysis suggested that specific collaborative learning projects used as a part of a comprehensive course structure can have a significant effect on student success. However, this success is contingent upon a suitable period of instructor practice, training, and revision of course structures and assignments. With a bit of experience, collaborative group work in stable base groups can lead to increases in student performance on exams of approximately two-thirds of a letter grade and about a 13 percentage point gain in successful course completion compared to standard courses using a lecture format. (Received September 22, 2011)

1077-M1-2679 **Nicole Engelke*** (nengelke@fullerton.edu), California State University, Fullerton, Department of Mathematics, 800 N. State College Blvd., Fullerton, CA 92831, and **Todd CadwalladerOlsker**, California State University, Fullerton, Department of Mathematics, 800. N State College Blvd, Fullerton, CA 92831. *Identifying Student Difficulties in Combinatorial Proof Production.*

Combinatorial proof, the art of counting a set in two distinct ways to prove a statement, is a technique which emphasizes conceptual understanding of a problem and encourages creative thinking. Past work commonly divides proof production into semantic versus syntactic; combinatorial proofs do not appear to fit either category particularly well. However, we consider this proof production process more semantic than syntactic. We identified four broad categories of difficulties that students may have when attempting to semantically produce combinatorial proofs: language mimicking, inflexibility of context, misunderstanding of combinatorial functions, and failure to count the same set. A common theme emerged from our analysis in which students seemed to be doing more than mere pattern matching, yet failing to fully grasp the true meaning of what they are doing. We term this *pseudo-semantic* proof production; an attempt to write a combinatorial proof by relying on the syntax of previously encountered proofs. We illustrate the categories of student difficulties and pseudo-semantic proof production with four case studies drawn from a study of combinatorial proofs written by students in an upper-division combinatorics course and a graduate-level discrete mathematics course. (Received September 22, 2011)

1077-M1-2693 **John Paul Cook*** (jcook@math.ou.edu). *A Guided Reinvention of the Definitions of Ring, Integral Domain, and Field.* Preliminary report.

Within the last decade there has been a sizable increase in studies which develop innovative methods of teaching abstract algebra. In particular, the work of Larsen (2004, 2009) develops instructional theories to promote student reinvention of basic group theory concepts such as group, group isomorphism, and quotient group. Despite this spike in creative approaches to the subject, nearly all of the relevant literature pertaining to the teaching and learning of abstract algebra is confined to group theory, leaving ring and field theory relatively untouched. To this end, this talk presents some preliminary results from a study which aims to create an original approach to teaching ring and field theory. In particular, I will present preliminary results from a developmental research project designed to produce an instructional theory which supports the guided reinvention of the definitions of commutative ring, integral domain, and field, along with some results concerning the implementation of this instructional theory in a classroom setting. (Received September 22, 2011)

1077-M1-2739 **Ian G. Caldwell***, ian.caldwell@colorado.edu, and **Eric Stade** and **Hortensia Soto-Johnson**. *Student Conceptions and Misconceptions with Order of Operations in Calculus.* Preliminary report.

In this presentation, we report on a phenomenological study exploring student reasoning and understanding of operator precedence in a first semester Calculus course. Data were collected through surveys and interviews. The first survey focused on exponents, fractions, and trigonometric functions; the second survey centered on product rule (multiplying then differentiating versus differentiating then multiplying), chain rule (composing then differentiating versus differentiating then composing), and related rates and other word problems (differentiating and then plugging in particular values versus plugging in and then differentiating). In order to make meaning of the survey responses interviews were conducted with (N=8) students and (N=4) experts (i.e. graduate students and professors of Mathematics). We have found that procedures, such as distribution, and misconceptions, such as variables as objects, developed in K-12 persist all the way through advanced math. The results of the study will be used to improve teaching practices in secondary and introductory Calculus classes and will be further developed for use in advanced mathematics reform. (Received September 22, 2011)

1077-M1-2800 **Kyeong Hah Roh** and **Owen Davis*** (`odavis@asu.edu`), School of Mathematical & Statistical Sciences, Arizona State Uniiversity, Tempe, AZ 85233, and **Aviva Halani**. *Learning mathematics from peers with different reasoning styles.* Preliminary report.

The aim of this study is to explore how students might learn advanced mathematics from their peers with different reasoning styles. We conducted a teaching experiment in the fall semester of 2009 with two undergraduate students, neither of whom had previously studied advanced calculus. The students exhibited different reasoning styles when making arguments: One student was more intuitive in nature and produced semantic, especially visual, representation whereas the other was more formal in nature and produced syntactic representation. We found that the students often reinterpreted each other's ideas by requests from the instructor. Such activities challenged the students to understand their peer's mathematics and provided opportunities to deepen conceptual understanding and improve proof constructions by adapting their peer's reasoning style. In this presentation, we illustrate three episodes where the students tried to understand the formal definition of sequence convergence, construct an existence proof, and rigorously define the continuity. Particular attention will be paid to the role of the instructor in facilitating student interaction and its effect on the reasoning of each student. (Received September 22, 2011)

1077-M1-2805 **Aviva Halani*** (`aviva.halani@gmail.com`), aviva.halani@asu.edu. *Students' Ways of Thinking about Enumerative Combinatorics Problems: Deletion and Equivalence Classes.*

This presentation aims to address students' ways of thinking about enumerative combinatorics problems. Fourteen undergraduates with no formal experience with combinatorics participated in individual task-based interviews in spring 2011. Open coding was used to identify students' ways of thinking about the set of elements being counted, called the solution set, as they engaged in combinatorics problems. This presentation focuses on two ways of thinking which emerged from the data analysis: Deletion and Equivalence Classes. Both involve creating a new, related combinatorics problem and then finding a relationship between the solution set of the new problem and that of the original problem. The students found an additive relationship in Deletion and a multiplicative one in Equivalence Classes. In the study, students naturally engaged in Deletion but for certain tasks they were able to construct the solution set of a new problem, yet were unsuccessful in finding the size of the original solution set. Through instructional interventions, they developed Equivalence Classes and were successful in solving the tasks. We will discuss student struggles with engaging in Equivalence Classes and suggest ways to guide students to develop and extend their preliminary ways of thinking. (Received September 22, 2011)

1077-M1-2829 **Wendy Aaron***, 2600 School of Education, 610 East University Ave, Ann Arbor, MI 48109, and **Yvonne Lai** and **Hyman Bass**. *The Role of Collective Work in Undergraduate Teaching of Mathematical Knowledge for Teaching to Future Elementary Teachers.* Preliminary report.

Well-trained mathematicians have a fluent understanding of the mathematics of elementary school, yet they would face serious challenges trying to teach place value to third graders, or fractions to fourth graders. And so, in content courses for prospective elementary teachers, they need to equip students with a kind of mathematical knowledge that they themselves, as instructors, do not normally possess. We analyze the use of instructional materials for teaching Mathematical Knowledge for Teaching (MKT), a construct developed by Ball, Bass, and their colleagues at the University of Michigan. The materials address key content areas, yet are unusual in that they serve a dual audience: both prospective teachers and course instructors. The materials aim to help mathematics faculty develop sensibilities about the content and nature of MKT-while supporting instruction of that knowledge. Providing this support is difficult through written materials alone. We hypothesize the importance of collective work in teaching these courses, for example, through professional exchanges about locally suited pedagogical practices and the content being taught. We report on a study in which we analyzed pilot user experiences to better understand the role of collective work in supporting implementation. (Received September 22, 2011)

Scholarship of Teaching and Learning in Collegiate Mathematics

1077-N1-47 **Patrick Bahls*** (pbahls@unca.edu), Department of Mathematics, University of North Carolina, Asheville, CPO #2350, One University Heights, Asheville, NC 28804-8511, and **Amy Mecklenburg-Faenger** (mecklenburgfaengera@cofc.edu), **Marguerite Scott-Copses** (scottcopsesm@cofc.edu) and **Chris Warnick** (warnickc@cofc.edu). *A cross-disciplinary analysis of math students' writing.* Preliminary report.

For the last few decades, scholars in rhetoric and composition have recognized the importance of *writing in the disciplines* as a means by which students learn to communicate effectively in a particular field. Effective writing in the disciplines tasks challenge students to adopt and master the idiosyncratic grammatical, syntactic, and semantic conventions of their discipline as they become authentic practitioners of that discipline.

Relatively little research has been done on the ways in which college mathematics students learn adopt the rhetorical conventions of research writing in math. In this, the first stage of our ongoing research in this area, we identify these conventions (which include use of metacommentary, use of sources, style and tone, visual rhetoric, and contextualization of research) through careful analysis of the writing performed by student participants in the mathematics REU hosted at the University of North Carolina, Asheville. We also indicate how a better understanding both of these conventions and of the ways in which students learn to master them will help to improve mathematics education, and we give a preview of the next stage of our research. (Received July 06, 2011)

1077-N1-612 **Jane P Coffee*** (jane.coffee@csi.cuny.edu) and **Jesenko Vukadinovic**, College of Staten Island. *Using Data to Develop an Adaptive Syllabus for PreCalculus Course at the College of Staten Island, City University of New York.*

The central research question is how a data-driven curriculum and faculty development can improve student learning and success in the gateway course to most STEM majors, College Algebra and Trigonometry (average enrollment of 600 students in 15 sections per semester). In spring and fall 2010 approximately half the sections participated with the rest the control group. For all sections, the MAA Maplesoft tests were used to pre-test the students on the prerequisite topics at the beginning of the semester and post-test the students on the course topics at the end of the semester. The participating instructors developed an adaptive syllabus that contained the same required topics but the time allotment was at their discretion. These instructors used several tools to adapt their teaching: pre-test data provided an item-analysis of prerequisite topics that required additional attention; computer-based homework was assigned by instructors; and computer projects designed to bridge the gap between abstract math concepts and real-world applications. The participating instructors kept a log about their findings and adjustments made to the syllabus. Based on data, changes were made in the departmental syllabus and funding was provided for continued use of pre/post testing with MAA Maplesoft. (Received September 08, 2011)

1077-N1-793 **Jennifer Vandenbussche*** (jvandenb@spsu.edu), **Christina Scherrer**, **Alexandra Brigham** and **Anasstasia Semenova**. *An analysis of the effectiveness of using exclusively workshop-style instruction in the College Algebra classroom.* Preliminary report.

Over the past few decades, evidence has grown for the effectiveness of collaborative learning in STEM fields. The question of how best to balance collaborative learning workshops with traditional lectures, however, remains open. In particular, there is little literature available investigating the effects of workshop-only instruction, especially in lower-level math courses.

This talk reports the results of a study intended to investigate this issue. The presenter taught a section of College Algebra in a workshop-only format and a traditional lecture section concurrently, giving each section similar assignments and exams. The two sections were administered surveys throughout the semester, measuring their attitudes toward mathematics. An undergraduate research assistant also conducted interviews of the students.

Analysis of the students' performance at the end of the semester found very little statistically significant difference between the sections. This suggests that the additional resources needed for workshop-only instruction may be better allocated elsewhere. However, positive feedback from the surveys and interviews suggests that the idea of including a workshop component in College Algebra merits further study. (Received September 12, 2011)

1077-N1-1020 **Gerald W. Kruse*** (kruse@juniata.edu), Juniata College, Huntingdon, PA 16652, and **David Drews**. *Assessing and Improving Quantitative Reasoning Skills with CLA Performance Tasks.* Preliminary report.

Juniata College's MA 103, Quantitative Methods, is taken by students to satisfy a quantitative skills graduation requirement, and to assess their quantitative reasoning skills, a Scholarship of Teaching and Learning (SoTL) project was implemented. The pre and post assessments used in this project are based on the performance tasks which are a component of the Collegiate Learning Assessment (CLA), and which have been identified as useful assessments of quantitative reasoning. The structure of the course is conducive to a valid design, including course time dedicated for assessment, multiple sections, and several in-depth projects. The experiment is based on Solomon's four-group design, where students in one section took the pre-assessment and post-assessment, and completed course projects during the semester which were CLA performance tasks. Students in a second section took the pre-assessment and post-assessment, but completed traditional open-ended projects, and students in a third section only took the post-assessment. The detailed scoring rubric and results of the experiment will be presented, with a focus on how completing performance tasks during the semester affected quantitative reasoning skills. (Received September 15, 2011)

1077-N1-1032 **Mindy Capaldi***, 1900 Chapel Dr., Valparaiso, IN 46383. *A Semi-IBL Finite Mathematics Course: Is it possible and can it be successful?* Preliminary report.

One of the challenging aspects of teaching Finite Mathematics is dealing with a lack of student involvement and engagement. For many students, it could be the last math class that they will take. In this course, I investigated the benefits and drawbacks of teaching Finite Mathematics with an emphasis on group work, reading assignments, and student presentations. While the course was not strictly inquiry-based learning (IBL), it adopted some of the pedagogy of that style. In this presentation, I discuss the methods used and the results as evaluated through grade assessment, student feedback, and comparison to previous lecture-based Finite courses. (Received September 15, 2011)

1077-N1-1154 **Dana C. Ernst***, dcernst@plymouth.edu, and **Angela Hodge** and **Andrew Schultz**. *Collaborative peer review between two IBL number theory courses.*

In the spring of 2011, D.C. Ernst (Plymouth State University) and A. Schultz (Wellesley College) chose to adopt an inquiry-based learning (IBL) approach in their number theory courses at their respective universities. Two times during the semester, students in each class submitted proofs of 2-3 theorems to be peer reviewed by students in the other class. Each student was then responsible for typing up an anonymous and formal referee report of the submitted theorems, which were then returned to the respective students. Ernst and Schultz, together with mathematics education specialist A. Hodge (University of Nebraska at Omaha) developed a pre- and post-test survey to study the impact of this form of peer review, as well as student perception of the effectiveness of IBL, in general. In this talk, we will relay the similarities and differences between the approaches to IBL in each number theory course, describe the details of the peer review exercise, and discuss the results of the survey as it relates to peer review. (Received September 16, 2011)

1077-N1-1364 **C. Adam Feldhaus*** (cfeldhau@cscc.edu), C. Adam Feldhaus, Columbus State Community College, 550 E. Spring St., Columbus, OH 43215, and **David L. Reedy** (dreedy2@cscc.edu), David L. Reedy, PhD, Columbus State Community College, 550 E. Spring St., Columbus, OH 43215. *Outside of Class Learning: Perspectives on Mathematics Tutoring Programs at a Community College.* Preliminary report.

Due to several decentralized tutoring initiatives enacted over several years, Columbus State Community College (CSCC) has multiple options for students seeking help outside of their mathematics classes. CSCC offers a mathematics tutoring lab with drop-in tutoring staffed by adjunct mathematics faculty, a peer-tutoring program with weekly scheduled appointments, synchronous and asynchronous online tutoring, and most recently CSCC is piloting a Supplemental Instruction (SI) program for several mathematics courses.

Two years ago, CSCC received a Title III grant to (in part) help organize the various tutoring initiatives and pilot new forms of tutoring (including the SI program). As part of this grant, CSCC was able to hire a tutoring coordinator and a research analyst to help organize and analyze these programs. This talk will explore some data gathered on those initiatives, including student usage, effectiveness (in terms of grades), and students' opinions of those experiences, as well as some possible directions CSCC may go in light of the data. (Received September 19, 2011)

1077-N1-1560 **Gregory A Kelsey*** (gkelsey@immaculata.edu). *Using Wikis in a Geometry Class for Future Teachers.*

In a geometry course taken by future teachers in Fall 2010, students posted projects on Wikiversity designed to enhance the students' ability to communicate mathematics. At the beginning and end of the semester, students completed values and interest surveys, and at the end of the semester students evaluated the communication project assignments. In Spring 2011 in the same course, the students completed the same communication projects, but without the wiki component. The data reveal that this population found the wiki interface difficult and frustrating, however the students did benefit from viewing their peers' work in progress as well as having the finished product as a study tool. This suggests that a low-tech collective creation of a class study guide might serve this population well. (Received September 20, 2011)

1077-N1-1899 **Jennifer A Czocher*** (czocher.1@osu.edu) and **Jenna Tague** (tague.6@osu.edu). *Smartpen Technology as an Instructional Medium.* Preliminary report.

A "pencast," an interactive video of written material, was used to digitize and update curriculum materials for an introductory course on differential equations. Solutions to selected problems and examples were written out by hand and simultaneously explained verbally by the course professor. The students then accessed the pencasts at their own convenience. The report will focus on the students' reception of the instructional medium used and on our own challenges we faced when developing and implementing the pencasts in mathematics courses for engineering students. (Received September 21, 2011)

1077-N1-1972 **James S Rolf*** (rolf.jim@gmail.com), **Lauren Scharff** and **Thomas Hodge**. *Does "Thinking about Thinking" Impact Completion Rates of Pre-class Assignments?* Preliminary report.

Pre-flight assignments are an essential component of the Just in Time Teaching (JiTT) process. This process involves the following steps: students read and answer questions prior to class (pre-flight assignment), teachers review the responses before class, and then teachers modify lesson content and activities based on the responses. Pre-flights can be effective at increasing student preparation for class and allowing class time to be used more effectively.

Previous work has shown strong correlations between instructor use of pre-flight responses (e.g. responses used to tailor class sessions, formative feedback given to students) and several variables: completion rates, student motivation, and the perceived value students had for the pre-flight components. The number of points assigned also significantly correlated with completion rates.

We report on a study in a discrete math course to determine whether or not additional manipulation of student awareness of their attitudes regarding the benefits of JiTT might impact the completion rates and perceived value of pre-flights. The sections with increased awareness showed less decline in pre-flight completion across the semester and a tendency to complete more optional homework problems in addition to the assigned problems. (Received September 21, 2011)

1077-N1-2040 **Ibrahim A. Saleh*** (iasaleh@math.ksu.edu), Dept. of Math, Kansas State University, 138 Cardwell Hall, Manhattan, KS 66506, and **Andrew G. Bennett** (bennett@math.ksu.edu), Dept. of Math, Kansas State University, 138 Cardwell Hall, Manhattan, KS 66506. *Helping Algebra Students Succeed at Word Problems.* Preliminary report.

Students often have trouble solving word problems even when they can successfully solve the underlying equation. To try to find how best to help students reduce word problems to equations, we compared the effectiveness of providing explicit instruction in developing equations from a description with providing additional examples of such problems. These techniques were used both with traditional algebra students at a university and non-traditional students taking algebra at a local army post. We will discuss which techniques worked best for which types of students. (Received September 21, 2011)

1077-N1-2051 **Fabiana Cardetti*** (fabiana.cardetti@uconn.edu) and **Amit Savkar** (amit.savkar@uconn.edu). *Pedagogy in large lectures and the age of digital media: Keep up or be left out!*

With the growing need of offering courses in large lecture format, it is becoming increasingly important to understand instructional resources that can be used to aid student learning in this setting.

Our work involves the integration of technological tools as effective means of instruction in large lecture calculus courses that address some of the main issues related to large lecture settings while helping students become successful learners of college mathematics.

In this presentation we will report the findings from a research study that explores students' use and perceptions of these tools. (Received September 21, 2011)

1077-N1-2058 **Ann C. Stewart*** (stewart@hood.edu). *Using and Analyzing Student Confidence in Classroom Voting.* Preliminary report.

Classroom voting is a teaching method which requires each student in the classroom to actively engage with new material by discussing and then voting on true/false and multiple choice questions presented to the class. Project MathVote: Teaching Mathematics with Classroom Voting is an ongoing NSF-funded study with collaborators from two two-year colleges and several private institutions. One area that we are especially interested in exploring is the level of student confidence as they cast their vote; in other words, how confident are they in the answers they have chosen? We will present some preliminary results from this study. Questions being considered include: What can student confidence tell us about students' understanding during voting? How can student confidence influence the direction of whole class discussion? Is student confidence different in true/false questions versus multiple choice questions? In what ways does student confidence evolve while using classroom voting? (Received September 21, 2011)

1077-N1-2377 **David D Barker*** (dbarker@ilstu.edu), Department of Mathematics, Campus Box 4520, Illinois State University, Normal, IL 61790-4520, **Saad El-Zanati** (saad@ilstu.edu), Department of Mathematics, Campus Box 4520, Illinois State University, Normal, IL 61790-4520, and **Wendy O'Hanlon** (wohanlon@icc.edu), Illinois Central College, One College Drive, East Peoria, IL 61635. *Implementing Mathematics Research Experiences into Teacher Preparation Programs.*

Focusing on the scholarship of teaching and learning in mathematics is an important component in the preservice education of secondary mathematics teachers. Unfortunately, preservice teachers rarely have the opportunity to engage in work that leads to mathematical discoveries and the communication of those discoveries. The Research Experiences for Undergraduates (REU) Site for Secondary Mathematics Teachers at Illinois State University was designed in response to the national need for highly qualified mathematics teachers and the call for prospective mathematics teachers to experience scholarship. The goals of the program are to expose teachers to mathematics research, expand their views of mathematics as a dynamic endeavor, to provide opportunities for mathematical discovery, and to enhance their content and pedagogical content knowledge. This presentation will describe the REU program, sample research problems, components designed to help teachers translate their research experience to the classroom, and suggestions for implementation. In addition, data will be provided that characterizes the changes in teacher beliefs as a result of experiencing mathematics research. (Received September 22, 2011)

1077-N1-2490 **Lee Evans*** (lee.evans@usma.edu), **Heather Jackson** (heather.jackson@usma.edu), **Christopher Weld** (christopher.weld@usma.edu) and **Gerald Kobylski** (gerald.kobylski@usma.edu). *They Can Do It: Applications of a Hybrid Classroom Model in a Traditional Classroom.*

Doing more with less is a topic of discussion among many institutions trying to increase efficiencies and sustain output despite funding cutbacks. These ideas extend to academia and motivate alternative teaching models that effectively flip the classroom, placing more emphasis on student learning out of the classroom. This year, we provided students with the resources to learn basic matrix algebra concepts on their own. Without prior experience developing and implementing hybrid courses, we were able to build, execute and assess this student-centered lesson. In this talk, we will share the tools used to create and assess an out-of-class experience. In particular, we will show how pencasts and existing online videos can be compiled to engage students, allowing them to take ownership of their learning. Quantitative and qualitative assessment techniques include the use of web analytics services and surveys. We will also discuss modifications and plans for future implementation of this limited extent hybrid model. (Received September 22, 2011)

1077-N1-2660 **Anne Albert*** (albert@findlay.edu), Mathematics Department, The University of Findlay, 1000 N. Main Street, Findlay, OH 45840. *Role of Prerequisite Knowledge in Student Learning in Lower Level Mathematics Courses.*

The mathematics department at the University of Findlay is investigating ways to improve student success in lower level mathematics classes. Raising the prerequisite and enforcing the prerequisite are parts of the changes being proposed for fall 2012. Our goal will be to improve student learning in the courses.

A fall 2011 study was completed on the the algebra preparedness of the students in four mathematics courses, Intermediate Mathematics, Elementary Statistics, Precalculus, and Applied Mathematical Analysis. Their previous mathematics courses were reviewed, a brief algebra pretest was given at the beginning of the four courses, and exam grades in the course were analyzed. Enrollment (including number withdrawn) and course final grades were also collected for use in comparison with 2012 and 2013. The study involved 25 classes.

The algebra pretest and exam data was paired by student. The variability of the student's exam score was reviewed based on their algebra prerequisite. A separate analysis was done for each section of each course. The results of this first semester of the study will be presented along with plans for the future. (Received September 22, 2011)

1077-N1-2740 **Edwin P Herman*** (eherman@uwsp.edu). *Using Inquiry Based Learning to Enhance Student Attitudes in Complex Analysis.* Preliminary report.

I redesigned my Complex Analysis course for Fall 2011 to utilize an Inquiry Based Learning (IBL) method of teaching. Rather than using lectures, IBL encourages students to learn through direct work and presentation. Under my guidance, class time consisted primarily of students questioning and critiquing each other's work, supplemented with bi-weekly group quizzes.

I hoped students would develop more confidence in their ability with mathematics and gain a deeper understanding of complex analysis than they would have if I had used a more traditional method.

Students were given attitude surveys at the beginning of the course and again at its end to measure gains in confidence and appreciation of mathematics; these results will be presented and compared with those of a control group (other upper division mathematics courses were also surveyed). Student feedback will also be presented in various forms, including a direct comparison of student work and perception of ability level.

Depth of understanding is more difficult to assess, but rough measures of student comprehension of specific topics will be compared to similar assessments in previous years' classes. (Received September 22, 2011)

1077-N1-2747 **Paula Shorter*** (paula.shorter@rockhurst.edu), 1100 Rockhurst Road, Kansas City, MO 64110, and **Mairead Greene** (mairead.greene@rockhurst.edu). *A First Attempt at Categorizing and Assessing Different Levels of Student Understanding.* Preliminary report.

As part of writing active-learning, inquiry-based course activities for several of our math courses (including precalculus, calculus, and differential equations), we have begun investigating exactly what it is that we are assessing on exams. We realized that when students successfully complete a given exam question, they may be demonstrating different types or levels of understanding. For example, they may be implementing skills, they may be adapting and applying a previously developed method, and/or they may be reasoning directly from their understanding of the meaning of a concept. Each of these examples of understanding is important and being able to distinguish them and assess them individually helps us better understand the learning taking place in our classrooms. To investigate this, we have developed a weighting system that categorizes the different levels of understanding being assessed in an exam question. We have also surveyed our students for their thoughts on the types of mathematical thinking that they actually engaged in while answering these same exam questions. In this talk, we will describe the weighting system that we developed, the survey we gave our students, and the results from comparing our categorization of questions and the student feedback. (Received September 22, 2011)

1077-N1-2791 **Curtis D. Bennett*** (cbennett@lmu.edu), Department of Mathematics, Loyola Marymount University, Los Angeles, CA 90045, and **Jacqueline M. Dewar**. *How does mathematics contribute to a liberal education?*

The study of mathematics, especially in a mathematics major, is often sold as being a great foundation for any career because of the logical thinking and problem solving skills it is touted to develop (Paulos, 1995; Tucker, 2011). Our study investigated a far less pragmatic question: How does mathematics contribute to a liberal education? We wanted to find out what students transferred from their mathematics classes to other disciplines or to their daily lives (Agresto, 2002). Our subjects included approximately 30 mathematics majors at a medium-sized comprehensive university. In addition to gathering student perspectives through survey, interviews and a focus group, we interviewed humanities and education faculty who had taught some of these math majors.

Expectations that mathematics majors would carry the problem solving skills gained in the major over to other domains or daily life were partially supported. But evidence also pointed to an unexpected result regarding the major's influence on nontechnical writing. These findings may have applications to quantitative literacy or first-year-seminar courses. (Received September 22, 2011)

1077-N1-2866 **Debbie Gochenaur*** (dlgochenaur@ship.edu), 1871 Old Main, Dept. of Mathematics, MCT 250, Shippensburg, PA 17257. *From Fred Flintstone to Ferraris, Driving Mathematical Content through Questioning.*

In content courses for elementary preservice teachers, there is often a misconception that the mathematics will also be elementary, or easy; but, when faced with a short essay question asking students to describe their logic and reasoning, they often stumble especially when asked to respond without giving a numerical example. Writing rich questions to guide students in their development from procedural to conceptual understanding of mathematics, is an instructional journey to increase student achievement. This session will describe a model of questioning utilized to enrich students' conceptual understanding through writing. Questions start at a basic level, gradually shift away from procedural descriptions towards explanation of concepts, and finally move to written comparisons of ideas and processes. Woven throughout is the progression of student work from proofreading prepared submissions to effectively answering logic and reasoning questions individually. Example questions and the results of pre-post tests on students' perceptions of their ability to answer short essay questions which require logic and reasoning will be shared in addition to the course components which students identified as being most beneficial in helping them learn to write clear, concise responses. (Received September 22, 2011)

Topics and Techniques for Teaching Real Analysis

1077-N5-187 **Don L Hancock*** (don.hancock@pepperdine.edu). *Using the Banach-Mazur Game in an Undergraduate Real Analysis Class to Investigate Different Types of Infinite Sets.*

The distinction between countably infinite and uncountable sets of real numbers is especially significant in real analysis. For example, the set of discontinuities of a function f cannot be uncountable when f is monotonic, although it may be when f is Riemann-integrable or a derivative. It is in real analysis that most students get their initial exposure to some subtler aspects of infinite sets, with many finding this material nonintuitive and challenging. In this talk I will describe the simple Banach-Mazur mathematical game, unfamiliar to many teachers and not found in standard texts, and show how this game can be used as a classroom tool in real analysis. For example, I use the game to easily prove that the irrationals are uncountable and to motivate Cantor sets and the notion that infinite sets may be "large" in one sense yet "small" in some other. Finally, the game is used to establish that a nondegenerate interval cannot be of Baire first category, and several applications appropriate for a real analysis course are suggested. (Received August 09, 2011)

1077-N5-255 **Steven George Krantz*** (sk@math.wustl.edu), Dept. of Mathematics, Washington University, Campus Box 1146, St. Louis, MO 63130. *Communication and Learning.*

An essential part of learning real analysis, or any difficult subject, is communication. Students must learn to communicate the ideas to each other, to myself (the instructor), and to themselves. This is part of the Piaget-inspired internalization process.

In teaching real analysis, we endeavor to construct activities that will promote communication. This includes class participation, working at the board, collaboration on assignments, the writing of term papers, and other features as well.

This talk will treat the circle of ideas described here. (Received August 16, 2011)

1077-N5-288 **Robert L Brabenec*** (robert.brabenec@wheaton.edu), Department of Mathematics, Wheaton College, Wheaton, IL 60187. *Some of my Suggested Topics and Techniques for the Real Analysis Course.*

In order to include some review of calculus while reinforcing the need for rigor in analysis, I have students develop in careful axiomatic form such topics as the derivative formulas for the transcendental functions or the proofs for convergence tests of infinite series. I have used a wide variety of techniques while teaching a real analysis course over the past 45 years. A recent technique involves dividing the class into small discussion groups (last year I divided a class of 18 students into 3 groups of 6 students each) that meet with me for one hour each week. In this setting, I ask a variety of questions over the material of the previous week to which students must respond. Their responses are part of the course grade. I will describe some sample sessions and share student evaluations of this technique. (Received August 18, 2011)

1077-N5-407 **Peter A Loeb*** (loeb@math.uiuc.edu), Department of Mathematics, University of Illinois, 1409 West Green Street, Urbana, IL 61801. *Calculus: A Missed Opportunity.*

The principles of real analysis, an important part of mathematical culture, should play a major role in generating the impact of a freshman education. As many students pass through our hands, however, we miss this opportunity by teaching courses that continue the principle of high school mathematics: "Shut up and calculate". This diminution in intellectual content is unnecessary since a few changes to the usual approach produce a simpler, more complete and satisfactory explanation of what's going on.

At the beginning, rather than general limits, one can first introduce functions having a zero limit of the output as the input tends to zero. This is the easiest limit to explain, and, as we shall show in the talk, all other limits in the course are applications. In particular, the necessary aspect of uniform continuity can be explained at the appropriate level in terms of such limits, and the Riemann integral can be defined using such a limit. Moreover, while upper and lower Riemann sums fail to justify the use of the integral for many simple applications, a general justification can be given in terms of these simple limits. (Received August 29, 2011)

1077-N5-498 **Eddy A Kwessi*** (ekwess@trinity.edu), One Trinity Place, San Antonio, TX 78212. *The Lebesgue Integral : Motivations, advantages and Limitations.* Preliminary report.

In this presentation, we will give a brief introduction on the motivation behind the Lebesgue integral. We will also present some of its advantages over the Riemann inte- gral. We will finish by presenting some limitations of the Lebesgue Integral and introduce existing alternatives such as the Kurzweil-Henstock Integral and Denjoy Integral. (Received September 05, 2011)

1077-N5-662 **Erik Talvila*** (Erik.Talvila@ufv.ca), 45635 Yale Road, Chilliwack, BC V2P 6T4, Canada, and **Matthew Wiersma**. *A simple derivation of the trapezoidal rule for numerical integration.*

A simple proof of the trapezoidal rule is given for numerical integration on a compact interval. The integrand is assumed to be twice continuously differentiable. The error is estimated in terms of the uniform norm of the second derivative of the integrand. The proof uses only integration by parts, applied to the second derivative of the integrand, multiplied by an appropriate polynomial. A corrected trapezoidal rule that includes the first derivative of the integrand at the endpoints of the integration interval is also proved in this manner, the coefficient in the error estimate being smaller than for the midpoint and trapezoidal rules. The proofs are suitable for presentation in a calculus or elementary numerical analysis class. Several student projects are suggested. (Received September 09, 2011)

1077-N5-827 **Antonia E. Cardwell*** (antonia.cardwell@millersville.edu), Department of Mathematics, Millersville University of Pennsylvania, P. O. Box 1002, Millersville, PA 17551. *Use of a "Connections Journal" in an undergraduate Real Analysis course.*

In an introductory course in Real Analysis, it frequently occurs that the same concept is introduced in different contexts, or that objects that initially appear different are given the same name. To encourage the student to consider why this occurs, and how the topics across the course are related, I introduced a weekly "Connections Journal" in my "Introduction to Real Analysis" course. I will present a description of the project, provide examples of student submissions, and present the results of an informal survey conducted upon the completion of the course. (Received September 13, 2011)

1077-N5-991 **William Johnston*** (bwjohnst@butler.edu). *Teaching the Lebesgue Integral with a Calculus II Prerequisite.*

A description of a course on the Lebesgue integral, using a method first established by Percy John Daniell in 1917, further refined and concisely discribed in a 1950's text by Frigyes Riesz and Béla Sz.-Nagy, and exposited in detail in a 1973 Alan J. Weir text. This "Daniell-Riesz approach" succeeds in defining Lebesgue's integral (using either Lebesgue measure or any Borel measure) in a manner different from the one Lebesgue used, nearly avoiding measure theory altogether. The technique is so fundamental that undergraduates can learn the integral even as a first (independent) course on functions. The presentation will describe the results of the course taught in the undergraduate curriculum at two institutions (including material on Hilbert and Banach spaces), will show how the course only requires a Calculus II prerequisite (no longer is learning the Lebesgue integral dependent on having taken *Real Analysis I*), and will introduce a new manuscript designed specifically with this course in mind. (Received September 15, 2011)

1077-N5-1078 **Robert Kantrowitz*** (rkantrow@hamilton.edu), Department of Mathematics, Hamilton College, 198 College Hill Road, Clinton, NY 13323, and **Michael Schramm**. *When absolute convergence fails to imply convergence.* Preliminary report.

If a series of real numbers converges absolutely, then it converges. The usual proof invokes completeness in the form of the Cauchy criterion. Absent completeness, the result is false, but examples of series of rational numbers that illustrate this point are sometimes elusive to students. In this talk, we provide several such examples and, in their construction, other concepts from undergraduate real analysis emerge, including a cameo appearance by the Cantor set. (Received September 16, 2011)

1077-N5-1088 **Barbara A. Shipman*** (bshipman@uta.edu). *Constructing Definitions in Undergraduate Real Analysis.*

This presentation will highlight selections from my Active Learning Materials for Critical Thinking in a First Course in Real Analysis (www.uta.edu/faculty/shipman/analysis) with a focus on how they engage students in the creative mathematical processes of formulating good definitions. Through targeted questions and teamwork, students distill the meaning and subtleties of concepts in real analysis to create discerning definitions on topics including cardinality, convergence, and continuity. This work is supported in part by NSF grant #0837810. (Received September 16, 2011)

1077-N5-1205 **Padraig M. McLoughlin*** (mcloughl@kutztown.edu), 265 Lytle Hall, Department of Mathematics, Kutztown University of Pennsylvania, Kutztown, PA 19530. *A Proemial Proposition on Teaching Real Analysis: Instruct Via a "Strong" Modified Moore Method.*

The author argues analysis of the reals & real functions is an essential part of the mathematics canon. The paper's thesis is that learning requires *doing*; we learn best by inquiring, and so proposed is a programme of use a 'strong' modified Moore method (SMMM) under the rubric of inquiry-based learning (IBL) for teaching undergraduate Real Analysis (RA). An authentic RA course needs to exercise students' imagination to create meaningful results & hone their abilities.

We explain what a 'strong' modified Moore method is as opposed to other IBL methods and argue why we opine it is a Scrivens best practice. Pedagogical and practical justification are submitted; the course model and content is detailed (what is effective, why, & what practices or material was accentuated, modified, or deleted); and, the successes or lack thereof are discussed.

It is forwarded that the SMMM establishes an authentic scholarly environment, motivates learning, and assists in forging meaningful student study. We end with evidence illustrating that students (math majors and math education majors) who experience such a RA course find further exploration of math more facile; have a deep understanding the material that was investigated; and seem to have much post-RA success. (Received September 22, 2011)

1077-N5-1468 **Craig J. Calcaterra*** (craig.calcaterra@metrostate.edu), 700 E. 7th St., Saint Paul, MN 55106. *Flows on metric spaces: ODEs, PDEs, SDEs and DDEs.*

The ultimate purpose for studying compactness and uniform convergence is to prove convergence of approximating families, such as function approximation and existence of solutions to differential equations. Such justifications are usually hidden from students until well into graduate school or later. This report discusses the use of the elementary concept of flows on metric spaces to efficiently introduce several important applied analysis subjects typically relegated beyond the undergraduate curriculum. This unified approach allows students to breach varied topics in one semester, including existence theory, control and stability of ordinary, partial, stochastic, and delay differential equations (ODEs, PDEs, SDEs and DDEs). (Received September 19, 2011)

1077-N5-1707 **Lynette J. Boos***, Department of Mathematics and CS, Providence College, 1 Cunningham Sq, Providence, RI 02918. *Motivating Real Analysis Students with Puzzles.*

To emphasize the problem-solving aspect of real analysis, I have collected various puzzles to challenge my students throughout the semester. In this talk I will explain why I think puzzles are a good motivator, describe how I incorporate puzzles into my class, and give several examples of puzzles that I have used. (Received September 20, 2011)

1077-N5-2211 **Manmohan Kaur*** (mkaur@ben.edu), Department of Math and CS, 5700 College Road, Lisle, IL 60532. *Undergraduate research in a Real Analysis course.* Preliminary report.

In order to motivate undergraduates to study real analysis, an essential yet technically difficult part of the mathematics curriculum, we involve students in expository or original research. Our goal is to convince the student that the hard work that goes into learning this topic is worth it because of all the wonderful ways in which it continues to change our world. In the second semester of our real analysis sequence, apart from learning the analytic techniques, the students pick a topic of their interest to research on. Although most students tend to choose topics that expose applications of analysis to chemistry, medicine, music, photography, fingerprinting, etc, some students pick more traditional topics like applications of the Banach fixed point theorem, the intricacies of fractals and the Thomae's function. A relatively new development is in the field of quantum information systems. This topic is of interest to undergraduates not only because of its theoretical beauty but also because of its ground breaking potential to help make quantum computers a reality. The topic especially lends itself to undergraduate research because some calculations can be performed by undergraduates. In this talk we will share our experiences with the undergraduate research in our course. (Received September 21, 2011)

1077-N5-2237 **Judit Kardos*** (kardosj@tcnj.edu), TCNJ, Mathematics Department, 2000 Pennington road, Ewing, NJ 08628. *Understanding the infinite.* Preliminary report.

Hegel writes in the Science of Logic that "Mathematics owes its most brilliant successes to ideas contradicting discursive reason." The idea of the actually infinite is one such idea.

Let us call a subset of the natural numbers, S, potentially infinite if for any $n \in S$ there exists an $m \in S$ satisfying $m > n$. A good initial problem that leads students to realize the difference between the actual and the potential infinite is the following simple question: "Can we color the natural numbers using two colors, say red and blue, so that neither the blue set nor the red set contains any infinite arithmetic progressions?" Students frequently come up with the following solution:

$$\mathbf{1}, 2, 3, \mathbf{4}, \mathbf{5}, \mathbf{6}, 7, 8, 9, 10, \mathbf{11}, \mathbf{12}, \mathbf{13}, \mathbf{14}, \mathbf{15}, 16, 17, 18, 19, 20, 21, \ldots$$

Clearly, the length of the arithmetic progressions both in the red (***bold***) and in the blue set (*standard*) form a potentially infinite set, but it is easy to prove that the above coloring will allow for no actually infinite arithmetic progression in either color. In this talk we discuss examples and problems that help students acquire proper intuition regarding the actually infinite as part of an introductory Real Analysis course. (Received September 21, 2011)

1077-N5-2367 **Karel Hrbacek*** (khrbacek@sci.ccny.cuny.edu). *Analysis based on the concept of level.*
This is joint work with R. O'Donovan and O. Lessmann. We propose a framework for analysis that is loosely modeled on the physicists' intuitive but vague concept of scales of magnitude. We take the point of view that every mathematical entity appears at some *level* $\mathbf{V}$. Levels are *not sets*, but they have some definite properties: For every mathematical object x there is a coarsest level $\mathbf{V}$ where x appears; For every level $\mathbf{V}$, there exist real numbers h *ultrasmall relative to* $\mathbf{V}$ (i.e., such that $0 \neq |h| < r$ for every $r > 0$ that appears at $\mathbf{V}$); A number, function or set that is uniquely defined from parameters at some level $\mathbf{V}$, appears itself at the level $\mathbf{V}$. These postulates suffice to define and calculate derivatives and integrals in the style of Leibniz. A few additional axioms make possible a fully rigorous development of elementary analysis. Use of ultrasmall numbers dispenses with the epsilon-delta machinery, proofs become simpler, and fundamental results can be proved from first principles without need for the notion of supremum. Epsilon-delta arguments can be introduced naturally when studying estimation. The approach has been classroom-tested in Geneva. (Received September 22, 2011)

1077-N5-2456 **Paul M. Musial*** (pmusial@csu.edu), Chicago State University, Department of Mathematics and Computer Sci., 9501 South King Drive, Chicago, IL 60628. *Using Illustrations to Motivate Definitions and Proofs in Real Analysis.*

Many of the concepts in Real Analysis, e.g., limits and differentiation, are relatively easy to grasp intuitively, but have abstract definitions. In addition, the proofs associated with these concepts are frequently difficult to visualize. The expert in Real Analysis often has a mental image of the concept in his/her head. One challenge to the teacher of Real Analysis is to select illustrations and examples that help the student develop such a mental image. Effective illustrations need to motivate without trivializing. We will discuss ways of illustrating results such as Leibniz's Alternative Series Test and various approximation theorems. (Received September 22, 2011)

1077-N5-2680 **Cesar E. Silva*** (csilva@williams.edu), Department of Mathematics, Williams College, Williamstown, MA 01267. *Cantor's set throughout real analysis.*

The Cantor set in its various forms can be used as an example to introduce and illustrate many concepts and proofs in introductory real analysis. We start with the set $2^{\mathbb{N}}$ of infinite sequences of 0's and 1's to illustrate countability arguments, then we put a metric on this and discuss compactness, then define functions on $2^{\mathbb{N}}$ such the shift to illustrate continuity, proceeding to its identification with the middle thirds set in the unit interval, to end with its identification with the 2-adic integers, to illustrate concepts such as the non-Archimedean property. Some topics are assigned as projects, such as the completion of $2^{\mathbb{N}}$ under the 2-adic metric to obtain the 2-adic numbers, convergence of sequences and series in the 2-adics, and the notion of measure zero sets. (Received September 22, 2011)

Touch it, Feel it, Learn it: Tactile Learning Activities in the Undergraduate Mathematics Classroom

1077-O1-366 **Michael D Smith*** (smithm@lycoming.edu), 629 US Route 15, Williamsport, PA 17702. *The Parity Theorem Shuffle.*

This in-class activity is based on the ropes course initiative T.P. Shuffle. In this initiative, students must stand in alphabetical order on an inverted log. Then, they must switch places until they are in the order of their birthdays (or some other predetermined order) without any feet touching the ground, which has the effect of limiting their moves to adjacent transpositions. To make this interesting, I add the following catch: students must do this twice, once using an even number of moves and once using an odd number of moves. Then, I watch students try in vain to complete this task and slowly discover, convince their classmates, and try to explain why this is impossible. This activity, which is scheduled to appear in PRIMUS, leads to a discussion of inversions and a tangible inversion count proof of the parity theorem. (Received August 26, 2011)

1077-O1-373 **Sharon L Crumpton*** (sharon.crumpton@belmont.edu), Mathematics Department, Belmont University, 1900 Belmont Blvd, Nashville, TN 37212-3757. *Using Models to Help Students Understand Calculus Topics.*

Many excellent calculus students have trouble understanding topics in three dimensions. One reason for this difficulty is that three dimensional models are drawn in two dimensions, which results in models that are difficult for students to understand. The use of three dimensional models can help students understand many topics in multivariate calculus. Models from the following list of topics will be presented: graphs of quadric surfaces, the graph of a helix, level curves, partial derivatives, tangent planes and linear approximations, directional derivatives, and multiple integrals. Clay, index cards, potato chips, straws, blocks, and other materials will be used to model various topics. If possible, participants will be able to make some of the models. (Received August 26, 2011)

1077-O1-554 **Elton Graves*** (graves@rose-hulman.edu), Rose-Hulman Institute of Technology, CM 131, Terre Haute, IN 47803. *Demonstrations That Work in the Mathematics Classroom.*

Over the years we have developed several "hands on" demonstrations which help our students to visualize the mathematics they are learning in our calculus and differential equations courses. This paper will present several of these demonstrations including the use of the cycloid curve and brachristochrone problem, Newton's Law of Cooling, directional derivatives, Lagrange multipliers, centers of mass, spring mass systems, and others as time permits. By having students participate in demonstrations the students in these mathematics courses actually see how mathematics is used and applied to "real world" situations. The students come away with a better sense why and how the mathematics they are learning is important and how the techniques they are learning relate to real or physical situations. (Received September 07, 2011)

1077-O1-565 **Richard D Summers*** (rds@reinhardt.edu), 7300 Reinhardt College Circle, Waleska, GA 30183. *Partition Numbers and Fractals: Insights Using Bulgarian Solitaire.*

Recently, Dr. Ken Ono of Emory University has developed a new finite formula for partition numbers. The complexity and fractal nature of partitions can be easily grasped by beginning mathematics students using Bulgarian solitaire, introduced in 1983 by Martin Gardner. Bulgarian solitaire will be used to construct directed graphs for partitions following the work of Suzanne Doree of Augsburg College. The presentation involves an actual hands on activity. (Received September 09, 2011)

1077-O1-599 **Rodney X. Sturdivant*** (Rodney.Sturdivant@usma.edu). *Euler Games for Differential Equations.*

Euler's Method is a commonly used numerical method used to introduce students to solutions when first learning differential equations. In practice, it quickly becomes a series of computations contributing littel to conceptual understanding. The "human object lessons" in this presentation move the numerical method off of the paper and out of the computer into the classroom and beyond. Students become an active player in the algorithm as, for example, they use a differential equation "compass" and navigate to win prizes in exercises such as "Uncle Euler's Egg Hunt". Several exercises are presented that have been extremely successful in both engaging students and exciting them about the mathematics they are learning. (Received September 08, 2011)

1077-O1-709 **James A Sellers*** (sellersj@math.psu.edu), Department of Mathematics, Penn State University, University Park, PA 16802. *Getting the "feel" for centers of mass.*

In this talk, we will discuss a manipulatives-based approach to helping first-year calculus students learn about centers of mass. We will model this technique by demonstrating the kinds of manipulatives which can be used, and we will discuss how such an activity can shed light on other needs the students have when learning about this subject (including trying to determine the function(s) necessary to define the boundaries for given two-dimensional objects, setting up a wise coordinate system in which to envision such shapes, and working with the definite integrals which can arise in the context of finding the center of mass of a given object). (Received September 10, 2011)

1077-O1-847 **Teena Carroll*** (teena.carroll@snc.edu). *Curve Sketching with Puzzle Pieces.*

In the introductory calculus sequence, students often struggle with problems where they need to produce a function satisfying a list of properties determined by the first and second derivatives. I designed an activity where students each determine one criteria for a function and work in teams to build a function satisfying all of the restrictions from the group. I provide them with large identical puzzle pieces which must be rotated correctly and taped to the wall to physically build this function.

The activity naturally produces functions which have cusps and corners, giving students a library of visual examples of these phenomena (which are relatively hard to come by using familiar functions at this level.) Including this activity has greatly improved students' test performance on related questions and has virtually eliminated "I-just-don't-know-how-to-start-this-problem" angst. As an added bonus, the functions on the walls create a de-facto mathematics art gallery in the classroom which inspires discussions both in and outside of our class. (Received September 13, 2011)

1077-O1-897 **Penelope H Dunham*** (pdunham@muhlenberg.edu), Muhlenberg College, Dept. of Math & CS, 2400 W. Chew St., Allentown, PA 18104. *Food for (Mathematical) Thought.*

What are carrots, candy bars, Pringles, and goldfish crackers doing in a math class? They are providing concrete models of mathematical concepts and enabling students to explore those concepts with hands-on activities. Using food to capture students' interest, while motivating discoveries, is a time-honored tradition in my courses. In this talk, I'll describe some of my most successful applications of food-for-thought to explorations and projects in precalculus, calculus, statistics, and even proof-writing. Topics include strong induction, exponential decay, saddle points, conics, solids of revolution, capture/recapture, and chi-squared analysis. (Received September 14, 2011)

1077-O1-1033 **Mariah Birgen*** (mariah.birgen@wartburg.edu), 100 Wartburg Blvd., Waverly, IA 50677. *The Chain Rule Dance.*

One of the most complicated algorithms in multivariable calculus is that of the chain rule. The chain rule is bad enough during the first semester of calculus, however, once students get to multivariable calculus and they have multiple variables, each of which can be functions of multiple other variables it becomes very difficult for the students to internalize. When I realized this, I developed what I refer to as the chain rule dance.

I give each student a card with a function, an operation, or a symbol. For example, one student may have $\frac{\partial}{\partial t}$ and another student would have v. Then I call out a variable and say that it is a function of other variables and they are functions of yet other variables. Then I asked the students to lineup in the chain rule for the derivative of my first variable as a function of one of the last variables. I like to start out fairly simple, but by the end of the dance we are taking derivatives of functions of three variables, each of which is a function of two variables and the act of physically representing the chain rule helps students internalize the algorithm.

This presentation will give the audience an example of how to perform this dancing around class and my list of cards which I hand out to the students. (Received September 15, 2011)

1077-O1-1351 **Kathleen Cage Mittag*** (kathleen.mittag@utsa.edu), One UTSA Circle, San Antonio, TX 78249, and **Sharon Taylor**. *Riding the Ferris Wheel: A Sinusoidal Model.*

When thinking of models for sinusoidal waves, examples such as tides of the ocean, daily temperatures for one year in your town, light and sound waves, and certain types of motion are used. Many textbooks also present a "Ferris wheel problem" for students to work with a canned set of data. This activity takes the Ferris wheel problem out of the abstract and has students explore a hands-on model of a sinusoidal scenario. Students will gather data, create their own sinusoidal function, and then verify their results with the calculator. This activity uses an inexpensive hamster wheel that makes it possible for small groups of students to experience the activity and it takes only one hour of class time. No expensive data collection devices are required. Students also experience working with number of seats as the independent variable instead of time. We have used this activity with high school, college, in-service and pre-service teachers successfully. (Received September 19, 2011)

1077-O1-1420 **B. Carrigan***, Auburn University, 221 Parker Hall, Auburn, AL 36849. *Building Art Galleries for Geometric Proofs.*

Using students as guards, the classic art gallery problem is presented to the students. then in small groups using geo-boards and guard markers students explore the solutions and patterns involved in the art gallery problem. The concepts of the guards sight produces the ideas of convexity and simplicies. Finally the use of triangulation and coloring is used to prove that patterns (hopefully found by the students!) hold in general. Once the concepts are developed through this hands on activity, students begin to readily accept the ideas that basic geometric concepts are built upon. (Received September 19, 2011)

1077-O1-1426 **John F Putz*** (putz@alma.edu), 614 W. Superior St., Alma, MI 48801. *Investigating Polytopes of the Fourth Dimension by Building Models.*

The broad context of this talk is a course whose goal is to come to a better understanding of the fourth dimension. The course has no prerequisites other than basic algebra.

One way to investigate the nature of regular polytopes in four dimensions is to reason by the powerful technique of analogy. The essential activity in this exercise is the construction of physical models. Working together in small groups, students fit congruent poster-board polygons together in all possible configurations around a vertex to create models of regular polyhedra in three dimensions. Then, they take some measurements from their models and pool their data. Next, in a manner similar to the way they put polygons together to form polyhedra, they fit their three-dimensional polyhedra together to predict configurations of four-dimensional polytopes. Finally, students use their collected data to corroborate their predictions. (Received September 19, 2011)

1077-O1-1479 **Ann N Trenk*** (atrenk@wellesley.edu), Mathematics Department, Wellesley College, 106 Central Street, Wellesley, MA 02481. *Active Learning in Discrete Mathematics.*

Jumping into a problem helps students gain a deeper understanding of the topic and creates a fun and memorable experience. In this presentation, audience members may participate in activities to illustrate topics in discrete mathematics, including derangements and Catalan numbers. (Received September 19, 2011)

1077-O1-1518 **Allan Struthers*** (struther@mtu.edu). *Loaded Dreidels.* Preliminary report.

Coins and dice provide natural probability distributions which students assume (correctly) to be defined by their symmetry. In contrast spinners (for example the four-sided Dreidel) must be crafted carefully to be close to fair. Most cheap Dreidels are biased with each Dreidel having a distinct clockwise and counter-clockwise spin probability distribution. As a result, they are useful for numerous classroom activities. Activities including estimating the probability distribution, estimating win/duration probabilities for the traditional childrens game, and computing win/duration distributions will be discussed. (Received September 20, 2011)

1077-O1-1543 **Gregory S. Warrington***, Dept. of Mathematics & Statistics, 16 Colchester Ave., Burlington, VT 05401. *A Photographic Assignment for Abstract Algebra.*

We describe a simple photographic assignment appropriate for an abstract algebra (or other) course. Students take digital pictures around campus of various examples of symmetry. They then classify these pictures according to which of the 17 plane symmetry groups they belong. (Received September 20, 2011)

1077-O1-1578 **Randall E Cone*** (conere10@vmi.edu), 439 Mallory Hall, Virginia Military Institute, Lexington, VA 24450. *Grocery Bags and Lasers.*

In order to facilitate student participation in freshman-level undergraduate mathematics classes, we demonstrate two hand-on activities that engage the interest, and promote tacile involvement, of students in early calculus concepts. These activities are:

1. Using paper grocery bags to teach the chain rule in single-variable calculus. By labeling some bags with functions and other bags as their derivatives, then using one-bag-inside-another (with labels still showing) as composition, a nice hands-on exercise arises. This activity may be naturally initiated and motivated by first visualizing the product rule through similar use of grocery bags.

2. Using a tape measure and laser range finder, numerical approximations (e.g. the Trapezoidal and Simpson Rules) of integrals are motivated via students taking regularly-spaced measurements under a building archway. This exercise may be approximated in the classroom setting by drawing a large curve on a chalkboard and then taking measurements from the floor to a book held along the curve. (Received September 20, 2011)

1077-O1-1689 **Melissa A Stoner*** (mastoner@salisbury.edu), Salisbury University, 1101 Camden Ave, Salisbury, MD 21801. *Traffic Jam: Teaching Critical Thinking through Games.* Preliminary report.

Engaging students has become increasingly difficult in our fast-paced, distracting world. Traditional style lecture or traditional group work can only go so far in reaching students. In this session, we will explore two games/puzzles in which students physically work through a solution to a mathematical task (hidden as a game) and use this experience to analyze their thinking processes. Posing critical thinking problems as physical tasks allows students to engage in the concrete and bridge to the abstract. These student-centered activities meet the needs of diverse learners, encourage perseverance through difficulty, and challenge students to put into action their critical thinking strategies. This style of engagement also requires students to develop their communication skills, both verbal and written. With correct facilitation, pre-service teachers begin to think like educators and are naturally engaged in many of the NCTM process standards. (Received September 20, 2011)

1077-O1-1702 **Heidi N Hulsizer***, P.O. Box 142, Hampden-Sydney, VA 23943. *Rolling the Dice in Statistics.*

In order to teach the Law of Large Numbers and the Central Limit Theorem in an Introductory Statistics course, why not let students see these two in action? The average sum of the digits of two fair dice should be seven. Pairing students and having them roll dice and observe the distribution of their observations gives them hands on experience with these two important theorems. (Received September 20, 2011)

1077-O1-1726 **Julie Barnes*** (jbarnes@email.wcu.edu), Department of Mathematics & Computer Science, Western Carolina University, Cullowhee, NC 28723. *Using feather boas to teach students about functions in pre-calculus, calculus, and real analysis.* Preliminary report.

Students in all levels of mathematics often have trouble visualizing what functions mean. In this talk, we look at how to use feather boas in class to help students understand topics from many levels of undergraduate mathematics. Examples will include function transformations, properties of derivatives, and epsilon - delta proofs of continuity. (Received September 20, 2011)

1077-O1-1767 **Nathan Axvig*** (axvignd10@vmi.edu). *How Many Mints Do I Have?*

This activity can be used to illustrate hypothesis testing, confidence intervals, or simply how repeated sampling can help a person make better decisions. All you need are the binomial distribution, paper bags, and chocolate. (Received September 20, 2011)

1077-O1-1862 **Donald C. Armstead** and **Michael A. Karls*** (mkarls@bsu.edu), Department of Mathematical Sciences, Ball State University, Muncie, IN 47306. *Does the Wave Equation Really Work?*

The wave equation is a classic partial differential equation that one encounters in an introductory course on boundary value problems or mathematical physics, which can be used to describe the vertical displacement of a vibrating string. Using a video camera and physics demonstration software to record displacement data from a vibrating string or spring, we verify the wave equation and a modified version that incorporates damping. (Received September 21, 2011)

1077-O1-2016 **Rebecca Bamford**, **Aminul Huq** and **Wei Wei*** (wwei@umn.edu), 300 University Square, 111 S Broadway, Rochester, MN 55904. *Project CAGE: Integrating mathematical and moral imagination through a hands-on learning project.* Preliminary report.

Mathematics students are challenged by applying optimization techniques to real world problems. Introductory courses in applied philosophical ethics involve a similar challenge: students learn and apply theoretical concepts at the same time as taking a case-based approach to ethical problems. We present a project integrating precalculus and calculus with applied ethics in three introductory level courses. Our project combines hands-on learning with conceptual analysis, aiming to support development of learning connections between the abstract and the practical. Students build a cardboard model of an animal cage to be used in laboratory animal research, and produce a report integrating application of optimization concepts from calculus with ethical guidelines for cage construction and ethical analysis of laboratory animal welfare. Students improve their understanding of optimization problems and learn to apply optimization techniques at the same time as they engage critically with ethical problems in health sciences. In addition to analysis of faculty experiences in delivering the project, we present some preliminary analysis of ongoing collection of attitudinal and metacognitive data concerning student learning in and through the project, and proposed modifications. (Received September 21, 2011)

1077-O1-2197 **Thomas C. Hull*** (thull@wne.edu). *Origami as Hands-on Math.*

Origami, the art of paper folding, has been used as an aid for teaching mathematics since at least the days of Fredrick Froebel in the 1800s. What is not as well-known is that origami can be used as a hands-on way to help students learn numerous aspects of the undergraduate math curriculum, including geometry, algebra, combinatorics, and even the skills of conjecture- and theorem-building. In this talk we will explore, hands-on, as many examples of using origami to do math as we can fit into the allotted time. (Received September 21, 2011)

1077-O1-2343 **Julie F Rogers*** (rogerjf@auburn.edu), 1961 Panda Ct., Auburn, AL 36832. *Hands-on Activity for Mutually Orthogonal Latin Squares.*

The hands-on latin square activity presented in this talk allows undergraduate students to physically play around with a set of 25 cards, each with a town and animal symbol on them, and place them in a 5x5 array such that each row and each column contains exactly one of each town and one of each animal. Once the students are able to succeed at this first task, they are given a third (how many more are possible??) characteristic, such as colors, to add to the cards so that each row and column contains exactly one of each color. Furthermore, each town and animal also receives exactly one of each color. Through this exploration they not only begin learning about mutually orthogonal latin squares, but also finite geometries and other applications can be introduced. This activity was successfully implemented during an NSF funded trip to Australia where graduate students ran math camps and interacted with teachers and students in aboriginal schools. (Received September 22, 2011)

1077-O1-2442 **John C Mayer*** (mayer@math.uab.edu), Dept. of Math - UAB, Birmingham, AL 35294-1170, and **William O Bond** (bond@math.uab.edu), Dept. of Math - UAB, Birmingham, AL 35294-1170. *Learning Through Re-Arrangement of Patterns.*

Our experience is that there is a difference in student performance and understanding when challenged to represent a growing pattern of blocks in multiple ways, including algebraic, provided the students are encouraged to (1) build and manipulate the pattern for themselves, as contrasted with (2) examine and possibly draw representations of the pattern on paper. The variety of solutions found by the students is also richer in case (1). We illustrate this with a couple of examples of growing patterns that have been particularly successful in eliciting these reactions. Our report will include examples of student work, and data from a randomized experiment with an undergraduate geometry class. (Received September 22, 2011)

1077-O1-2553 **Teresa E. Moore*** (moore@ithaca.edu), Dept. of Mathematics, 1212 Williams Hall, Ithaca College, 953 Danby Rd., Ithaca, NY 14850, and **L. Christine Kinsey** (kinsey@canisius.edu). *Geometric Models in Many Classrooms.* Preliminary report.

We present class-tested projects in which students make and use models to increase mathematical understanding.

Geometry students collaborate to build several models of non-Euclidean geometries, which we continue to work with throughout the unit. Building the model changes attitudes toward hyperbolic geometry from an absurd notion to one that is new but interesting and understandable. The models help students make conjectures or demonstrate results in an unfamiliar system. In liberal arts courses, the models help students discover that there are aspects of mathematics they have not seen. Finding a world where the angles of a triangle are too small or the circumference of a circle is too big changes a boring, "we already know this" subject into one that has surprising properties to explore.

Students draw star polygons and tie knots with strips of ribbon. In geometry, they will have discussed construction by ruler and compass and by origami. The knots provide another means of constructing regular polygons. These figures also show links between star polygons, modular arithmetic, and subgroups of finite cyclic groups. Liberal arts students use the models to make conjectures about the number of sides to a figure, the star pattern used to construct it, and common factors. (Received September 22, 2011)

1077-O1-2554 **Mike Long*** (malong@ship.edu), Shippensburg University, 1871 Old Main Drive, Math Dept. MCT 273, Shippensburg, PA 17257. *Building Mathematics Understanding with Toys.*

Did you ever consider building bridges out of clay in a Calculus class or physically packing Platonic solids in a Number Theory class? A clay bridge can be a very useful tool for helping students to understand the abstract concepts of limits and continuity. The packing of Platonic solids with Polydrons into larger Platonic solids is a great way to introduce some special sequences of numbers in a Number Theory class, to review some basic Geometry concepts in a Geometry class, or both! Come ready to be part of these student tested and proven building activities for enhancing mathematics understanding. (Received September 22, 2011)

1077-O1-2597 **Ron Taylor*** (rtaylor@berry.edu), Department of Mathematics & Computer Science, Berry College, Mount Berry, GA 30149, and **Todd Timberlake** (ttimberlake@berry.edu), Department of Physics, Astronomy & Geology, Berry College, Mount Berry, GA 30149. *Tearing Plastic: A laboratory exercise on fractals and hyperbolic geometry.*

We describe a hands-on activity for a liberal arts mathematics course that focuses on the beauty and unity of mathematics. The purpose of the activity is to tie together several topics in the context of a real-world situation – that of a torn plastic bag. These topics include: fractals, non-Euclidean geometry, symmetry, and Platonic solids. (Received September 22, 2011)

1077-O1-2603 **Erin Elizabeth Bancroft*** (eebancroft@gcc.edu). *The Candy-Coated Mathematics Classroom.*

In this talk, we will explore hands-on mathematical activities involving chocolate that "melt in your mouth, not in your hand". These activities span a wide range of undergraduate courses: from Finite Math to Abstract Algebra it's all in the mix", and allow students to literally "taste the [mathematical] rainbow" as they investigate new concepts. Demonstrations, resources and take-home manipulatives will be included as we discover how interactivity with candy "makes mouths [and students] happy" to learn mathematics. (Received September 22, 2011)

1077-O1-2669 **Jessica M Mikhaylov***, jessica.mikhaylov@usma.edu. *Cookies, Sidewalk-chalk, and Office Chairs: Hands-on Activities from Calculus to Comets.*

In every course I have taught, from pre-calculus to astrodynamics, I have found that manipulative materials allow the students to internalize the concepts more concretely. I will present a short sampling of activities and pictures of actual students participating in these activities. The first activity is applicable to any course that introduces multivariable functions: using cookies to build functions of two variables. The second and third activities are used in my advanced undergraduate astrodynamics course; however the ideas are fundamental enough to be presented in a seminar course for non-mathematicians. We explore the definition of an ellipse and use sidewalk chalk, string, meter sticks, and some quick calculations to draw a partial model of the solar system. Lastly, we explore how conservation of momentum relates to Kepler's second law using a spinning office chair and a quick "run around the sun" for a highly eccentric comet orbit. (Received September 22, 2011)

1077-O1-2696 **Aaron D Wangberg*** (awangberg@winona.edu). *Raising Calculus to the Surface.*

Many of the beautiful ideas in multivariable calculus are simple extensions of single variable calculus concepts. Too often, these geometric ideas are lost behind a myriad of parametrizations, coordinate-dependent formulas, and the need to use computer visualization technology in the course. In this talk, I'll share how groups of students used short 15-minute hands-on activities with physical wooden surfaces, cut with a CNC Machining Center, to discover the fundamental concepts in Multivariable Calculus. In addition to sharing activities involving the geometry of gradient vectors, directional derivatives, and the method of Lagrange multipliers, I'll also report on some surprising misconceptions that prevented students from raising their single variable calculus understandings to this multivariable setting. (Received September 22, 2011)

1077-O1-2709 **Dennis C. Ebersole*** (debersole@northampton.edu), 3835 Green Pond Road, Bethlehem, PA 18049. *Using 3-D Manipulatives to Teach Calculus.*

A manipulative that allows students to create graphs in 3-D has been shown to increase student success and learning. The presentation will discuss activities that use the manipulative to help students visualize various calculus concepts. (Received September 22, 2011)

1077-O1-2710 **Sarah E. Wright*** (swright@holycross.edu). *The Cheese Stands Alone.* Preliminary report.

This talk discusses a lab project designed to give students a hands on example of finding the volume of an object using integrals. The in class activity is presented similar to that of a science lab, walks the students through the steps and then gives them a method to check their accuracy. We discuss the success of the project, how it can be improved upon, and possible adaptations to various classroom situations. (Received September 22, 2011)

1077-O1-2810 **Benjamin J Thirey*** (benjamin.thirey@usma.edu), West Point, NY 10996, and **Robert D Wooster** (robert.wooster@usma.edu), West Point, NY 10996. *The Touchy-Feely Integral and Basic Properties of Integration.*

Elementary levels of education make use of manipulatives in the teaching of fundamental mathematical concepts. As students move on to more advanced topics, mathematical concepts become more abstract and harder to visualize. One approach we have implemented is the use of construction paper. This simple hands-on object can be used to demonstrate the basic properties of integrals, and even provide a visual means of verifying the Fundamental Theorem of Calculus. (Received September 22, 2011)

1077-O1-2843 **Ellizabeth McMahon*** (mcmahone@lafayette.edu) and **Rebecca Gordon**. *Hands-On SET®.*

The card game SET® can be used to understand finite geometry in a hands-on way. In Liberal Arts classes, this can be used to show how a fun game can involve surprisingly deep mathematics. In teacher training classes, future teachers can be shown how to use SET® to get students excited in math classes. The upper level mathematics courses where the game can be used include Combinatorics, Introduction to Proofs and Geometry. We will show some hands-on activities and provide handouts for more. (Received September 22, 2011)

Trends in Teaching Mathematics Online

1077-O5-94 **Ronald L Merritt*** (ronald.merritt@athens.edu), 300 North Beaty Street, Athens, AL 35611. *Implications for learning transition level mathematics using a distance delivery model.* Preliminary report.

Athens State University requires mathematics and computer science majors to take an undergraduate level discrete mathematics course. This course serves as the transition mathematics course for abstract algebra, introductory analysis, geometry, etc. During the summer of 2009, the mathematics department debuted a blended format of the course that included online instruction and online assessments with major examinations proctored on campus. The blended sections have since become an expected part of the curriculum by students, but have only been offered to supplement the number of traditional sections, not to replace them. Based on a sample size of 193 students, this paper reveals no significant difference between the performance of traditional versus blended students. This paper also indicates where improvements for the blended format may be required and students' perceptions of the benefits and disadvantages of the blended format for a transition mathematics course. (Received July 25, 2011)

1077-O5-195 **Bonnie L. Oppenheimer*** (boppenheimer@as.muw.edu), 1100 College Street W-100, Columbus, MS 39701. *An Analysis of 4 College Algebra Classes With or Without Computer Software Support.*

The author examines her experience teaching a College Algebra class entirely by lecture; teaching with supplemental MyMathLab for homework; teaching a pilot Course Redesign replacement class using Hawkes Learning software; and teaching a revised replacement class using Hawkes Learning software. Data on retention rates, homework averages, test averages, final exam scores, course grades, and chi-square analyses of pass rates will be presented. (Received August 10, 2011)

1077-O5-201 **Carles Aguilo*** (carles@wiris.com), Via Augusta, 59, 08006 Barcelona, Spain, and **Ramon Eixarch** (ramon@wiris.com), Via Augusta, 59, 08006 Barcelona, Spain. *WIRIS collection, a repository of ready-made online exercises for self-assessment.*

According to our experience, random elements for questionnaires are especially appreciated by authors. The automatic evaluation of the answers is critical for random questions. The integration of a system that performs mathematical calculations (a Computer Algebra System) is necessary for providing this automatic evaluation and for making sure that the student's answer is checked for mathematical equivalence and not simple equivalence.

The user interface of the student is the second crucial element of any online questionnaire system. Too often, the student fails to provide the correct answer due to minor syntactical errors that are introduced at the moment of typing in his answer. WIRIS quizzes offers a solution to all these problems, integrating an equation editor for the answer introduction and a powerful CAS for the answer check.

We present now the WIRIS collection (http://collection.wiris.com), released in May 2011 and containing today over 1 500 exercises created by teachers and shared under a Creative Commons license. This repository already shows a wide variety of approaches: from a course specially designed for a child with a learning disability through regular high school courses to a linear algebra course in a technical university. (Received August 11, 2011)

1077-O5-210 **Katrina M Palmer*** (palmerk@appstate.edu), Appalachian State University, Mathematical Sciences, Walker Hall, 121 Bodenheimer Dr., Boone, NC 28608. *Using SmartPens to Facilitate Math Communication Online.*

This presentation will describe how smartpens were used for an online computational math course. The instructor used smartpens to create mini lectures and to show students examples and thorough solutions. In addition, each student was provided a smartpen and expected to use their smartpen to post solutions and comment on other student solutions. Examples shown will be related to root-finding methods, computational integration techniques, and Taylor polynomials. The focus of the talk, however, will be how smart pens were used in an online course. Student feedback about the course and smartpens will be given. (Received August 12, 2011)

1077-O5-231 **Kuiyuan Li*** (kli@uwf.edu), Department of Mathematics and Statistics, University of West Florida, Pensacola, FL 32514, **Raid Amin** (ramin@uwf.edu), Department of Mathematics and Statistics, University of West Florida, Pensacola, FL 32514, and **Josphat Uvah** (kli@uwf.edu), Department of Mathematics and Statistics, University of West Florida, Pensacola, FL 32514. *On Synchronous Distance Teaching in a Mathematics MS Program.* Preliminary report.

A fully online graduate program that was developed at the University of West Florida, UWF, has been successfully implemented using synchronous instruction since fall 2009. The hybrid nature of the developed model has proven to be of benefit to both face-to-face and distance students. Aside from the robustness of students' discussions and interaction outside the regular class period via an e-learning platform, the fact that the instructor can be a part of the discussion when needed has been an added advantage. Moreover, our assessment results show that the model is flexible and cost effective. A statistical analysis of students' performance indicates that the distance students do as well as their face-to-face counterparts when this delivery model is used. We provide some recommendations for institutions wishing to adapt this hybrid model. (Received August 15, 2011)

1077-O5-350 **A S Elkhader*** (elkhadea@northern.edu), Dept. of Sciences and Mathematics, Northern State University, 1200 S. Jay St., Aberdeen, SD 57401. *Students' Attitude Toward Assessment of on-Line Learning of College Algebra and Intermediate Algebra.*

This research investigated students' attitude toward classroom assessment in two on-line math courses, College Algebra and Intermediate Algebra. The instrument for each of these investigations was a set of survey questionnaires powered by Surveymonkey, a web-based survey & questionnaire tool, to examined students' attitude regarding readiness for the course, amount of work involved, and self-reflection on course assessment. The surveys were conducted at the beginning and at the end of the summer semester. Findings revealed a slight shift in students' attitude toward the assessment tools throughout the implementation of these two courses. Additionally, students seem comfortable with the course expectations, grading scale and other assessment tools of the courses. (Received August 25, 2011)

1077-O5-396 **John C. Miller*** (xyalgebra@mindspring.com), 110 Riverside Dr AP 14C, New York, NY 10024. *Providing Intelligent Step-by-Step Help in Solving Practice Problems Online.* Preliminary report.

Math instructors routinely request that students show every step of each problem solution, in order to provide the best feedback if the last step is incorrect. Most online practice software, however, accepts as student input only a short final answer and responds with a stored solution often using a method different from the student's method. Online students, lacking routine access to an instructor, would greatly benefit from intelligent step-by-step help. Such help requires algorithms (a) to determine equivalence of each new step and (b) to describe and, if needed, provide a reasonable next step after literally any correct student step, regardless of method. Intelligent next step generation is not trivial even for a course as basic as Algebra I. The presenter will show and offer for free downloading a program incorporating such algorithms for most Algebra I problems. The goals are (a) to obtain feedback on this particular implementation and (b) to stimulate discussion of ways of making such help widely available at all levels. (Received August 29, 2011)

1077-O5-404 **Revathi Narasimhan*** (rnarasim@kean.edu). *Increasing interaction in online courses.*

Online courses can often be isolating, particularly in mathematics, due to the nature of the assignments that are usually given. In this talk, we discuss how low or no cost technologies for web based, interactive meetings can enhance an online course. Students taking online courses in mathematics prefer some form of lecture in addition to their reading requirements. A platform with active participation is usually preferred over a prerecorded lecture. An interactive lecture incorporating PowerPoint slides, screen sharing, and online videos can create a dynamic environment for students to learn. We will discuss some easily available platforms that can make this possible, using our online introductory statistics course as an example. (Received August 29, 2011)

1077-O5-577 **Cheryll E Crowe*** (cheryll.crowe@eku.edu), 521 Lancaster Ave., Wallace 301, Richmond, KY 40475. *Connecting Students with Mathematics: The Power of Combining ALEKS and Wimba.*

This presentation will highlight the successes of teaching modified online graduate mathematics courses combining two online tools: ALEKS and Wimba. ALEKS is an artificial intelligence system that adapts questioning to determine a student's content knowledge of specific math topics. Interfaced with Blackboard as an online meeting room, Wimba has become a tool to connect students with mathematics through real time chat, video capabilities, and desktop sharing. A discussion of strengths/weaknesses of these tools for content delivery will be explored, and participants will view a sample learning group from a Wimba archive. (Received September 07, 2011)

1077-O5-841 **Matthew Leingang*** (leingang@nyu.edu), 251 Mercer St, New York, NY 10012. *Gluing together Blackboard, Facebook, and Twitter.*

Students today spend more time on Facebook than on any other website. Course Facebook pages are a way to reach students where they are. But duplicating regularly updated content on an official course website as well as a Facebook page can become tedious. We will discuss methods of integrating a Blackboard or other course website with counterparts in social media spaces, including Facebook and Twitter. All techniques will use free online services and will not require programming. Once set up, connections update automatically and content is broadcast further without additional effort. (Received September 13, 2011)

1077-O5-1158 **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, 3368 TAMU, College Station, TX 77843-3368. *Improving Pedagogy Through Adaptive Problem Selection in Online Tutors.*

An essential part of online mathematics courses is the way students complete homework. Explicit lists of exercises are insufficient for poorly-prepared students and unchallenging for high-performing students. This problem is amplified by randomly generated problems with widely varying levels of difficulty.

The Maplets for Calculus (M4C) are used in several online courses as an effective electronic tutor. The 129 applets present algorithmically-generated problems, require correct intermediate responses before moving on to the next step, employ computer algebra to analyze student responses and provide customized hints and feedback. Algebraic, graphic, numeric and verbal approaches support diverse learning styles.

One innovation being added to M4C is the replacement of randomly selected problems by an adaptive system that moves to progressively more difficult problems only after the student exhibits mastery of the current level and moves to simpler problems or suggests another applet on prerequisite skills when students have trouble.

The matching of level of difficulty and identification of underlying weaknesses improves the pedagogical effectiveness of a resource like the M4C, particularly in online courses where direct monitoring of student work is not easily achieved. (Received September 17, 2011)

1077-O5-1167 **Bashar Zogheib*** (bzogheib@auk.edu.kw), Safat13034 Salmiya, Kuwait, Kuwait. *Exploring the Effect of Using Technology on the online Learning of Algebra.*

This study focuses on exploring the effect of using MathXL on online students' performance in college algebra classes. MathXL is an innovative series of text-specific online courses that is available for Pearson textbooks in mathematics and statistics. Two groups will be considered in this study. The first group is assigned the work through MathXL while the second group is assigned the work through the traditional way and by using blackboard. This article is divided into two parts, which describe the difference between the two groups, and compares students' performance. (Received September 17, 2011)

1077-O5-1221 **Mike May*** (maymk@slu.edu), Dept of Math and Computer Science, Saint Louis University, 220 N Grand Blvd, St Louis, MO 63103. *Online PREP Workshops: The experience of teaching online professional development courses in mathematics.*

Continuing professional education seems particularly suited for online education. In particular, you generally have a geographic spread and work commitments that make travel to a central location impractical. You also generally have enough individual motivation from the participants to make individual work practical. Over the past 9 years the faculty at SLU have offered 11 weeklong online workshops through the MAA PREP program. The workshops have covered a variety of topics. We have found in doing distance education in mathematics that we need to pay particular attention to keeping the participants active, building a community of learners, and providing individual feedback outside of class time. While none of these issues are unique to distance learning, the lack of face-to-face contact makes them more challenging. The talk will discuss how we addressed these issues using wikis, screen sharing software, and extended group assignments. (Received September 18, 2011)

1077-O5-1914 **Shumei C Richman*** (richmansmc@gmail.com), 220 North Woodlake Dr., Columbia, SC 29229. *On WeBWork: how to Design a Model Course that is Concise and Complete?* Preliminary report.

When designing a model course on WeBWork, there are many factors to consider in order to make it effective. Above all is how to achieve conciseness and at the same time completeness. More precisely, how to include all the necessary problems, but avoid any duplicated ones? This question is more complex than it seems, and the answer varies, depending on one's teaching experiences, philosophies of math, and goals for students to reach. In this talk, we will first discuss degrees of duplicatedness. Then, based on an ultimate goal for students to master math, we will discuss what problems should be considered necessary. As an example, for the topic of solving linear equations, we try to answer whether the following two equations

A. $3(5x + 4) - 7(5x - 4x) = 2(5x \bullet 4) + 8(5x/4)$,

B. $9[(5x^2 - 4)]^3 - 7 = 2$

should be included as core problems. (Received September 21, 2011)

1077-O5-2044 **James Baglama*** (jbaglama@math.uri.edu), Department of Mathematics, University of Rhode Island, Kingston, RI 02881. *Teaching a General Education Math Course Online with Discussion boards and a Screencast system.*

In this talk, I will describe how I transformed a face-to-face general education math course into a successful online math course. I will discuss my pedagogical strategies for designing this course. In particular, I will describe the use of discussion boards and the use of a Screencast system, Jing. Discussion boards are used as a collaborative teaching tool, and I believe the discussion boards are the driving force behind the success of my online math course. The Screencast system is used as an online version of going to the board to present a problem. The Screencast system helped the students' learning of the material while giving me insight into each student's problem solving skills. (Received September 21, 2011)

1077-O5-2122 **Elizabeth A Eagle*** (eaeagle@uncc.edu), 9501 University City Blvd, Charlotte, NC 28223. *Expanding Redesign Success.* Preliminary report.

The Math Department at the University of North Carolina in Charlotte has implemented a complete redesign of its Intermediate Algebra course. The redesign was implemented with technology that enhanced instruction and evaluation. Mastery learning and course-wide consistency were also big components of this restructure.

The focus will be on how the redesign aspects were applied in a higher-level math courses, such as Business Calculus. Comparisons will be drawn between the previous traditional course set up and the new redesigned structure. Also to be covered are details on planning, implementation, use, and outcomes of the changes. The effects of mastery learning and student results, along with reactions and comments about the course will be explored. Helpful software resources will be shown, such as step-by-step instructions and an interactive tutor that gives student feedback on their work.

This redesign has not only had a positive impact on students, but instructors have found it to be extremely beneficial as well. Implementation tips, methods proven to be successful, and lessons learned will be shared so others who may be considering similar changes can benefit from learning about our successful experience. (Received September 21, 2011)

1077-O5-2333 **William M. Kinney*** (bkinney@bethel.edu), Bethel University, P.O. Box 95, 3900 Bethel Drive, St. Paul, MN 55112. *Teaching an Online Sophomore-Level Differential Equations Course.* Preliminary report.

I taught a sophomore-level differential equations course online during the springs of 2008, 2009, and 2010. I especially wanted to focus on two things: freeing up student exploration time because of reduced lecture time (lectures were videotaped) and developing student collaboration skills and creativity by having them make their own video productions for group projects. I will discuss how I structured the course to give sufficient time for students to complete the course requirements. I will also discuss my philosophy, pedagogy (especially focused on the use of technology), successes and obstacles, assessment, student performance, and student opinions. (Received September 22, 2011)

1077-O5-2391 **Graeme Kemkes** and **David Pritchard*** (daveagp@gmail.com). *Teaching Python In One Browser Window.*

We recently developed a website for first-time programmers to learn Python in an easy and fun manner. What makes our website novel is the user experience: rather than a page of instructions and a separate programming environment, each webpage contains instructions intermingled with bite-sized exercises in a variety of flavors. This removes the hassle of installing an IDE at home or school. At the same time, the student really is programming: we use an auto-judge server to execute their code snippets on test cases, giving immediate feedback in the same browser window.

Since the goal is to make this a fun and interesting experience, we have used a variety of question types. For example in a Code Scramble problem, the program is already complete but its lines are in the wrong order, and the student must drag-and-drop the lines into the correct order before auto-judging.

This website, Computer Science Circles, is hosted by the Centre for Education in Math and Computer Science at the University of Waterloo. Currently there are 25 topics beginning with "Hello world," moving on through math and strings, up to recursion and an introduction to algorithmic efficiency. URL: `http://cemclinux1.math.uwaterloo.ca/~cscircles` (Received September 22, 2011)

1077-O5-2472 **Aimee J Ellington*** (`ajellington@vcu.edu`), PO Box 842014, 1015 Floyd Avenue, Richmond, VA 23284. *The Instructor's Perspective: How to Make Learning Mathematics an Interactive Experience in an Online Environment.*

In Spring 2010, I was part of the instructional team for the first mathematics course in a program for teachers completing a masters degree for Mathematics Specialists. This course was primarily taught online, using the Wimba platform, with two weekend sessions, one to kick off the course and one to conclude the course. This course was not taught through a traditional lecture format. By integrating a writing tablet and encouraging discussion, participants were an integral part of the instruction process. This session will outline the experiences of the instructors in preparing for and teaching this course. Particular attention will be paid to the approaches we used to make the course an interactive, engaging experience for the participants. The assessment methods we used will also be outlined. This session will highlight the challenges and successes of offering an interactive mathematics course in an online environment as well what the instructors plan to do differently in the next course we teach online. (Received September 22, 2011)

1077-O5-2498 **Barbara Margolius*** (`b.margolius@csuohio.edu`), Math Department, RT15th, 2121 Euclid Ave, Cleveland, OH 44115-2214, and **Daniel Gries**, **L Felipe Martins** and **Yuping Wu**. *A new kind of online homework: Flash enabled WeBWorK homework problems.*

Under our NSF-CCLI grant, DUE-0941388 we have developed a library of Flash applets embedded in WeBWorK homework assignments for entry level university mathematics courses including calculus, pre-calculus and differential equations. Applets are self-contained programs that play within the user's web browser. These applets are designed to interact with the WeBWorK online homework system to facilitate the creation of a richer array of assessment and enhancement of student learning than has been offered by most online homework resources or by standalone applets. Many of these problems are now available through the WeBWorK National Problem Library. We are continuing to add to the library as we develop new applets.

Flash applet enhanced homework problems presently in available require students to sketch the derivative or antiderivative of a given function; allow students to manipulate a solid of revolution; allow students to sketch on and overlay graphs that they are asked to identify as function, fi rst and second derivative; allow drag and drop matching, or provide step by step solutions to problems. (Received September 22, 2011)

1077-O5-2536 **Ellen Cunningham*** (`ecunning@smwc.edu`). *High Touch to High Tech: Distance Learning in a Small Liberal Arts College.*

As a pioneer in distance education, Saint Mary-of-the-Woods College has undergone an institution-wide evolution in course delivery methods. The mathematics faculty has generally been in the forefront of this evolution, since we offer the entire mathematics major online and also have a large service load. This paper will briefly discuss the institutional changes in methodologies for distance learning, along with such challenges as setting the limits to flexibility and meeting the Federal and accrediting body requirements for "online" versus "correspondence" delivery. Specific applications for math courses from College Algebra to Real Analysis and Seminar will then be addressed. These include developing interactive methods of content delivery, incorporating group work, linking to environmental and social concerns, using Maple labs in Real Analysis, and creating the seminar experience. (Received September 22, 2011)

1077-O5-2544 **Kyle Siegrist*** (siegrist@math.uah.edu), Department of Mathematics, 258K Shelby Center, University of Alabama in Huntsville, Hutnsville, AL 35899, and **Ivo Dinov** and **Dennis Pearl**. *Distributome–An Interactive Web-based Resource for Probability Distributions.* Preliminary report.

A probability distribution is a mathematically rich object that includes a number of functions (density, distribution, quantile, generating, etc.) and parameters (mean, variance, other moments, median, etc.). In addition, probability distributions are related in myriad interesting ways (special cases, deterministic transformations, various types of limits, conditioning). Finally of course, probability distributions are of fundamental importance in many areas of pure and applied mathematics, and in partner disciplines in science and engineering.

The goal of the Distributome project is to display the rich structure of probability distributions in modern web-based formats. A particularly interesting feature of the project is a dynamic, interactive graph in which the nodes represent probability distributions and the edges represent relations between the distributions.

The Distributome Project is supported by NSF, under grants DUE-1022560, DUE-1022636, and DUE-1023115. (Received September 22, 2011)

1077-O5-2887 **Ahlam E.H Tannouri*** (ahlam.tannouri@morgan.edu), Mathematics Department, Morgan State University, 1700 E.Cold Spring, Baltimore, MD 21251. *Designing, Developing and Assessing an Online Mathematics Course.* Preliminary report.

Learning and teaching mathematics has become a prominent topic in mathematics education. The advent of new technology has revolutionized the options available to instructors and students alike. Modes of delivery like Blackboard, MyMathlab and Mathzone, as well as other technologies like Adobe Connect, WebEx, Jing, and YouTube offer new possibilities to facilitate cooperative learning for the enrichment of the mathematical experience. I will share my five years' experience of teaching online undergraduate and graduate mathematics courses, starting with the design and development of a course based on the Quality Matters rubric, and ending with assessment of online education learning outcomes. I will additionally share examples of the modules developed using these technologies to offer further insight into promising practices in this innovative education environment. (Received September 22, 2011)

1077-O5-2912 **Sarah L Mabrouk*** (smabrouk@framingham.edu), Framingham State University, 100 State Street, PO Box 9101, Framingham, MA 01701-9101. *"Elluminate-ing" Online Course Meetings.*

Since summer 2005, I have taught sixteen sections of introductory statistics online. One factor which most affects how students approach the course is their having taken an online course in another discipline. This results in their having low expectations regarding course workload since, for many online courses, discussion postings involve personal opinion rather than analysis and the course grade is determined by discussion postings and a collaborative project or research paper. However, this is not the case, nor should it be, for an online mathematics course. Learning mathematics requires exploring and applying concepts and methods to a variety of problems at various levels of difficulty as well as in real applications. So, working together online, just as in the traditional face-to-face classroom environment, necessitates interaction and collaboration to facilitate exploring and learning concepts, development of theories, and application of methods: this can be accomplished using discussion forums, virtual chat and virtual classroom environments, and tools such as Elluminate Live! for online course meetings. In this presentation, I will discuss my use of such tools in teaching statistics online, the benefits of the use of these tools for student learning, and student reaction. (Received September 22, 2011)

Trends in Undergraduate Mathematical Biology Education

1077-P1-352 **Mike Martin*** (michael.e.martin@gmail.com), 6319 Sherwood Lane, Merriam, KS 66203. *Deviation from the Norms – Algebra, Trigonometry, & Calculus for the Aspiring Life Scientist.*

This talk will discuss the outcomes and implementations from an NSF grant charged with developing a textbook and web tools for those pursuing careers in the life sciences and medicine. Models will range from ecology, genetics, developmental biology, physiology, cellular processes, and the more general areas of space-filling models and biological rhythms. Mathematical areas include algebra, trigonometry, discrete mathematics, statistics, calculus, and differential equations. The tools featured include those utilizing webMathematica, the Wolfram Demonstration project, and Wolfram alpha. (Received August 25, 2011)

1077-P1-561 **Timothy D Comar*** (tcomar@ben.edu), Dept of Mathematics, Benedictine University, 5700 College RD, Lisle, IL 60091. *Undergraduate Research Projects in Mathematical Biology: Modeling and Simulation in MATLAB.*

This presentation highlights two summer undergraduate research projects in mathematical biology on which students have worked with the presenter over the last few years. Both of these projects extensively used MATLAB to create simulations of the mathematical models.The first project is an investigation of a density-dependent one predator, two-prey model for integrated pest management using impulsive differential equations. In this investigation, students explored conditions under which both prey species would be eradicated, only one species would be eradicated, and both species would remain within controlled population levels. In addition to studying the long-term dynamics of the system, bifurcation behavior of the stroboscopic map of the system was also explored to reveal complex and varying dynamical behavior. The second project addresses the spread of the urban weed, Ailanthus altissima, which is an nonindigenous invasive species in the United States. We consider the spread of this species as disease and use versions of network SI and SIR epidemic models to model the spread of Ailanathus and suggest strategies for controlling the spread. We discuss the biology of the models, the mathematics involved in analyzing the models, and the MATLAB implementation. (Received September 07, 2011)

1077-P1-728 **Carrie Diaz Eaton*** (ceaton@unity.edu), Center for Biodiversity, Unity College, Unity, ME 04988. *So, why do you require Calculus?*

At Unity College, an small environmental sciences college, Calculus I is required by several programs: Wildlife, Wildlife Biology, Aquaculture and Fisheries, Environmental Biology, Environmental Science, and Marine Biology. It is also highly advised for promising students who wish to pursue graduate studies. Faculty advising students in these and other natural resource and sustainability-related majors readily recognize and champion Statistics as a need, but why do they require Calculus? What are they expecting from us, and how do we best serve these students? Cross-disciplinary survey and interview results are presented as well as resulting modifications to curricular approaches for both Calculus I and Calculus II. (Received September 11, 2011)

1077-P1-1288 **Matthew Glomski*** (matthew.glomski@marist.edu), Department of Mathematics, Marist College, 3399 North Road, Poughkeepsie, NY 12601. *Mathematical epidemiology without differential equations.* Preliminary report.

Differential equations have proved an effective tool in modeling the spread of infectious diseases. But can students in math and biology begin to address fundamental questions in mathematical epidemiology before having mastered differential equations–or even integral calculus? In this talk we will discuss two fundamental discrete models, each appropriate for inclusion in the "pre-DE" classroom. (Received September 18, 2011)

1077-P1-1860 **Sepideh Khavari**, **Tara Sansom**, **Bradley Slabe**, **Jonathan Caguiat** and **George T Yates*** (gyates@ysu.edu), Department of Mathematics & Statistics, Youngstown State University, One University Plaza, Youngstown, OH 44555. *Cross Disciplinary Research by Undergraduates in Mathematics and Biology to Examine Cellular Processes.*

A program in Mathematical Biology and Undergraduate Research (MBUR) at Youngstown State University teams biology and mathematics student to conduct genuine research under the mentorship of faculty members in mathematics and in biology. Three or four teams are selected each year to conduct research projects. The program uses a combination of courses, intensive summer research and sustained involvement to educate and motivate the students. Students presented their findings at local, regional and national meetings. A regional conference in mathematical biology was initiated and an interdisciplinary minor in biomathematics was developed. Existing courses were modified and new courses developed. During 2011 student research projects included (1) mathematical modeling and analysis of the growth and butanol production of *Clostridium beijerinckii*, (2) examination of the cellular breakdown of toxins and the proteins involved in the selenite resistance of *Stenotrophomonas maltophilia* ORO2 and (3) the tachykinin modulation of prefrontal cortex neuronal activity in hamsters. The program was funded by NSF grant DBI-0827205. (Received September 21, 2011)

1077-P1-2145 **Timothy A Lucas***, Pepperdine University, Natural Science Division, 24255 Pacific Coast Highway, Malibu, CA 90263. *Undergraduate Research in Modeling the Response of Chaparral Plants to Wildfires.*

This talk will focus on a recent collaboration with an ecologist that has led to an undergraduate modeling project. Specifically, a group of mathematics students have developed several discrete-time models of how various species of chaparral plants respond to wildfires. The chaparral shrubs can be divided into three life history types according to their response to wildfires; non-sprouters are completely killed by fire and reproduce by seeds that germinate in response to fire, obligate sprouters resprout after fire, but their seeds are destroyed by fire, and facultative sprouters both reproduce by seeds and resprout. The students have validated these models using over 25 years of data on the sizes, survival rates, and distribution of chaparral plants. The main study site is located adjacent to Pepperdine University in the Santa Monica mountains which has the highest fire frequency in all of Southern California. Besides the research itself, I will discuss the recruitment and training of mathematics undergraduates and their contributions to the data collection, statistics, modeling and programming involved in the project. (Received September 21, 2011)

1077-P1-2482 **Christopher C. Leary*** (leary@geneseo.edu), Department of Mathematics, SUNY Geneseo, Geneseo, NY 14454. *When the Bloom is Off the Rose, or, How to Avoid Depression After the Stimulus Package Runs Out.*

So, the NSF funding has ended, the book is in its third edition, and the course releases are a distant memory. This biomathematics stuff is starting to feel less like a grand adventure and more like a job. What can you do? We'll discuss strategies for keeping your interest high and the enthusiasm of your students up. At SUNY Geneseo we have successfully utilized a combination of co-taught courses, student research projects, internal funding and long naps to encourage excitement and engagement among a growing number of faculty and students. (Received September 22, 2011)

1077-P1-2849 **Terrell L. Hodge*** (terrell.hodge@wmich.edu), Dean's Office, College of Arts and Sciences, 2304 Friedmann Hall, Western Michigan University, Kalamazoo, MI 49008-5308, and **Raina Robeva** (robeva@sbc.edu), Department of Mathematical Sciences, Sweet Briar College, Sweet Briar, VA 24595. *Mathematical Concepts and Methods in Modern Biology: Using Modern Discrete Models - A Book in Progress.*

We describe a collaborative multi-author, crossdisciplinary book project elucidating frameworks that systematically analyze, predict and modulate the behaviors of complex biological systems using modern discrete models. After beginning with an important topic from biology, each chapter continues by laying out mathematical methods appropriate for addressing related questions. With an emphasis on modern molecular and systems biology, chapter topics include gene expression and regulation, neuronal networks,codon usage and CpG islands, phylogenetics and more. Mathematical methods include elementary discrete mathematics, computational algorithms, graph theory, probability, linear, polynomial, and abstract algebra, and more. Prominent toolkits in the life sciences, such as agent-based modeling (ABM), cluster analysis, and discrete dynamical systems are featured, and combined with significant new developments, e.g., an algebraic approach to ABM and optimal control in the life sciences via algebraic geometry. Exercises and projects embedded within each chapter support interaction with the models and computational methods through hands-on activities. Early sections are written at the undergrad level while later sections may facilitate connections with advanced topics or ongoing research. (Received September 22, 2011)

Wavelets in Undergraduate Education

1077-P5-101 **Karleigh Cameron**, **Michael Gustin*** (mjgustin@gmail.com), **John Holden** and **Stacy Siereveld**. *Investigation of Second Generation Wavelets.*

It is well known that any element in L_2 has a basis expansion. Because of its localization property and fast transform algorithms, a wavelet basis expansion has many applications including speech, images, video, graphics, and engineering. For an infinite or periodic function a traditional wavelet basis works well. However, in many applications the domain of a function is not infinite and functions are not periodic. The need for improvements of wavelet bases introduces the second generation wavelets. We study properties of a lifting operator that serves as a tool to construct these second generation wavelets. (Received July 27, 2011)

1077-P5-329 **Rachel J Weir*** (rweir@allegheny.edu), Department of Mathematics, Allegheny College, Meadville, PA 16335. *Applications of Wavelets: a sophomore-level seminar course.*

In Fall 2011, the seminar course *Applications of Wavelets* was taught for the first time at Allegheny College, with Calculus I as the only prerequisite. The course was part of Allegheny's First-Year/Sophomore Program, which is designed to enhance students' writing and speaking skills. After describing the structure of the course, we will present a summary of the successes and challenges. (Received August 22, 2011)

1077-P5-772 **Joseph Michael Gonzalez***, 4122 Causeway Vista Dr., Tampa, FL 33615. *Facial Detection and Recognition Using the Haar Transform in Static Images.*

The topic of facial recognition has become an intensely investigated field both in the consumer industry as well as the research industry. Various facial recognition algorithms have been developed mainly making use of eigenfaces as well as principal component analysis and other similar linear algebraic methods. In this paper, we explore the wavelets approach to this exceedingly difficult and important topic. In particular, we chose the Haar wavelet due to its inexpensive computational needs, as well as robustness. Fast computational times were further achieved due to developing our code in MatLab. (Received September 12, 2011)

1077-P5-901 **Edward F Aboufadel*** (aboufade@gvsu.edu), **Nathan Marculis** (nathanmarculis@gmail.com) and **SaraJane Parsons** (znsp@iup.edu). *Smartphone Sensors and Wavelets.*

Data logs from accelerometers in android-based smartphones are a source of noisy, spiky data. This data can be collected while driving on bumpy roads or from other dynamic activities. This talk will discuss analyses of this data using wavelet filters and other mathematical tools that are accessible to undergraduates. (Received September 14, 2011)

1077-P5-1875 **Jeff Zeitler***, 77 Martin Road North, Bethpage, NY 11714. *What Are You Hiding? Steganography Using Wavelets.*

Steganography is the art of writing hidden messages in such a way that their presence goes unnoticed to the outside world. Discrete wavelet transforms may be employed to “hide” messages, in the form of text, sound, or images, within audio or image host files in such a way that the manipulation of the host file is undetectable to the ear or eye of the average person. Inverse wavelet transforms can then be used to extract the hidden data. I will discuss the concepts behind the processes of hiding and extracting secret messages, which implement MATLAB algorithms, and display successful examples of wavelets-based steganography. (Received September 21, 2011)

1077-P5-2611 **Kenneth R. Hoover*** (khoover@csustan.edu) and **Brody Dylan Johnson**. *Some Ideas for Undergraduate Projects Involving Periodic Wavelets.*

A recent paper appearing in the book Wavelets and Multiscale Analysis presents a new approach to constructing MRA wavelets on the two-dimensional torus which improves upon the previously used method of periodizing non-periodic wavelets. This construction will be briefly presented with emphasis given to possible undergraduate projects which could be associated with it. (Received September 22, 2011)

1077-P5-2808 **J. D’Andrea*** (jdandrea@westminstercollege.edu) and **T. Sibbett**. *Discrete signal processing with fractal wavelets.* Preliminary report.

Discrete wavelet transforms provide an accessible introduction to wavelets for undergraduate students. Considering the discrete Haar wavelet transform as a prototype, we construct Dutkay-Jorgensen fractal wavelets by encoding fractal structure into the high-pass and low-pass filters of our wavelet system. While the Hilbert spaces based on the enlarged fractal spaces of Dutkay and Jorgensen rely on Hausdorff dimension and Hausdorff measure for their construction, in the discrete setting it is enough to use familiar matrix operations from a first course in linear algebra to describe these fractal wavelet transforms. The second author (undergraduate student) successfully implemented several discrete fractal wavelet transforms in Matlab, including discrete two-dimensional Cantor, Sierpinski gasket, and Sierpinski carpet wavelet transforms. We will demonstrate this fractal wavelet construction using selected two-dimensional fractal wavelet examples compared to the two-dimensional Haar wavelet. Also, we explore the use of fractal wavelets in basic compression and denoising algorithms, as well as giving results of ongoing numerical experiments. (Received September 22, 2011)

1077-P5-2868 **John C. Merkel*** (john.merkel@gmail.com). *Applications of Discrete Wavelets to Stock Price Prediction.*

This talk reports on undergraduate research conducted during Fall, 2011. In a 2005 paper, Yousefi, et al., developed a wavelet-based method for predicting oil prices. We adapt their method to the prediction of stock prices. (Received September 22, 2011)

1077-P5-2886 **Bruce Atwood**, **Helmut Knaust**, **Caroline Haddad*** (haddad@geneseo.edu) and **John Merkel** (john.merkel@gmail.com). *Undergraduate Research Projects on Wavelet-Based Time Series Forecasting.*

In this talk we present ideas for undergraduate research projects based on oil price forecasting techniques utilizing discrete wavelets. We discuss our attempt to confirm results reported by Yousefi, et al., and discuss issues we encountered. We offer suggestions for future research projects. (Received September 22, 2011)

1077-P5-2893 **Helmut Knaust*** (hknaust@utep.edu), Department of Mathematical Sciences, UTEP, El Paso, TX 79968-0514. *Smoke Detection in Stationary Video Using Wavelets.* Preliminary report.

Automatic fire detection is a highly desirable feature of video surveillance technology. We will present a wavelet-based algorithm to detect smoke in stationary video. This algorithm is based on the observation that the presence of smoke causes changes in the high-frequency content of the video still frames. In color video, smoke also affects the chrominance channels.

This open-ended topic is suitable for student projects in an undergraduate applied mathematics course. Prerequisites include some familiarity with basics of digital signal processing and wavelet transforms. (Received September 22, 2011)

Writing the History of the MAA

1077-Q1-334 **Leon M. Hall*** (lmhall@mst.edu), Missouri S&T, Department of Mathematics and Statistics, 400 W. 12th Street, Rolla, MO 65409-0020. *Highlights in the History of the Missouri Section.*

From B.F. Finkel and E.R. Hedrick in the beginning, to Deborah Tepper Haimo and Christine Stevens more recently, members of the Missouri Section of the MAA have played active, sometimes leading, roles in the founding, development, and growth of the Association. This talk will highlight some of the notable events and people from the history of the Missouri Section. (Received August 23, 2011)

1077-Q1-374 **Benjamin V.C. Collins*** (collinbe@uwplatt.edu) and **Jeganathan Sriskandarajah**. *Know Your Wisconsin Mathematician: The Oral History of an MAA Section.*

In fall, 2006, at the prompting of then-Chair J. Sriskandarajah, the newsletter of the Wisconsin Section of the MAA added a feature called "Know Your Wisconsin Mathematician". Since then, twice each year, the newsletter has featured an interview with a prominent member of the section. We didn't set out to create an oral history of the section. However, we have recorded some interesting insights about the past, present, and future of mathematics teaching in general and the MAA in particular. We will share some of our experiences and provide tips for sections that wish to start a similar feature. (Received August 26, 2011)

1077-Q1-378 **Steve Carlson*** (carlson@rose-hulman.edu) and **Amy Shell-Gellasch** (shella@beloit.edu). *The History of SIGMAAs (Special Interest Groups of the MAA).* Preliminary report.

The SIGMAAs program of the MAA was initiated in response to the January 1999 MAA Board of Governors' publication A New Agenda for the 21st Century, which itemized five priority action recommendations. One of those recommendations was "Facilitate the Formation of Special Interest Groups." In late spring of 1999, an MAA Taskforce on Special Interest Groups was appointed and initiated an effort that laid the foundation for a program that has grown to include twelve such groups with a total membership of nearly three thousand members. Upon completion of its charge, the Taskforce was disbanded and replaced by a newly created MAA Committee on SIGMAAs in summer of 2001. In this talk the presenters will reveal the interesting history of the SIGMAAs program from its inception to the present. (Received August 27, 2011)

1077-Q1-481 **J. J. Tattersall*** (tat@providence.edu), Department of Mathematics, Providence College, Providence, RI 02760. *A History of the Northeastern Section: A Work in Progress.*

We will discuss how the project started, what has been done, and what needs to be done. (Received September 04, 2011)

1077-Q1-661 **Daniel J. Curtin*** (curtin@nku.edu), Northern Kentucky University, College of Arts and Sciences, SL 410, Highland Heights, KY 41099. *The Kentucky Section.* Preliminary report.

The Kentucky Section of the MAA was formed in 1917, in association with the "Mathematics Section of the Kentucky Colleges" founded nine years earlier. Thus our section is one of the oldest. The section had a female Chairman (yes, that was the title) in 1923, and many other women served as officers over the years. The annual meetings showcased many distinguished speakers from outside the Commonwealth, as well as presentations from faculty members in public institutions, private colleges, high schools and industry. As Dick Davitt has shown, the section, and especially the University of Kentucky, had a good record in welcoming Jewish mathematicians fleeing Germany in the 1930s. The section continues to flourish, with a dramatic rise in the number and quality of undergraduate and graduate student presentations at the annual meeting, being a noteworthy recent development. (Received September 09, 2011)

1077-Q1-723 **Joel K. Haack*** (joel.haack@uni.edu) and **Linda L. Haack** (haackj2@mchsi.com). *Writing a History of the Iowa Section of the MAA.* Preliminary report.

Considerations and progress to date of writing a history of the Iowa Section of the MAA. (Received September 11, 2011)

1077-Q1-742 **Lawrence A. D'Antonio*** (ldant@ramapo.edu), 505 Ramapo Valley Rd, Mahwah, NJ 07430. *Dean Meder and the Origins of the MAA - New Jersey Section.* Preliminary report.

The New Jersey MAA section was initiated by Albert E. Meder Jr., longtime Dean of Rutgers University. After an organizational meeting in 1955, the first meeting of the section took place in November 1956 at Rutgers. In this talk we discuss Dean Meder and the early years of the MAA - New Jersey section. We will also look at the talks given at the first meeting, where Brockway McMillan, later Under Secretary of the Air Force, gave the very first address. (Received September 12, 2011)

1077-Q1-771 **Betty Mayfield*** (mayfield@hood.edu), Department of Mathematics, Hood College, 401 Rosemont Avenue, Frederick, MD 21701, and **Jon Scott** (Jon.Scott@montgomerycollege.edu). *Digging up the History of a Capital Section.* Preliminary report.

The Maryland-District of Columbia-Virginia Section has formed a committee to write our Section's history in anticipation of the MAA Centennial. So far we have collected all of the old documents we can find, often rescued from the basements of previous Section officers; made a list of Section members we want to interview; and scoured old *Monthlys* for information about our Section. We will report on what we have learned so far. (Received September 12, 2011)

1077-Q1-1275 **James R Choike*** (choike@math.okstate.edu), Oklahoma State University, Department of Mathematics, Stillwater, OK 74078. *Writing a History of an MAA Section.* Preliminary report.

Records, informally passed down over the years to various Secretary-Treasurers of the Oklahoma-Arkansas (OK-AR) section of the Mathematical Association of America (MAA), indicated that the 1988 spring meeting was the 50th annual meeting of this MAA section. In anticipation of celebrating this auspicious anniversary, I was drafted, at the spring 1987 OK-AR section meeting, to write a history of the first 50 years of the OK-AR section of the MAA. In this session, I want to share this experience through the following goals: (1) present a simple outline which can be used to put together a section history; (2) identify resources that I found useful in writing an OK-AR section history; (3) offer tips for "digging deeper" into the history of an MAA section; (4) highlight reasons why writing a history of an MAA section provides a strong local historical confirmation of the importance of the MAA in fostering, in its original intent, "a more organized and continuing concern for collegiate mathematics," which, in 1915, the year the MAA was founded, was "the large field between the fields of secondary school mathematics and the field of pure research"; and (5) share highlights of the first 50 years of the Oklahoma-Arkansas section, as it approaches its 75th anniversary 2013. (Received September 18, 2011)

1077-Q1-1402 **Robert W. Neufeld**, **Elaine L. Tatham** and **Timothy W. Flood*** (tflood@pittstate.edu), Pittsburg State University, Department of Mathematics, 1701 S Broadway, Pittsburg, KS 66762. *The Kansas Section: Were We First?*

The Kansas Association of Teachers of Collegiate Mathematics first met on November 12, 1915, 48 days before the organizational meeting of the MAA itself and was the first organization to apply for admission as a section. In addition, the Kansas Section was also first to hold a section meeting on March 18, 1916. However, the Ohio section was the first to receive a letter granting their request to form a section, dated March 1, 1916.

Regardless of whether the Kansas Section of the MAA was first or not, it certainly has a long and colorful history. In 1980, Elaine Tatham, a former chair of the section prepared an extensive 65-year history of the section. In 2006, Bob Neufeld updated the history and prepared a 90-year history of the section. Highlights of these histories will be presented along with the current efforts to extend the results. (Received September 19, 2011)

1077-Q1-1710 **Kenneth A Ross*** (rossmath@pacinfo.com). *History of National Meetings.* Preliminary report.

Jim Tattersall at Providence College, and Ken Ross at the University of Oregon, are writing a history of national meetings, going back to 1916, from the perspective of the MAA. Almost all of the meetings have been joint with the AMS, except for MAA MathFests since 1997. The process of collating information will be outlined, and there will be some comments about how the meetings have changed over the years. (Received September 20, 2011)

1077-Q1-2032 **T. Christine Stevens*** (stevensc@slu.edu), Dept. of Mathematics and Computer Science, Ritter Hall 104, 220 North Grand Blvd., Saint Louis, MO 63103. *Recovering and recapitulating the history of Project NExT.* Preliminary report.

Project NExT (New Experiences in Teaching) is the MAA's professional development program for new and recent Ph.D.s in the mathematical sciences. It addresses all aspects of an academic career: improving the teaching and learning of mathematics; engaging in research and scholarship; and participating in professional activities. Since its inception in 1994, Project NExT has helped over 1300 new faculty to make the transition from graduate student to faculty member. In addition to outlining the origins, development, and impact of Project NExT, we will discuss some of the challenges posed by the task of writing descriptively and accurately about an activity in which one has been a major participant, and we will reflect upon the competing claims of "memoir" and "history." (Received September 21, 2011)

1077-Q1-2249 **Agnes M. Kalemaris*** (akalemar@optonline.net), Mathematics Department, Farmingdale State College, 2350 Broadhollow Road, Farmingdale, NY 11735. *Women Welcome in the Metro New York Section!* Preliminary report.

Planning for the Metro New York Section of the MAA began in 1940 with an organizational meeting in 1941. The first annual meeting was held in 1942. From the beginning, women were welcome and have been active members. This section also wisely recognized the value of participation by high school mathematics teachers, electing the first Vice-chair for High Schools in 1941. This presentation will highlight some of the people who were involved through the years. It will also discuss the range of interests and activities of this section. (Received September 21, 2011)

1077-Q1-2371 **David Kullman**, **Thomas Hern** and **Daniel E. Otero*** (otero@xavier.edu), 3800 Victory Parkway, Hinkle 104, Cincinnati, OH 45207-4441. *The Ohio Section also celebrates its centennial.*

Sporting a justifiable claim as the first among the MAA Sections, the Ohio Section instituted a Centennial Committee in 2008 to prepare for the MAA Centennial by celebrating its own 100th anniversary in 2015. This talk will report on the activities of the Ohio Section Centennial Committee, including: exploratory "dives" into its Archive to mine for interesting tidbits of information that it shares with the Section at a regular meeting fixture called the Centennial Minute; a revision of the Section history; and ongoing provision of tchotchkes to distribute at each Section meeting to remind members about the coming anniversary. (Received September 22, 2011)

1077-Q1-2590 **Carolyn Connell*** (cconnell@westminstercollege.edu). *The Intermountain Section: an exceptionally brief history.* Preliminary report.

As the 29th and newest section of the MAA, only about 40 years in existence, one would think that a complete history would be at one's fingertips. However, it's amazing how quickly facts/dates/important events disappear from records. We have a collective project in the section currently to re-create the history of these years of our section. Several of the original active MAA members of the section are no longer with us, so we are contacting all of our 'senior' members to gather as much information as possible.

The Intermountain section, which consists of Utah and much of southern Idaho, split off from the Rocky Mountain Section in about 1970, not due to any feuds or disagreement, but rather due to the geologic fact of a continental divide that made travel between the two sections difficult except in summer months. Our section encompasses an area that is relatively sparsely populated, with only 14 colleges and universities, and about 160 MAA members currently. The history project in the section has already generated interesting discussions which will hopefully result in a fairly complete history of our past forty years. (Received September 22, 2011)

General Session on Assessment and Outreach

1077-VA-314 **Noureen Khan*** (noureen.khan@unt.edu). *Closing the loop!*

We present a case study in effort to explore and implement College and Career Readiness Standards in training of pre- service mathematics teachers. The project was devised to invoke two standards: (1) problem solving and reasoning (2) connection to real world, aligned with mathematics standards of College & Career Readiness Standards. The study supports the need of awareness and execution of standards in training of prospective teachers. (Received August 20, 2011)

1077-VA-452 **Bradley Forrest**, **Pamela Kosick*** (pamela.kosick@stockton.edu) and **Chia-Lin Wu**. *Increasing Math Proficiency in High School Teaching.*

With the support of a Research and Professional Development grant from Stockton College we designed and implemented a 5 day long summer professional development workshop for high school mathematics teachers of the Greater Egg Harbor Regional School District in NJ. The goal of this workshop was to enrich the mathematical content knowledge of the teachers. We focused on the areas of Abstract Algebra, Calculus, and Geometry discussing the theoretical foundation of each and its connections with high school mathematics. Here we discuss the strengths and weaknesses of the workshop as well as our next steps to continue and improve the workshop. (Received September 02, 2011)

1077-VA-462 **Sue Brown*** (browns@uhcl.edu). *Teacher Created Multiple-Choice Assessments and the Use of Assessment Data for Planning Instruction.*

Middle School teachers participated in a two-year externally funded grant and the second year of the grant focused on creating multiple-choice assessments similar to state required assessments students complete every April.

Teachers were presented with research-based recommendations for creating multiple choice test items and in groups of six created test items for their grade level. Each teacher administered the test prior to teaching a specified unit and based on data from the test, decisions were made on instruction. At the end of the unit, the same test was used as a posttest. A discussion of the results of this project will be shared with participants.

Participants will have the opportunity to create assessment items using the information presented. (Received September 02, 2011)

1077-VA-645 **Tom Denton*** (sdenton4@gmail.com), Tom Denton, Department of Mathematics, N520 Ross, 4700 Keele Street, Toronto, ON M3J 1P3, and **Emily Hobbs**, **David Stern**, **Zach Mbasu**, **Michael Obiero** and **Jeff Goodman**. *Report on the First Kenyan Maths Camp.*

The 1st Maseno University Annual Maths Camp for high school students has been a resounding success, with over fifteen schools taking part and people travelling the whole length of the country to attend. In August 2011, students and teachers came to Maseno University for the weeklong camp exploring Mathematics from a new perspective. One major aim of the camp was to show how computers can help the teaching of mathematics.

The students were introduced to ideas in mathematics beyond their curriculum, such as game theory, spherical geometry and number theory through talks, discussions, games, activities and computer software. Students, some of who were using computers for the first time, were able to explore mathematics and explain difficult ideas through the use of free software including Wolfram CDF Player, Geogebra, CAST and Gapminder.

Mathematical games involving playing cards taught students about the importance of following rules and applying strategy to improve performance. All participants received a resource pack including two dvds of data and software to share with their peers and colleagues at their own school. They also take away decks of cards and geometric sculptures donated by Wolfram Research to help spread the word that maths is more than just calculation. (Received September 09, 2011)

1077-VA-691 **Rebecca C. Metcalf*** (rmetcalf@bridgew.edu), Bridgewater State University, Mathematics and Computer Science, 229 Hart, 90 Burrill Avenue, Bridgewater, MA 02325. *CONNECT Math: A Partnership in Higher Education.*

Since 2007, the CONNECT Math Partnership has been making a positive impact on undergraduate mathematics education in southeastern Massachusetts. The structure and collaboration between mathematics faculty at three community colleges, two state colleges, and a state university will be outlined. The goals of the group and the impact of our outreach will be discussed. These include: continuing to promote consistency in mathematics preparedness of native and transfer students; easing transfer of mathematics courses among the six institutions; and extending and expanding communication among mathematics faculty at the six institutions. (Received September 10, 2011)

1077-VA-931 **Jerry C Obiekwe*** (accessx@uakron.edu). *An Alternative Approach to Assessing Instructional Effectiveness: Implications to Teaching and Learning Undergraduate Mathematics.*

More than eighty percent of the job description of mathematics instructors is teaching, particularly in either two or four year colleges; and yet assessing the effectiveness of it is still elusive. The most prevalent approach is the student evaluation instrument that students complete at the end of each semester regarding their classroom experiences with their instructors. Questions have been raised whether the instrument is measuring student satisfaction or teaching effectiveness. Cognitive Holding Power Questionnaire could present an alternative approach to evaluating quality teaching.

Cognitive Holding Power Questionnaire (CHPQ) is an instrument that was developed and validated in Australia (Stevenson, 1990). It is used to measure the effects of learning settings on students. The instrument has two dimensions. Essentially, students tend to choose which order they want to apply to their learning depending on the learning settings or the parameters of the instructional methodology of the teacher.

This paper examines the construct and the predictive validity of the instrument from the American perspective. The results will be discussed in this presentation along with the implications of teaching and learning undergraduate mathematics. (Received September 14, 2011)

1077-VA-993 **Leah Childers**, **Karla Childs*** (kchilds@pittstate.edu) and **Bobby Winters**. *How to start a discussion on your campus about assessing general education mathematics.*

Pittsburg State University called a task force to explore general education mathematics across campus. In addition, the task force was charged to develop an assessment instrument for general education mathematics. We will discuss how we engaged the campus at large, resources we found helpful, and the findings from the task force. (Received September 15, 2011)

1077-VA-1373 **Jiyoon Park*** (parkx666@umn.edu), 2920 Aldrich Ave S #239, Minneapolis, MN 55408, and **Robert delMas** (delma001@umn.edu). *Development and validation of an instrument to assess college student's statistical inference-an argument based approach to validity.* Preliminary report.

Concepts of statistical inference are often misunderstood. There has been much recent interest in developing student's inferential reasoning in statistics. However, research on how to assess students statistical inference is scarce. This study describes the development and validation of an instrument to assess college student's inferential reasoning in statistics. As validity is the most important aspect of psychological assessment, this study subsequently collects and integrates different sources of validity evidence of the instrument. Each of the sources is investigated to support validity arguments made about test score interpretations and uses. The analysis results from content expert reviews, student cognitive interviews, and pilot testing are presented. An argument-based approach to validity is used as a theoretical framework to examine strength of validity arguments supported by the different validity evidence. (Received September 19, 2011)

1077-VA-1881 **Gregory R Baker*** (baker@math.ohio-state.edu), Dept Mathematics, Ohio State University, 231 W 18th Ave, Columbus, OH 43210. *An effort to coordinate conceptual development in math and physics education for engineering undergraduate students.* Preliminary report.

There is a pressing need for students to learn and understanding how to use mathematics in physics and engineering. In particular, engineering students must be able to express ideas that arise in physics and engineering in mathematical terms and then use their problem-solving skills to understand the consequences. Based on my experiences in teaching ordinary differential equations to engineering students, students see their mathematical education as simply a vast collection of specific procedures. The question raised here is whether better coordination of the content in first-year math and physics courses could improve student ability to use math in subsequent engineering courses. If this is so, then the mathematical content used in the physics course must be documented before changes in the content in the math course can be planned. At the same time, the physics course might benefit from a better illustration of important mathematics concepts, helping students to appreciate what they need to know mathematically. This talk highlights just such a documentation of the mathematical content in a typical first-year physics course. (Received September 21, 2011)

1077-VA-1913 **Joseph E Hibdon, Jr*** (j-hibdonjr@neiu.edu), 5500 N. St. Louis, BBH-235, Chicago, IL 60625, **Melissa Yates** (m-yates@neiu.edu), 5500 N. St. Louis, BBH-235, Chicago, IL 60625, **Marilyn Saavedra-Leyva** (m-saavedra-leyva@neiu.edu), 5500 N. St. Louis, BBH-235, Chicago, IL 60625, and **Stephanie Levi** (s-levi@neiu.edu), 5500 N. St Louis, BBH-235, Chicago, IL 60625. *Strategies to Help Underrepresented and First Generation Students in the STEM Fields.*

In this paper we examine the challenges of recruiting and retaining underrepresented and first generation students in the STEM fields for a Hispanic-Serving Institution and present some of the successful solutions we have utilized. Some of the challenges we have observed are: getting the students in the STEM fields and educating the students about careers; reaching and helping the students that are not prepared for college courses in math; and finally making sure our students have the resources necessary to be successful in school and when they leave. To help our students from the time they arrive until they finish we have developed an advising center staffed by scientists. They meet with the students to discuss the classes they are taking, research and internship opportunities, graduate school, and possible career paths. The advising office has been successful in helping students conduct research, present their work at conferences, get into graduate school, and medical school. For incoming students a transition program was developed to help students needing developmental math courses. This was done by producing peer led team learning to help with course material and the transition to college. In general the students that have used these opportunities have performed better. (Received September 21, 2011)

1077-VA-1977 **Todd Moore*** (`thm7799@math.ksu.edu`). *What Calculus do students learn after Calculus?* Preliminary report.

Engineering majors and Mathematics Education majors are two groups that take the basic, core Mathematics classes. Whereas Engineering majors go on to apply this mathematics to real world situations, Mathematics Education majors apply this mathematics to deeper, abstract mathematics. Senior students from each group were interviewed about function and accumulation to examine any differences in learning between the two groups that may be tied to the use of mathematics in these different contexts. Variation between individuals was found to be greater than variation between the two groups; however, several differences between the two groups were evident. Among these were higher levels of conceptual understanding in Engineering majors as well as higher levels of confidence and willingness to try problems even when they did not necessarily know how to work them. (Received September 21, 2011)

1077-VA-2134 **Marilyn Reba** (`mreba@clemson.edu`), Department of Mathematical Sciences, Martin O-202, Clemson University, Clemson, SC 29631, **Calvin Williams** (`calvinw@clemson.edu`), Department of Mathematical Sciences, Martin O-323, Clemson University, Clemson, SC 29631, **Roy Pargas** (`teech@clemson.edu`), School of Computing, Clemson University, Clemson, SC 29631, **Allen Guest** (`aguest@clemson.edu`), Department of Mathematical Sciences, Martin 0-12, Clemson University, Clemson, SC 29631, and **Ellen Breazel*** (`ehepfer@clemson.edu`), Department of Mathematical Sciences, Martin 0-211, Clemson Univesrity, Clemson, SC 29631. *Mathematics Parterning with Computer Science to Improve Calculus Instruction and Investigate Student Learning Difficulties.*

With NSF funding, we experimented with how we teach Calculus at Clemson and how we interact with at-risk students. Increased student interaction and improved instructor presentation in Calculus have been achieved through the use of digital ink and web-based software from the Computer Science Department, and through the use of a technology classroom facilitating group work and providing multiple projections. Sharing our active-learning model and our technology with a neighboring community college initiated an online calculus course, joint-taught in real time in Fall 2011, to help at-risk transfer students. The investigation of student learning difficulties through an extensive online error-tagging project (analyzing more than 5000 pages of free- response solutions) directed the development of online interventions to remediate and focus student attention on targeted concepts outside the calculus classroom. Also, beginning in Fall 2011, a few calculus students participated in the first of four creative-inquiry modules (over four semesters) that relate mathematical concepts to biomedical applications, with the dual purpose of motivating greater interest in calculus and of monitoring online remediation and tutoring to promote successful completion of their current course. (Received September 21, 2011)

1077-VA-2538 **Justin Edward Sukiennik*** (`jsukienn@umn.edu`), MathCEP, 4 Vincent Hall, 206 Church Street S.E., Minneapolis, MN 55455. *Investigating Gender Differences in UMTYMP Entrance Exam.*

For the last thirty years, the University of Minnesota Talented Youth Mathematics Program (UMTYMP) has taught college-level Calculus to high school students. During the students' three years in the Calculus program, they learn single-variable calculus, differential equations, linear algebra, and multi-variable calculus. After completion of the program, students are usually ready to take an advance topics course, an upper-level math course in post-secondary education at the university, or other courses as new college students (after they graduate high school). In order to complete this program by the end of high school, these students in middle school take an accelerated version of regular high school courses: Algebra I & II, Geometry, and Math Analysis. Since the program is accelerated and independent studying is crucial, students who wish to entire UMTYMP must complete an entrance exam. For years, we had seen a disparity in average exam scores between females and males. In 2011, we decided to re-organize the exam in order to determine whether it is possible for this disparity to lessen. In this talk, we will investigate the disparity from past exams and look at how the disparity changes for the 2011 exam. (Received September 22, 2011)

1077-VA-2540 **Tivadar Diveki** (diveki@gcschool.org) and **Zsuzsanna Szaniszlo*** (Zsuzsanna.Szaniszlo@valpo.edu). *ABACUS International Math Challenge.*

ABACUS International Math Challenge was launched in 1997. Students from elementary and middle schools around the world are invited to submit answers to nontraditional mathematics problems through the web. Many teachers use the problems in math clubs or even in the classrooms. In this presentation we discuss how the program is run, how it can be used by teachers and how undergraduate students are involved. We also present several problems from the program together with submitted solutions. The website of the program can be found at http://www.gcschool.org/program/abacus/index.aspx (Received September 22, 2011)

1077-VA-2551 **Ali S Shaqlaih*** (ali.shaqlaih@unt.edu), University of North Texas at Dallas, Department of Mathematics and Inf. Sciences, 7400 University Hills Blvd, Dallas, TX 75241. *Another approach to Pre-service Teachers' preparation programs.*

Mathematics content knowledge is necessary for succeeding in teaching high school mathematics but of course it is not sufficient. Most of the secondary teachers' preparation programs require pre-service teachers to take many advanced mathematics courses such as real analysis and abstract Algebra; yet we see many pre-service teachers that don't understand the high school mathematics as concepts rather than as just solving problems. In this talk, I will present a research study results about the mathematics content knowledge of pre-service secondary teachers. A different approach for the teachers' preparation programs in mathematics education will be introduced based on the results of the study. (Received September 22, 2011)

1077-VA-2892 **Violeta Vasilevska*** (Violeta.Vasilevska@uvu.edu), 800 W. University Parkway, Orem, UT 84057, and **Clare Wagner**. *Math Days for Women.*

In this talk we give an overview of the outreach program "Math Days for Women." The program had been funded by TENSOR/MAA Foundation for three years in a row (2007-2010). The program targeted high school girls who enjoy math and want to have fun exploring interesting math topics, and at the same time want to learn more about women and math and careers in math. The goal of this program was to encourage high school girls to maintain an interest in succeeding in mathematics. The talk will provide information on the program: its structure, the activities undertaken during the three years, and some survey results about the impact of the program on the participants. (Received September 22, 2011)

General Session on Teaching Introductory Mathematics

1077-VB-976 **Jason A Price*** (jason.price@nichols.edu), Nichols College, 100 Center Rd, Dudley, MA 01571. *Teaching using the iPad and Air Sketch.*

Air Sketch is an iPad app that permits one to use their iPad as a white board and project it wirelessly to another computer that is on the same network. If this computer is connected to a projector one may present pdf documents and pictures, mark them up with the class and then save the result as a pdf file. I started using Air Sketch this semester and have found that it is a good tool for working through examples with a class. It allows a student to "hold the chalk" without leaving their seat. In this talk I will demonstrate how I use Air Sketch, using examples from College Algebra and Business Calculus. (Received September 15, 2011)

1077-VB-1381 **Peter T. Olszewski*** (pto2@psu.edu), 4205 College Drive, Erie, PA 16563. *Money, That's What I Want!* Preliminary report.

Recently, the mathematics department at Penn State Erie, The Behrend College, has discontinued a mathematics class for liberal arts majors called *Insights into Mathematics* and has replaced it with *The Mathematics of Money.* This course has proven to be a wonderful addition to our mathematics department. Ever since I started teaching the class, I have noticed that students who say they "can′t do mathematics" or "aren′t good at mathematics" do much better when problems have dollar signs attached to the numbers. This is more evident from the older adult learner's point of view. I believe a large part of students′ difficulty with mathematics is failing to make the connection between abstract concepts and the practical. The algebra used in this class is minimal. Students are not running around trying to hunt down the value of x without motivation, as they would be in a traditional College Algebra class. In this talk, I will present how I teach the course using various clever techniques and technologies such as the Texas Instruments Graphing Calculator, Microsoft PowerPoint presentations, and Microsoft Excel spreadsheets. (Received September 19, 2011)

1077-VB-1391 **Don Small*** (don.small@ymail.edu). *Refocusing Intermediate Algebra.*

The major goal of Introductory Algebra should be to assist students in developing their mathematical reasoning skills. A primary medium for doing this is solving realistic word problems. Mathematical reasoning is developed by emphasizing:

a. Translating word problems into mathematical models, b. Solving practical problems in a real-world context, c. Interpreting charts and graphs, d. Interpreting solutions in the context of the problem, e. Creating trend lines, f. Converting from one measurement system to another, and g. Developing a comfort level that supports mathematical exploration.

Algebraic skills are important as tools for computation, but are subordinate to modeling word problems in the development of mathematical reasoning. (Received September 19, 2011)

1077-VB-1495 **Jerry J. Chen*** (chenj@sunysuffolk.edu), 533 College Road, Selden, NY 11784, and **Myung-Chul Kim** (kimm@sunysuffolk.edu), 533 College Road, Selden, NY 11784. *Pass with CARE (Clicking Algebra-Related Education).* Preliminary report.

Algebra-related courses use the clicker teaching technique to ask good questions, combined with visual lessons. The method has proven to enhance students' success, increase conceptual understanding, and promote critical thinking in an interactive learning environment. Most students expect and enjoy learning with the clickers. (Received September 20, 2011)

1077-VB-1541 **Stefanos Orfanos*** (sorfanos@kfupm.edu.sa). *The origin of error: A study of the reasons behind common mistakes in introductory Mathematics.* Preliminary report.

We investigate one of the fundamental questions in the teaching of Mathematics: what is the origin of error. We list possible contributing factors (subject-specific, educational, societal etc.) and we formulate ways to quantify the effect of each of them. (Received September 20, 2011)

1077-VB-1681 **Carrie Muir*** (Carrie.Muir@Colorado.edu). *Minimum Academic Preparation and Performance in First Year Mathematics Courses.* Preliminary report.

The University of Colorado at Boulder has a "Minimum Academic Preparation Standard" (MAPS) for mathematics of four years of high school coursework, including at least as far as Algebra II. However, students can be, and are, admitted without having met this standard. However, all mathematics coursework offered by the campus includes prerequisites which assume the preparation standard has been met; there are no remedial or developmental courses offered.

The purpose of this study is to compare the performance in entry level mathematics coursework of students who have not met the mathematics MAPS requirement with students who have met the requirement. The different levels of high school background among students who have met the MAPS requirement will be considered. The classes which will be considered are all Fall 2009 and Fall 2010 sections of both a College Algebra course and a Quantitative Reasoning course. (Received September 20, 2011)

1077-VB-1910 **Sheldon P Gordon*** (gordonsp@farmingdale.edu). *Why Should Any Students Take Developmental Math?*

Considering (1) the horrendous success rates in developmental math courses; (2) the fact that all of these courses are intended to prepare students for calculus, something that few plan to get to and virtually none will; and (3) the fact that the client disciplines need and want a very different flavor of mathematics for their students, we need to think seriously about the question of why should any students take developmental mathematics as it is currently offered. It is possible to offer alternative courses at the algebra level that are far better matches to what students really need to get out of mathematics, that provide them with the algebraic skills that are important for the courses that they will take subsequently, that are far more interesting and motivating to almost all students, and which are intellectually stimulating and challenging. (Received September 21, 2011)

1077-VB-2025 **William O Bond*** (bond@math.uab.edu), Dept. of Math - UAB, Birmingham, AL 36294-1170, and **John C Mayer** (mayer@math.uab.edu), Dept. of Math - UAB, Birmingham, AL 35294-1170. *Improving Student Success in Developmental Algebra and Its Impact on Subsequent Mathematics Courses.*

Experiments conducted in the Fall 2009 and Fall 2010 in a developmental algebra course at UAB will be discussed. After students selected a time slot they were randomly split into the treatment groups. While all treatments shared a computer assisted instruction component in a mathematics lab, the classroom meetings differed among treatments. In Fall 2009 there were two treatments: one which had an inquiry-based meeting (involving collaborative group work) combined with computer work and another that had a lecture with computer work. In Fall 2010 the three treatments were two inquiry-based meetings, two lectures, or one each of lecture and inquiry, all with the same computer work each week. Statistical results concerning student test scores, final grades, scores on both open-ended and objective pre/post tests, and student success in subsequent mathematics courses will be presented. Factors studied influencing performance in subsequent mathematics courses include treatment, time until subsequent course taken, and nature of subsequent mathematics course. We will also present the reasons for how UAB now teaches this course based on the previously mentioned data, analysis, and student satisfaction survey. (Received September 21, 2011)

1077-VB-2048 **Jim Sobota*** (jsobota@uwlax.edu), Department of Mathematics, University of Wisconsin - La Crosse, 1725 State Street, La Crosse, WI 54601, **Karoline Auby** (kauby@uwlax.edu), Department of Mathematics, University of Wisconsin - La Crosse, 1725 State Street, La Crosse, WI 54601, and **Maighread McHugh** (mmchugh@uwlax.edu), Department of Mathematics, University of Wisconsin - La Crosse, 1725 State Street, La Crosse, WI 54601. *Growing a Learning Center: From a small, underfunded closet to a popular learning space.*

The Mathematics Department tutor facility has undergone a transition from a few tutors working in a variety of spaces including a classroom, storage area, and student dining area to a large number of tutors in a multidisciplinary Learning Center with permanent space in the University Library. The center had a limited budget for tutoring that was managed by the Department Academic Assistant for many years. Several years ago, a student funded Academic Initiative fee began to support additional tutors and a Learning Center Director. An emeritus faculty member serving on an interim basis guided the evolution of the Learning Center, which is now led by a permanent director. In this presentation, the evolution of the tutoring center will be discussed by the people involved. This will include a description of the funding initiative, the development of the center with certified tutors, a new process for selecting, interviewing, and hiring student tutors as well as a continuous improvement plan. (Received September 21, 2011)

1077-VB-2876 **Joshua Ducey*** (duceyje@jmu.edu). *Daily Quizzing as a Means of Motivating Review and Preview.*

This talk will describe the results of an experiment I performed while teaching Introductory Calculus I. The students were primarily freshmen majoring in business or the social sciences, and I found a significant percentage of them to be lacking in basic pre-calculus skills.

My purpose was to foster success by increasing the number of students who regularly (1) do homework, (2) attend class, and (3) preview the material that will be covered in lecture.

To accomplish (1) I made heavy use of the online homework program WeBWorK, which not only gives students immediate feedback but also gives the instructor very detailed information about each student's progress. To accomplish (2) and (3), very short daily quizzes were given at the start of each class. The quiz would consist of a very simple question about the content of the lecture to come, and also a simple problem testing a prerequisite pre-calculus skill (the same skill was tested for several consecutive quizzes).

Having a quiz given and a homework due *each class day* motivated the students to keep from falling behind. The online homework technology and format of the quizzes helped to keep the increased load on the instructor manageable. (Received September 22, 2011)

General Session on Calculus

1077-VC-97 **RADOSLAV DIMITRIC*** (rdimitric@juno.com), NEW YORK. *USING STUDENTS' TESTS TO IMPROVE TEACHING AND LEARNING.* Preliminary report.

Tests are used most often as an obvious assessment tool; there is more value in these tests than meets the eye however. I show, on concrete examples of calculus tests, how careful analysis of students' solutions (or the lack thereof) provides useful feedback on what concepts are objectively difficult, and how to better introduce them to the students, then possible drawbacks of instructor's approach to teaching certain concepts, as well as causes of difficulties students may have in acquiring concrete knowledge. (Received July 26, 2011)

1077-VC-529 **Denise LeGrand*** (djlegrand@ualr.edu), Mathematice Dpartment, 2801 S University Ave, Little Rock, AR 72205. *The Big 'BUT' about Blogs in Online Calculus.* Preliminary report.

Sometimes as teachers we must ask students to do things they do not like. For instance I require Blog writing in my online Calculus classes where I use writing prompts. At semester's end, every student comment received basically stated "I hated the Blogs, BUT I learned so much from writing them." I will present how blogs and discussions are used to foster deep understanding and reflection. Many students are afraid to "speak up". The solution is to provide a place where students feel safe to ask questions, interact and post their ideas. Weekly prompts in the Blogs start the student's thought process and the discussions build from those. The amazing responses incorporate historical and amusing comments and hyperlinks. The students come to realize how mathematics makes an impact on their lives and learn to think in new ways. The discussions are graded by a rubric based on quality not quantity. There is a stark difference between the students' first few posts and their mathematical explanations versus their posts at the end of the semester. One student comment reinforces this: "Writing the Blogs gave me the Blogs BUT they forced more interaction with the material. Admittedly I have a stronger grasp of the material because I had to do them." (Received September 06, 2011)

1077-VC-929 **Shannon R Lockard*** (Shannon.Lockard@bridgew.edu), Department of Mathematics & Computer Science, Hart Hall 236, Bridgewater State University, Bridgewater, MA 02325, and **Irina Seceleanu**. *Multiple Choice Versus Open Response Assessment in Calculus.*

The use of multiple choice questions is becoming more widespread in recent years as an assessment tool in Calculus; with the introduction of online homework systems in mathematics such as MyMathLab and WebAssign, it is becoming increasingly common for instructors to use multiple choice or short answer questions to assess student understanding on homework assignments. Motivated by the question of whether or not it is appropriate to use multiple choice questions on quizzes and exams in Calculus, we conducted a study to investigate the impact of multiple choice questions versus open response questions on student understanding. In this talk we will discuss initial observations of this study. (Received September 14, 2011)

1077-VC-1130 **Mark E Gruenwald** (mg3@evansville.edu), Department of Mathematics, University of Evansville, 1800 Lincoln Avenue, Evansville, IN 47722, and **David J Dwyer*** (dd4@evansville.edu), Department of Mathematics, University of Evansville, 1800 Lincoln Avenue, Evansville, IN 47722. *Resequencing Calculus: An Early Multivariate Approach.* Preliminary report.

The presenters will describe the development and implementation of a reformulated three-semester calculus sequence at the University of Evansville, constructed so that the first two semesters constitute an appropriate two-course sequence for students in the life sciences and certain other STEM disciplines. To accomplish this, the sequence and text (under development) introduce matrices and multivariate calculus in Calculus 2 and postpone infinite series until Calculus 3. Because there is a net reduction in the required content in Calculus 3, instructors are able to complete vector calculus through Stokes Theorem. As a consequence of this and the deferral of series, the difficulty level rises through the sequence, instead of peaking at Calculus 2. Moreover, the early treatment of multivariate calculus enables students who complete Calculus 2 to enter directly into courses in differential equations, calculus-based probability, or linear algebra. The presenters will discuss their approaches for dealing with multiple challenges, including those posed by course transfers and AP credit. This project is supported by NSF DUE CCLI grant #0836676. Details can be found at http://www.resequencingcalculus.com. (Received September 16, 2011)

1077-VC-1448 **Laurie Lenz*** (Laurie.Lenz@marymount.edu), 2807 N. Glebe Rd., Arlington, VA 22203, and **Jill Guerra**, **Catherine Beneteau** and **Zdenka Guadarrama**. *The POGIL project: Student-Centered Learning in Calculus.* Preliminary report.

POGIL is a student centered, guided inquiry teaching method that has been shown to increase student engagement and achievement in the classroom by having students work in self-managed teams to analyze data and draw conclusions, modeling the way a team of scientists function in the research laboratory. This talk is a report on a new NSF-funded project to develop a set of POGIL learning materials for Calculus and Pre-Calculus and to build faculty expertise within the mathematics community to implement these new materials. The talk will include a discussion of the POGIL project as well as examples of learning materials currently being tested in the classroom. (Received September 19, 2011)

1077-VC-1859 **Rebecca J. Schmitz*** (rjschmit@mtu.edu), Mathematical Sciences, Fisher Hall, Room 319, 1400 Townsend Drive, Houghton, MI 49931, and **Harvey Keynes**, 4 Vincent Hall, 206 Church Street SE, Minneapolis, MN 55455. *Student understanding and misconceptions of infinite repeating decimals in a Sequences and Series Bridge course.* Preliminary report.

This paper looks at understanding and misconceptions of infinite repeating decimals and their connections to sequences and series for students in a Sequences and Series Bridge class. We look at the influence of different instructional practices, which include conceptual discussions and related groupworks, and the role of previous coursework on student understanding. We measure pre- and post-instructional levels of understanding and examine certain demographical data for the varied backgrounds of the students in this course. FInally, we discuss Tzur and Simon's Reflection on Activity-Effect Relationships Model for student understanding and its application to and questions raised about the current study. Possible directions for additional investigations will be discussed. (Received September 21, 2011)

1077-VC-2178 **Thomas Koshy** and **Zhenguang Gao*** (zgao@framingham.edu). *Convergences of Catalan Series.*

Using Catalan properties and general solutions to first-order differential equations, we determine the convergence of the Catalan series $\sum_{n\geq 0} \frac{1}{C_n}$ and evaluate the sum. We also evaluate the sum $\sum_{n\geq 0} \frac{1}{C_n}$, where n is odd or even. (Received September 21, 2011)

1077-VC-2368 **Todd G Will*** (twill@uwlax.edu), Mathematics Department, University of Wisconsin - La Crosse, 1725 State Street, La Crosse, WI 54601, and **David Finn**. *Search for the Stokes-vergence Theorem.* Preliminary report.

Green's Theorem says that the flow around a region in the plane equals the sum of the curl over the region. We tell our students that Stokes's theorem is a generalization of Green's Theorem to surfaces in space. Green's Theorem for divergence says that the flux out of a region equals the sum of the divergence over the region. If we ask our students to predict a three dimensional generalization we might be hoping for the divergence theorem for solids, but really this seems like too much to expect. Wouldn't they more likely predict a Stokes's like divergence theorem for surfaces? We explore how a student might discover whether such a theorem exists. (Received September 22, 2011)

1077-VC-2601 **Daniel L Kern*** (dkern@fgcu.edu), Dept of Chemistry and Mathematics, Florida Gulf Coast University, 10501 FGCU Boulevard S., Fort Myers, FL 33965-6565. *Analysis of Student Achievement and Retention Regarding Online Calculus Homework.*

A comparative analysis of student retention, achievement and attitudes is made for first-year calculus students using a well-known online homework system. Limited differences in overall achievement were seen compared to a control group, though not on all individual assessments. The class with online homework had a higher retention rate, but also had a larger proportion of withdrawals close to the final deadline.

Student surveys taken at multiple points in the semester indicate a general preference for online homework in both groups, but the motivation behind the preference is unclear. Additional analyses from the surveys are also presented. (Received September 22, 2011)

1077-VC-2618 **Stephen M Walk*** (smwalk@stcloudstate.edu), Dept. of Mathematics & Statistics, ECC 139, St. Cloud State University, 720 4th Ave. S., St. Cloud, MN 56301-4498. *Reverse Mathematics and the Lost Proofs of Calc One.*

I'm thinking of four theorems. All four are interesting, useful, even *vital* for first-semester calculus. Nevertheless, for the first few semesters I taught calculus, I didn't bother to dignify those theorems with proofs in class. They seemed too obvious to need proof, and their proofs seemed too difficult to be enlightening.

Then reverse mathematics changed my mind. Reverse mathematics is a program in the foundations of mathematics that aims to determine which set-existence axioms are logically necessary to prove established theorems—such as those four. In this talk, I will describe how an encounter with reverse mathematics not only convinced me that my students should see proofs of the four theorems, but also helped me to make the proofs palatable for students. (Received September 22, 2011)

1077-VC-2636 **Karen L. Hulsebosch*** (khulsebosch@olympic.edu), Olympic College, 1600 Chester Avenue, Bremerton, WA 98337-1699, and **Paul E. Seeburger**. *Enhancing Student Learning: The Use of CalcPlot3D Graphing Technology in Developing Core Competencies in Multivariable Calculus.* Preliminary report.

CalcPlot3D is a dynamic visualization tool that can help enhance student learning of multivariable calculus. The online exploration environment allows students to create and investigate graphs of functions of two variables, contour plots, gradient vectors, and more. This talk presents the results of a two-year study focused on differences in performance and retention for underrepresented groups of students in multivariable calculus at Olympic College and the use of graphing technology to enhance student learning. The purpose of the study was to investigate whether having students complete an online CalcPlot3D Lagrange Multiplier Exploration helped certain groups of students develop core competencies. The competencies under investigation included student abilities to use technology to construct graphical representations of a model and the use of technology to investigate the effect of changing a parameter within the model. Student and instructor impressions will be shared. (Received September 22, 2011)

1077-VC-2654 **Javier Garza*** (garza@tarleton.edu), Box T-470, Department of Mathematics, Tarleton State University, Stephenville, TX 76402. *Moving Toward a More Effective Learning Environment in First Semester Calculus.* Preliminary report.

The presenter will share some of his experiences in utilizing clickers and structured learning activities to create a more engaging learning environment in the classroom; WebAssign and Mathematica to enhance student independence in learning outside of the classroom; and educational research and assessment techniques to enhance instructional effectiveness on the whole. Some formative and summative results will be shared. (Received September 22, 2011)

1077-VC-2798 **Robert D. Poodiack*** (rpoodiac@norwich.edu), Department of Mathematics, Norwich University, 158 Harmon Drive, Northfield, VT 05663. *Generalized trigonometric substitution.*

On a generalized unit circle $|x|^p + |y|^p = 1$, $p \geq 1$, we de fine generalized sine and cosine functions to represent the coordinates of points on this curve. We use these generalized trigonometric functions to expand the class of functions integrable via trigonometric substitution. We also relate the inverses of our generalized trigonometric functions to hypergeometric functions. (Received September 22, 2011)

1077-VC-2909 **Janet L Fierson*** (fierson@lasalle.edu), 100 West Ave #206W, Jenkintown, PA 19046. *Reducing anxiety and increasing interest in business calculus.*

Business calculus has been a historically difficult course, generating high numbers of withdrawals and failures. At the beginning of the semester, many students in the course identify themselves as being poor mathematics students or disliking the subject, or both. This talk will reveal approaches taken to change these opinions and to make the class a more successful, enjoyable, and valuable experience for the students involved. Topics discussed will include group work, competition, supplemental instruction, and expectations with respect to homework and student use of the textbook. Results of student surveys, as well as suggestions for improvement in future semesters, will be provided. (Received September 22, 2011)

General Session on Teaching Mathematics Beyond the Calculus Sequence

1077-VD-77 **Elana Reiser*** (ereiser@sjcny.edu), 155 W Roe Blvd, Patchogue, NY 11772. *Using a capstone course to learn how to teach mathematical proofs.*

Students in a capstone course picked a branch of mathematics and thought of a fun way to teach proofs within that subject. By challenging them to think about proofs in unorthodox ways, students have an easier time grasping this conventionally frustrating topic. Groups researched proof techniques and used this knowledge along with their own experiences to create an activity to teach proofs. Through this project, students have started to think about how to teach proofs in their future classrooms and have seen five different techniques that they might choose to use as a springboard. Hopefully this experience made them more confident and this will get a new generation of mathematicians excited about proofs. (Received July 18, 2011)

1077-VD-342 **Mark L. Daniels*** (mdaniels@math.utexas.edu), Mathematics Department, 1 University Station C1200, Austin, TX 78712. *Scaffolding for Inquiry Instruction in Mathematics.*

The author will use examples to emphasize the importance of scaffolding inquiry-based lessons in order to facilitate student progression toward higher level thinking in mathematics. (Received August 24, 2011)

1077-VD-444 **Stephen Andrilli*** (andrilli@lasalle.edu), 1900 W. Olney Avenue, Philadelphia, PA 19141. *Some Strategies for Teaching a Course Based on Douglas Hofstadter's Gödel, Escher, Bach.* Preliminary report.

Douglas Hofstadter's Pulitzer-Prize 1979 winning classic Gödel, Escher, Bach can form the core of a thought-provoking Honors course (or Senior Seminar) for motivated students with an interest in logic, mathematics and/or computer science. Having now taught such an Honors course ten times (since 1991), I will outline a successful approach to the material that has evolved over time, covering most of the text (including Hofstadter's proof of Gödel's Incompleteness Theorem) while also exploring the music of Bach, the art of Escher, the works of Lewis Carroll, and the pioneering efforts of Babbage and Turing in computer science. (Received September 01, 2011)

1077-VD-474 **Emre Tokgoz*** (Emre.Tokgoz-1@ou.edu), 601 Elm Ave., Room 423, Norman, OK 73071.
Numerical Method/Analysis Students Function Concept Knowledge.

Engineering and mathematics undergraduate students conceptual function knowledge can have important impacts on their success in conceptually more developed courses such as Numerical Methods-Analysis courses. In this building blocks of concepts, function concept requires knowledge of sub-concepts such as limit, first derivative, second derivative, and continuity. In this paper, undergraduate and graduate engineering and mathematics Numerical Methods-Analysis course students conceptual function knowledge with a calculus graphing question is observed similar to Baker, Cooley, and Trigueros (2000). The participants are asked to define what it means to have a function and explain the function definition on a given function where the responses are evaluated by using Vinner's (1992) function concept image and concept definition knowledge idea. In addition, the participants are asked to draw the graph of a function by observing limiting values, first derivative, second derivative and asymptotes of a given function. Four questions related to the function concept were asked to the participants during the interviews to observe their function knowledge in detail. (Received September 03, 2011)

1077-VD-547 **Howard I Dwyer** and **William R Green*** (wrgreen2@eiu.edu), 600 Lincoln Ave., Charleston, IL 61920. *Integrating factors and repeated roots of the characteristic equation.*

Most texts on elementary differential equations solve homogeneous constant coefficient linear equations by introducing the Characteristic equation; once the roots of the characteristic equation are known the solutions to the differential equation follow immediately, unless there is a repeated root. We show how first order methods, namely an integrating factor, can be used to find all of the solutions in the case of a repeated root without depending on an assumption about the form that these solutions will take. We also show how an integrating factor can be used to explain the "extra" power of t which appears in the trial form of the solution when using the method of undetermined coefficients on a nonhomogeneous equation in the case where the right hand side is a polynomial multiple of the corresponding homogeneous solution. (Received September 07, 2011)

1077-VD-836 **Trent Kull***, kullt@winthrop.edu, and **Heakyung Lee**. *Developing the capstone experience at Winthrop University.* Preliminary report.

The Mathematics Department at Winthrop University is currently designing a capstone experience for our senior majors, to be piloted in the Spring 2012 semester. Our University Level Competencies, department Student Learning Objectives, and assessment efforts are central to the development of our "Capstone Assessment" and "Senior Seminar" courses. With undergraduate mathematics degrees available with or without teacher certification, we are taking into account the different needs of students in each program, and fitting capstone requirements accordingly. We will discuss our past and current efforts to this specific challenge, as well as our planning processes, program goals, survey and data collection, and the inclusion of writing intensive and oral communication components to the program. (Received September 13, 2011)

1077-VD-1567 **Carl Mummert*** (mummertc@marshall.edu), Department of Mathematics, 1 John Marshall Drive, Huntington, WV 25755. *An inquiry-based, writing intensive introduction to proofs course.* Preliminary report.

This talk will describe a sophomore-level bridge course developed at Marshall University. The course incorporates several inquiry-based techniques, including reduced lecture and daily student presentations. It also meets university requirements for a writing-intensive class through the use of prose assignments including proof analyses. (Received September 20, 2011)

1077-VD-2519 **Melvin G. Royer*** (melvin.royer@indwes.edu), 4201 S Washington St, Marion, IN 46953. *Getting the Act Together.* Preliminary report.

The Mathematics Department at Indiana Wesleyan believes that our Senior Seminar students should demonstrate: (1) the ability to learn independently, (2) preparedness for their future career goals, (3) an understanding of various philosophical issues of mathematics and the role of mathematics in related disciplines, and (4) a personal worldview which coherently integrates mathematics, truth, ethics, and Christianity. Consequently, the course centers around: (1) an independent research project in mathematics or mathematics education culminating in a paper and symposium presentation, (2) a portfolio including a resume, cover letter, and graduate school and/or job application as well as a "scrapbook" of selected college assignments and registration for appropriate standardized tests, (3) class discussions and presentations centered around readings from mathematical ontology, mathematical epistemology, and the nature of the infinite, and (4) a personal philosophy paper and student-led panel discussions on the relationships between one's personal life, beliefs, abilities, academic training, and professional goals. The presentation will describe the above activities and student reaction to them as well as the role of the course in program assessment. (Received September 22, 2011)

1077-VD-2624 **Kate G McGivney*** (kgmcgi@ship.edu), 1871 Old Main Dr., Shippensburg University, Shippensburg, PA 17257. *Moving from Theory to Practice: A Lesson Plan Activity for a History of Mathematics Course.*

In this talk I will discuss a lesson plan activity that I implemented in my history of math course this past semester. Students worked in small groups to investigate a historical math topic and then created a lesson plan and accompanying materials appropriate for a middle/high school class. The project design and materials will be shared in the talk. (Received September 22, 2011)

1077-VD-2652 **Alina N. Duca*** (anduca@ncsu.edu), NC State University, Box 8205, Raleigh, NC 27695, and **Dianne Raubenheimer** and **Hatice Ozturk**. *Bridging mathematics concepts to engineering contexts: Just-in-time review modules.* Preliminary report.

The mathematical education of the engineering undergraduates essentially consists of the students assimilating a large collection of 'methods' and 'techniques' which later on in their education and profession should enable them to understand and solve advanced engineering problems. The continuous assessment process performed by the mathematics department shows that the majority of engineering students have mastered core concepts outlined by the course outcomes. However, engineering educators consistently face a two-fold 'mathematics problem'. On one hand, they are dealing with the fact that students easily forget material from one year to another and do not recognize the extent of what they have forgotten. This is further complicated by the fact that students tend to focus on the immediate assessment and often do not clearly understand, at the time they were taught, how the mathematics relates to their field of study. In this talk we present an overview of the proposed solution to this broad problem encountered across engineering disciplines. Faculty from the Mathematics Department and various Engineering Departments collaborated on integrating the relevant mathematical content into specific applied engineering contexts while students take the required engineering courses. (Received September 22, 2011)

1077-VD-2790 **Bogdan Doytchinov*** (doytchinovb@etown.edu), Elizabethtown College, Department of Mathematical Sciences, One Alpha Drive, Elizabethtown, PA 17022. *Reading and writing assignments in a Real Analysis course.*

A Real Analysis course for undergraduates introduces the students to the axioms of the real numbers, to abstract notions and to rigorous reasoning. The large amount of topics to be covered, combined with the difficulty they present for the novice, force the instructor to pack the teaching time maximally with serious theory. No time can be afforded for historical digressions, discussions about the nature and methodology of mathematics, or for reading and writing assignments "about" mathematics. In this presentation, I will talk about my attempt to defy this common sense view, and about the results of my attempt. (Received September 22, 2011)

1077-VD-2841 **Suzanne I Doree*** (doree@augsburg.edu). *Keep them guessing: teaching conjecturing in a discrete transition course.* Preliminary report.

How do we help potential mathematics majors transition from lower level, computational, courses to upper level, theoretical, courses or more open-ended experiences such as undergraduate research? Many colleges teach an intro to proofs course to try to meet this need. At Augsburg College we take a different approach, focusing our course on conjectures and counterexamples (well, and some proof). The results have been impressive, both in terms of preparing our students and for attracting more students to the major. This talk describes the overall structure of the course and shows several examples of classroom activities from discrete mathematics that develop students conjecturing skills. (Received September 22, 2011)

General Session on Statistics

1077-VE-293 **Jianfeng Zhang*** (jianfeng.zhang@chattanoogastate.edu), 4103 Dayton Blvd Apt D78, Chattanooga, TN 37415, **David Olive** (dolive@math.siu.edu), Department of Mathematics, 4408, Southern Illinois Univeristy, 1245 Lincoln Drive, Carbondale, IL 62901, and **Ping Ye** (yepi@quincy.edu), 3010 Fox Run W, Quincy, IL 62301. *A Robust Dispersion Estimator and its Applications.*

Robust estimators for multivariate location and dispersion should be $\sqrt{n}$ consistent and highly outlier resistant, but estimators that have been shown to have these properties are impractical to compute. The RMVN estimator is an easily computed outlier resistant robust $\sqrt{n}$ consistent estimator of multivariate location and dispersion, and the estimator is obtained by scaling the classical estimator applied to the RMVN subset that contains at least half of the cases. Several robust estimators will be presented, discussed and compared in detail. The applications for the RMVN estimator are numerous, and a simple method for performing robust principal component analysis

(PCA), canonical correlation analysis (CCA) and factor analysis is to apply the classical method to the RMVN subset. Two approaches for robust PCA and CCA will be introduced and compared by simulation studies. (Received August 25, 2011)

1077-VE-478 **Guy-vanie M Miakonkana*** (gmm0006@auburn.edu) and **Ashere Abebe**. *Rank-based estimation for generalized linear models.*

In this paper we consider the estimation of parameters of a generalized linear regression model. An estimator defined iteratively, starting from an initial obtained by minimizing the Wilcoxon dispersion function for independent errors, is considered.The consistency and the asymptotic normality of the initial estimator as well as the asymptotic normality of the updated estimator are proved under minimal assumptions.Like in linear model,the procedure results in estimators that are robust in the response space. We present results of a simulation study as well as real world data example to illustrate the robustness and efficiency of the estimator. (Received September 03, 2011)

1077-VE-951 **Seung-Hwan Lee*** (slee2@iwu.edu), Mathematics, Illinois Wesleyan University, PO Box 2900, Bloomington, IL 61702, and **Eun-Joo Lee** (elee@millikin.edu), Department of Mathematics, Millikin University, Decatur, IL 62522. *Life Expectancy Estimate with Bivariate Weibull Distribution using Archimedean Copula.*

Archimedean copulas are used to construct bivariate Weibull distributions. Co-movement structures of variables are analyzed through the copulas, where the tail dependence between the variables is explored with more flexibility. Based on the distance between the copula distribution and its empirical version, a copula that may best fit data is selected. With extra computing costs, the adequacy of the copula chosen is then assessed. When multiple myeloma data are considered, it is found that relationship between survival time of a patient and the hemoglobin level is well described by the Clayton copula. The bivariate Weibull distribution constructed by the copula is used to estimate value at risk from which we investigate the anticipated longest life expectancy of a patient with the disease over the treatment period. (Received September 14, 2011)

1077-VE-954 **Huybrechts Bindele*** (hfb0001@auburn.edu), 221 Parker Hall, Auburn University, AL 36849, and **Asheber Abebe** (abebeas@auburn.edu), 221 Parker Hall, Auburn University, AL 36849. *Bounded influence nonlinear signed-rank regression.*

In this paper we consider weighted generalized-signed-rank estimators of nonlinear regression coefficients. The generalization allows us to include popular estimators such as the least squares and least absolute deviations estimators but by itself does not give bounded influence estimators. Adding weights results in estimators with bounded influence function. We establish conditions needed for the consistency and asymptotic normality of the proposed estimator and discuss how weight functions can be chosen to achieve bounded influence function of the estimator. Real life examples and Monte Carlo simulation experiments demonstrate the robustness and efficiency of the proposed estimator. An example shows that the weighted signed-rank estimator can be useful to detect outliers in nonlinear regression. (Received September 14, 2011)

1077-VE-1117 **Priya Kohli*** (pkohli@stat.tamu.edu), 3143 TAMU, Department of Statistics, Texas A&M University, College Station, TX 77840, and **Mohsen Pourahmadi**. *Prediction on Random Fields with Maximum Entropy Models.*

The predictors of a stationary time series can be found by either factorizing a nonparametrically estimated spectral density (Parzen, 1984) or by fitting finite-parameter autoregressive moving average (ARMA) models to the data. A procedure based on the finite-parameter exponential spectral density (maxent density) has both the features. Its extension to the stationary spatial processes is expected to play more prominent roles. In this work, we develop a framework for forecasting such processes both in the time-and spectral-domain using recursive formulas which expresses the predictor coefficients in terms of the Fourier coefficients of the logarithm of the spectrum (Pourahmadi, 1983). A brief discussion is also provided for some of the major applications of modeling and predictions of regular homogeneous random fields, cancer detection and classification. References:

E. Parzen, Time series ARMA model identification by estimating information, Proceedings of the 15th Annual Symposium on the Interface of Computer Science and Statistics, Amsterdam: North Holland, 1984.

M. Pourahmadi, Exact factorization of the spectral density and its application to forecasting and time series analysis, Communication in Statistics-Theory and Methods, 12(18), 2085-2094, 1983.

(Received September 16, 2011)

1077-VE-1317 **Veera Holdai*** (vxholdai@salisbury.edu), Salisbury University. *Detection of slightly expressed changes in random environment.*

Consider a regular parametric family of distributions $F(\cdot\,,\theta)$. The classical change point problem deals with observations corresponding to $\theta = 0$ before a point of change, and $\theta = \mu$ after that. We substitute the latter constant μ by a set of random variables $\theta_{i\,,n}$ called a random environment assuming that $E[\theta_{i\,,n}] = \mu_n \to 0$. The random environment can be independent or obtained by random permutations of a given set. We define the rates of convergence and give the conditions under which the classical parametric change point algorithms apply. (Received September 19, 2011)

1077-VE-1422 **Barbara A. Wainwright*** (bawainwright@salisbury.edu), 1101 Camden Ave., Salisbury, MD 21801. *Teaching Statistics through the years: What works? What doesn't? What's next?*

For several years a laboratory based Statistical Thinking course has been taught at Salisbury University. The speaker will share some of the activities that are conducted in the computer lab sessions. These activities include Minitab projects, applets, and use of real data from the web. In addition, innovations to that course and how the course has evolved over the past decade will be addressed. There will be a discussion of how the addition of applets to some lab activities has affected student understanding. In conclusion, the speaker will share her opinion of what has and has not worked well in helping students acquire statistical thinking. (Received September 19, 2011)

1077-VE-2009 **Salam Md. Mahbubush Khan*** (khan@math.fsu.edu), Department of Mathematics, Alabama A&M University, 4900 Meridian Street, Normal, AL 35762. *Approximation to the Generalized Gamma Distribution.*

The generalized gamma distribution is a flexible three-parameter family of distributions. This useful distribution includes special cases all of the life time distributions. It is one of the most frequently used parametric lifetime distribution models. Here we approximate the generalized gamma distribution by using different techniques and suggested the best approximation. We also derive the standard normal approximation this 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. 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 these generalized distributions and their cumulative sums. It is also useful to obtain approximations for the generalized distributions and to know their relationship with other distributions. (Received September 21, 2011)

1077-VE-2286 **Connor Ahlbach**, **John Choi**, **Michael Orrison**, **Laura Passarelli** and **Shujing Xu*** (flora.xushujing@gmail.com). *Linear Tests of Uniformity for Data Defined on Distance Transitive Graphs.* Preliminary report.

Suppose respondents in a survey are asked to choose an element from a finite set X. If we assume their responses are governed by an underlying probability distribution P, then it is natural to wonder whether P is actually the uniform distribution defined on X. In this talk, we present the results of our study of linear tests of uniformity when X is the set of vertices of a distance transitive graph. In particular, we construct several straightforward tests of uniformity, derive formulas for their associated degrees of freedom, and run the tests on example data sets to demonstrate their usefulness. (Received September 22, 2011)

1077-VE-2346 **Krishna Kaphle*** (kkaphle@iwu.edu), **Frits H Ruymgaart** and **George Gaines**. *Estimation of eigenvalues and their multiplicities of a covariance operator.*

Covariance operators play an important role in analysis of functional data. Estimation of eigenvalues, eigenvectors and eigenprojections of a covariance operator together with the problem of testing equality of covariance operators need to be addressed. Many discussions about those issues are already in literature, however, they have got little attention when eigenvalues are not simple. We will discuss the use of differentiation of an analytic function of an operator in estimating the eigenvalues, their multiplicities, and corresponding eigenprojections of covariance operator based on a sample of functional data. (Received September 22, 2011)

1077-VE-2350 **Sumona Mondal***, smondal@clarkson.edu, and **Tina Norton**, **Sarah Andres**, **Hosana Mamata** and **Steven Foti**. *Using Linear Mixed-Effects Models to Examine Correlates of stress, anxiety, depression to find the factors affecting psychosocial attributes.*

Caffeine is the most widely used psychoactive drug in the world. One objective of this study was to see what effects, if any, caffeine consumption had on depression, state anxiety, and stress levels of Clarkson students. A

second objective was to examine the relationship between the previously listed psychosocial attributes and the participants' reported average hours of sleep and quality of rest. In Phase one of this study, cross-sectional data was collected via survey from participating students in an Introductory Psychology course at Clarkson University. Phase two of this study examined longitudinal data on sleep, caffeine consumption, and psychosocial factors over an 8 week period of time from a subset of students from Phase one. Mixed effects models were used to determine the association between predictor variables of caffeine consumption, average hours of sleep, how rested the participant felt, age of the participant, and sex of the participant, and response variables of stress, anxiety, and depression. Data analysis showed a stronger correlation with stress, anxiety, and depression for average hours of sleep or how rested the participants felt versus the amount of caffeine consumed. (Received September 22, 2011)

1077-VE-2627 **Rebecca Nichols*** (rebecca@amstat.org), 732 North Washington Street, Alexandria, VA 22314. *Census at School: An Outreach Program to Teach Statistical Problem Solving in Grades 4-12 Using Real Student Data.*

The American Statistical Association (ASA) is seeking champions for the Census at School program. In 2010, the ASA and the Population Association of America (PAA) launched the U.S. version of Census at School, a free, international classroom project that engages students in grades 4-12 in statistical problems solving using their own real data. Students involved in the program complete an online survey, analyze their class census results, and then compare those results with results from random samples of participating students in the United States and other countries. Under the direction of their teachers, students apply the concepts in the GAISE Pre-K-12 Report (www.amstat.org/education/gaise) and the Common Core State Standards (corestandards.org) by exploring problems that require them to formulate questions of interest that can be answered with the Census at School data, collect/select and analyze the data, and make appropriate conclusions in context. The Census at School project began in the United Kingdom and includes Australia, Canada, New Zealand, South Africa, Ireland, Japan, and now the United States. (Received September 22, 2011)

1077-VE-2753 **Paul R. Coe*** (coepaul@dom.edu), 7900 W. Division Street, River Forest, IL 60305. *Exact Confidence Intervals for the Ratio of Two Proportions.*

Confidence intervals for a single Binomial parameter or the difference or ratio of two Binomial parameters are usually calculated using a Normal distribution approximation. However, when the sample size is small or the observed proportion is close to 0 or 1, the Normal approximation to the Binomial is inaccurate. Several methods have been developed for dealing with this inaccuracy.

Some years ago Ajit Tamhane and I developed an algorithm for calculating exact confidence intervals for the difference, ratio, and odds ratio of two proportions. However, the algorithm is only implemented in a usable form for the difference of two proportions. Recently I have created a usable implementation of the algorithm for the ratio of two proportions. In this paper I will talk about the algorithm for calculating exact confidence intervals for the difference and ratio of two proportions, and then I will present the new implementation of the algorithm for the ratio. (Received September 22, 2011)

1077-VE-2947 **Mehdi Razzaghi*** (razzaghi@bloomu.edu), Dept of Mathematics, Bloomsburg University, Bloomsburg, PA 17815. *Using Mixed Distributions to Model Count Data with Application.*

Mixed distributions have for a long time been used in statistics for modeling. Here, we consider some of these distributions that have particular applications in toxicology. Specifically, we discuss the applications of the Poisson-Gamma, Poisson-Lindley, and Poisson-negative binomial distributions. We show how they can be applied to model count processes in developmental toxicology. We will comapre and contrast the models. (Received September 23, 2011)

1077-VE-2948 **Christopher J Lacke*** (lacke@rowan.edu), 521 Crafton Ave., Pitman, NJ 08071. *Introducing The Idea of Fitting a Distribution to Data in a Probability Course.* Preliminary report.

Many students in a variety of disciplines are required to take a calculus-based course in probability without having to take a mathematical statistics course or a second course in data analysis. As a consequence, the concept of goodness-of-fit is foreign to many students. In this talk, I will demonstrate an activity I use in my probability class to use summary statistics, graphs, and the properties of various discrete and continuous probability distributions to help them determine which distributions are reasonable models for a data set. (Received September 23, 2011)

General Session on History and Philosophy of Mathematics

1077-VF-375 **Leslie Bolinger-Horton, Ed.D.*** (Lhorton@qcc.mass.edu), Mathematics Department, Quinsigamond Community College, 670 West Boylston Street, Worcester, MA 01606, and **Regina M. Panasuk, Ph.D** (regina_panasuk@uml.edu), Graduate School of Education, 61 Wilder Street, O'Leary 526, Lowell, MA 01854. *Raising Awareness of the History of Mathematics in High School Curriculum.*

This article describes a portion of a large scale study which investigated the issues related to the integration of the history of mathematics into high school mathematics instruction. We argue that while the community of mathematics educators puts forth efforts to implement curriculum reform in school mathematics, an explicit discussion of the importance of the inclusion of the history of mathematics is missing from the conversation. There exists a gap between what is espoused in the professional and scholarly arena regarding possible benefits of students learning the history of mathematics and teachers' perceptions of the use of the history of mathematics in curriculum. This paper is focused on the analysis and the comparison of two philosophical positions about the nature of mathematics and mathematics education held by teachers, fallibilist and absolutist, and how these positions affect teachers' decision to integrate the history of mathematics into their classroom. (Received August 28, 2011)

1077-VF-1263 **Sean F Argyle*** (sargyle1@kent.edu), OH. *Mathematical Thinking: Can we ever agree on a definition? A conceptual meta-analysis.* Preliminary report.

Various educational standards have demanded that teachers improve students' "mathematical thinking," but definitions are vague - if present at all. What little research on the subject exists is disjointed and dissenting, leading some researchers to lament the possibility of ever coming to an agreement on how to define "mathematical thinking" as a viable construct. How then can we properly educate the next generation in "mathematical thinking"? Rather than add one more voice into the cacophony of competing definitions, this presentation seeks to discuss the early results of a meta-analysis of the term's use in an appropriately titled journal - Mathematical Thinking and Learning. (Received September 18, 2011)

1077-VF-2076 **Todd H. Moore** (thm7799@math.ksu.edu), Dept. of Math, Kansas State University, 138 Cardwell Hall, Manhattan, KS 66506, **Andrew G. Bennett*** (bennett@math.ksu.edu), Dept. of Math, Kansas State University, 138 Cardwell Hall, Manhattan, KS 66506, and **Carlos W. Castillo-Garsow** (cwcg@math.ksu.edu), Dept. of Math, Kansas State University, 138 Cardwell Hall, Manhattan, KS 66506. *History of Computation as a Professional Development Course for Middle School Teachers.* Preliminary report.

We have offered a two-week intensive (3.5 hours/day) summer course in History of Computation targeted at middle school teachers. The course discusses the development of different representations of numbers and multiplication and division algorithms, false position, logarithms and slide rules, abacuses, and other topics. We connect these topics to proportional reasoning, introductory algebra, and other aspects of the common core standards for the middle school curriculum. Reaction from teachers has been very favorable. (Received September 21, 2011)

1077-VF-2181 **Jacqueline M. Dewar*** (jdewar@lmu.edu), Department of Mathematics, Loyola Marymount University, Los Angeles, 90045, and **Lily S. Khadjavi** and **Alissa S. Crans**. *Using the History of Women in Mathematics to Address Gender Equity and Prepare Future Teachers.*

This talk will describe the content and outcomes of an interdisciplinary course on Women and Mathematics. The course uses the lives and contributions of women mathematicians throughout history to engage students in mathematical topics related to the work of these women, and to address gender equity issues from kindergarten to doctoral level experiences in mathematics education and in mathematics-related careers. Common themes emerge from examining the lives and work of women mathematicians past, which are still relevant today. We will address how the course encourages students, some of whom are future K-12 teachers, to adopt a more expert view of mathematics as a study of patterns (rather than of numbers), provides them with an opportunity to do math in a supportive environment, and prepares them to discuss the current national situation regarding women's ability and participation in mathematics. The future teachers learn about role models for women doing mathematics, gain knowledge of equitable classroom practices, and resolve to incorporate these into their teaching. A TENSOR-MAA Women and Mathematics grant supported a team-teaching effort by the course originator to mentor two other faculty teaching this course. (Received September 21, 2011)

1077-VF-2530 **David S Richeson*** (richesod@dickinson.edu), Department of Mathematics and Comp Sci, Dickinson College, Carlisle, PA 17013. *Geometric constructions using a finite compass and a finite straightedge.*

We answer the following question: given a straightedge of length L, a compass that opens to a maximum radius R, and a unit interval, what is the set of constructible lengths? We also give a brief overview of the history of geometric constructions using a restricted tool-kit, e.g., rusty compass, compass-only, and straightedge-only constructions. (Received September 22, 2011)

1077-VF-2626 **Paul R. Bialek*** (pbialek@tiu.edu), Department of Mathematics, 2065 Half Day Road, Deerfield, IL 60015. *Best Web sites for the history of mathematics.* Preliminary report.

The World Wide Web has hundreds of sites related to the history of mathematics. I will survey the Web sites which I believe are most helpful or interesting. (Received September 22, 2011)

General Session on Modeling and Applications of Mathematics

1077-VG-304 **Laura K. Gross*** (laura.gross@bridgew.edu), Department of Mathematics & Computer Science, Hart Hall Room 228, Bridgewater State University, Bridgewater, MA 02325, and **Yi Yang** and **Jun Yu**. *Linear instability in a combustion problem.*

We describe the propagation of a reaction such as solid combustion, explosive solidification, and certain other exothermic phenomena using a simple conceptual model. In the model, a system of heat equations in the reacted and unreacted regions is subject to boundary conditions, including a nonlinear kinetic condition posed at the reaction front. The system supports steady propagation in certain parameter regimes. We present a linear analysis for the loss of stability in a one-dimensional problem. We show how the stability threshold depends on the disparities between material parameters in the reacted and unreacted regions. (Received August 19, 2011)

1077-VG-473 **Franziska Hinkelmann**, **Matt Oremland**, **Hussein Al-Asadi**, **Atsya Kumano**, **Laurel Ohm*** (ohm@stolaf.edu), **Alice Toms** and **Reinhard Laubenbacher**. *Methods for Reducing and Transforming Agent-Based Models into Polynomial Dynamical Systems.*

Discrete models, including agent-based models, are important tools for modeling biological systems, but model complexity may hinder complete analysis. Representation as a polynomial dynamical system (PDS) provides a framework for efficient analysis using theory from abstract algebra. In this manuscript, we provide general polynomials that describe common agent interactions as well as methods to reduce the complexity of the model while preserving key system dynamics. These methods lay the foundation for model translation. Algebraic tools are used in the construction of polynomials as well as in the reduction of the model. We demonstrate the feasibility of our methods by translating a complex agent-based model of the human innate immune response system (approximately 11,000 agents) into PDS of lesser complexity that we were able to simulate. We hope to eventually be able to apply optimal control to the resulting PDS. (Received September 03, 2011)

1077-VG-527 **Adam F Childers*** (childers@roanoke.edu), 221 College Lane, Salem, VA 24153. *Connections between bounded error parameter identification and confidence ellipsoids.* Preliminary report.

In this presentation we will investigate the connections between membership sets generated by bounded error parameter identification and confidence ellipsoids. The assumptions and computational time necessary to generate confidence ellipsoids are modest but they can conceal information about the estimated parameter that can be seen by using bounded error parameter identification. We will determine what types of problems are most appropriate for each type of parameter validation technique and the implications of parameters that are not contained in both sets. (Received September 06, 2011)

1077-VG-650 **Dr. Sushil Kumar*** (sushilk@ashd.svnit.ac.in), Applied Mathematics and Humanities Department, S.V.N. I. T Suart, Surat, 395007, India. *Study on freezing in cylindrical domain with convective cooling and energy generation.* Preliminary report.

In the present study, a heat transfer study is carried out to study the effect of volumetric heat generation on the freezing in a cylindrical domain. Finite difference method is used to solve the enthalpy formulation of the freezing process. It is found that an increase in heat generation slows down the freezing process for the given convective cooling. (Received September 09, 2011)

1077-VG-689 **Biyue Liu*** (bliu@monmouth.edu), Department of Mathematics, Monmouth University, West Long Branch, NJ. *Non-Newtonian Effects on the Blood Pressure Drop in Atherosclerotic Right Coronary Arteries.*

Atherosclerosis is a leading cause of mortality in the western countries. The initiation and progression of atherosclerotic plaques involve complex interactions between the blood flow and the vessel wall. It is believed that the blood pressure is one of the important factors affecting the atherosclerosis development and progression. We will examine the effects of the non-Newtonian blood viscosity on the blood pressure drop along the wall of a stenotic human right coronary artery segment by computer simulations. The numerical calculations are performed using the Newtonian Model and the non-Newtonian models with the fluid obeying the Power Law and the Carreau models for the simulations of unsteady blood flows. The differences on the spatial and temporal blood pressure drop patterns due to the different blood properties will be presented and compared. (Received September 10, 2011)

1077-VG-806 **Delong Meng*** (delong13@mit.edu), 290 Massachusetts Ave, Cambridge, MA 02139. *Learning in three multi-player auctions.*

We show that the first price-, second price-, and all pay auction all converge to their respective Bayesian-Nash equilibria under the fictitious play model given by Ellison and Fudenberg.

The basic idea of our model is as follows. A finite number of players participate in an infinitely repeated auction in which an identical object is sold at every stage (in discrete time). A player's valuation of the object changes in each stage, but it follows a fixed probability distribution. In every stage a player assumes that her opponents follow a weighted mean of their past strategies, and she evaluates her expected chance of winning accordingly, which enables her to calculate the bid that maximizes her expected payoff. The process repeats ad infinitum.

Our result provides a theoretical complement to the empirical study done by Kagel et al., who observed Nash equilibria in the first- and second price auction in their experiments.

(Note: this project is done under the supervision of Prof. Glenn Ellison from MIT's Department of Economics.) (Received September 13, 2011)

1077-VG-947 **Kevin Coltin*** (kcoltin@asu.edu). *Markov and Itō Representations of Option Price Models.* Preliminary report.

I evaluate existing models for pricing financial options quantitatively according to criteria such as computational efficiency, robustness to departures from normality, and ability to model assets with stochastic volatility and a stochastic interest rate. I present new variations on existing models that attempt to improve on some of their deficiencies, and then evaluate them according to the same criteria. In particular, I approach the problem of modeling assets by treating asset prices as a Markov chain defined by a circulant transition matrix, and attempt to make the models able to accurately account for harmonic behavior in prices. (Received September 14, 2011)

1077-VG-1039 **Brenae L. Bailey*** (bbailey@math.arizona.edu), Program in Applied Mathematics, University of Arizona, PO Box 210089, Tucson, AZ 85721-0089. *Stochastic Modeling of Ribosomal Frameshifting.*

Many viruses can produce different proteins from the same RNA sequence by encoding them in overlapping genes. One mechanism that causes the ribosomes of infected cells to decode both genes is called programmed ribosomal frameshifting (PRF). Although PRF has been recognized for 25 years, the mechanism is not well understood. We have developed a model that treats RNA translation as a stochastic process in which the transition probabilities are based on the free energies of local molecular interactions. The model reproduces observed translation rates and frameshift efficiencies, and can be used to predict the effects of mutations in the viral RNA sequence on the frameshift efficiency. (Received September 15, 2011)

1077-VG-1098 **Kenneth H Luther*** (ken.luther@valpo.edu), 1900 Chapel Drive, Department of Math & CS, Valparaiso, IN 46383. *A Boundary Value Problem for a Doublet.*

In mathematical models involving of a flux or velocity vector field, we often solve problems by developing a scalar potential function whose gradient is that vector field, and casting known conditions in terms of the potential function. A doublet (or dipole) is a recurring character in electromagnetism and fluid dynamics models whose potential function can be derived by allowing a point source and point sink to approach each other in a limiting process, and this is often the way that potential function is derived. It is rarer to see the potential function for a doublet derived as the solution to a boundary value problem. We will show a boundary value problem whose solution is the potential function for a two-dimensional doublet, and solve it using two different methods. (Received September 16, 2011)

1077-VG-1131 **Brittany E. Bannish*** (bannish@math.utah.edu), **James P. Keener** and **Aaron L. Fogelson**. *The effect of thrombin activatable fibrinolysis inhibitor (TAFI) in a multiscale mathematical model of fibrinolysis.*

The degradation of blood clots is a tightly regulated process. If the mesh of fibrin fibers securing the clot degrades too slowly, thrombi can form, leading to heart attack or stroke. If the fibrin degrades too quickly, excessive bleeding may occur. We study fibrinolysis (the degradation of fibrin by the main fibrinolytic enzyme, plasmin) using a 3-dimensional multiscale mathematical model. This talk will focus on the effect of thrombin activatable fibrinolysis inhibitor (TAFI) on the degradation of single fibers and whole clots. We use both stochastic and deterministic methods to model the various lytic processes. (Received September 16, 2011)

1077-VG-1195 **Andrew Kirby*** (ackirby@wisc.edu), **Analise Rodenberg** (alsrodenberg@gmail.com), **Andrew Bernstein** (asbernstein@gmail.com) and **Adrian McLean** (amclean9@broncos.uncfsu.edu). *Development of an Ozone Inhalation Model.* Preliminary report.

The goal of this project was to develop a mathematical dosimetry model that simulates the inhalation and deposition of ozone through the respiratory tract. The model is based upon a transport-diffusion partial differential equation which describes the flow of ozone through the respiratory tract and the diffusion of ozone in the air. The dosimetry model also encompasses the flux of ozone into the tissue giving total concentrations of ozone deposited in the lung. The model was solved using the Crank-Nicolson implicit scheme. Within our model, we split the domain into multiple compartments which mimic the different generations of the lungs. This required conservation of mass to be incorporated. The results generated by the dosimetry model were then linked with data regarding neurons called C-fi bers, which are located in the bottom of the lungs. When exposed to ozone, C-fi bers react and cause physiological changes such as frequency and depth of breathing. These are results of the body trying to counter the harmful effects of ozone inhalation. Incorporating this aspect to the inhalation model helps depict a more realistic cycle of ozone uptake. (Received September 17, 2011)

1077-VG-1208 **Kun Gou*** (kunjuzi@yahoo.com), Department of Mathematics, Mail Stop 3368, Texas A&M University, College Station, TX 77843. *Estimating the stiffness of healthy arteries via multi-dimensional secant method.*

An inverse spectral technique via multi-dimensional secant method is developed for recovering the shear modulus expressing the stiffness of soft tissue. The research is motivated by a novel use of the intravascular ultrasound technique to image arteries. Shear modulus is approximated to reflect the variation of stiffness of the arterial wall along the radial direction. The arterial wall is idealized as a nonlinear isotropic cylindrical hyperelastic body. First, boundary value problems are formulated for the response of the arterial wall within a specific class of static deformations by steady blood pressures. Then another category of boundary value problems is developed from intravascular ultrasound interrogation generating small amplitude, high frequency time harmonic vibration superimposed on the static finite deformations via an asymptotic construction of the solutions. This leads to a system of second order ordinary differential equations known as Sturm-Liouville problems, which are then employed to reconstruct the shear modulus in a nonlinear approach by an inverse spectral technique through multi-dimensional secant method. (Received September 18, 2011)

1077-VG-1455 **Avner Friedman** and **Najat Ziyadi*** (najat.ziyadi@morgan.edu), 1700 East Cold Spring Lane, Baltimore, MD 21251, and **Khalid Boushaba**. *A mathematical model of drug resistance with infection by health care workers.*

Antibiotic resistant organisms (ARO) pose an increasing serious threat in hospitals. One of the most life threatening antibiotic resistant organisms (ARO) is methicillin-resistant staphylococcus aureus (MRSA). In this talk, we will introduce a mathematical model which focuses on the evolution of two bacterial strains, drug-resistant and non-drug resistant, residing within the population of patients and health care workers in a hospital and we will discuss the results of the model predictions. (Received September 19, 2011)

1077-VG-1558 **He Huang*** (hh06c@fsu.edu), 208 Love Building, 1017 Academic Way, Tallahassee, FL 32306. *Point process models for order arrival rates in order book dynamics.* Preliminary report.

We use bivariate mutually-exciting Hawkes' point processes to model the high-frequency dynamics of the limit order book. We discuss the goodness-of-fit by QQ-plots and obtain several quantities of interest, such as the probability that the mid-price increases/decreases at its next move and the probability that an order is executed before the mid-price moves by simulating the best fitted models. (Received September 20, 2011)

1077-VG-1691 **Qiang Du**, **Lili Ju** and **Li Tian*** (tian@math.psu.edu), 217 McAllister, Penn State University, State College, PA 16802, and **Kun Zhou**.
A Posteriori Error Analysis of Finite Element Method for Linear Nonlocal Diffusion and Peridynamic Models.

In this paper, we present some results on a posteriori error analysis of finite element methods for solving linear nonlocal diffusion and bond-based peridynamic models. In particular, we aim to propose a general abstract frame work for a posteriori error analysis of the peridynamic problems. A posteriori error estimators are consequently prompted, and the connection between non-local a posteriori error estimation and classical local estimation is studied. Numerical experiments are also given to test the theoretical conclusions. (Received September 20, 2011)

1077-VG-1722 **Jared Barber***, 301 Thackeray Hall, University of Pittsburgh, Pittsburgh, PA 15260, and **Mark Tronzo**, **Gilles Clermont**, **Yoram Vodovotz** and **Ivan Yotov**. *A three-dimensional mathematical and computational model of necrotizing enterocolitis.* Preliminary report.

Necrotizing enterocolitis is a severe inflammatory disease in premature infants that is characterized by injured regions in the intestinal wall. The disease affects 7-10% of all very low birth weight premature infants and is associated with high mortality and morbidity rates. The dynamics of the disease depend upon a complex interplay between the immune system, intestinal bacteria, and cells lining the intestine. We use a three-dimensional computational model to examine this complex interplay and its dependence on the spatial structure of the intestine. The model consists of a system of transient partial differential equations that are solved numerically using cell-centered finite differences and an explicit Euler method. The model is used to track the evolution of an initial injured area of prescribed size and shape in the intestinal wall. The model produces pathophysiologically realistic results; decreasing the initial severity of the injury and introducing breast feeding to the system lead to healthier simulations. In addition, changing the initial shape of the injured area can significantly alter the overall outcome of a simulation. This finding suggests that the spatial details associated with an injury may be important in assessing the outcome for a given NEC patient. (Received September 20, 2011)

1077-VG-1799 **Ron Buckmire*** (ron@oxy.edu), Fowler Hall, Office 313, Occidental College, 1600 Campus Road, Los Angeles, CA 90041, and **Jacob Ortega-Gingrich** and **David Edwards**. *A Mathematical Investigation of the Financial Performance of Movie Sequels.*

The Edwards-Buckmire Model (EBM) is a mathematical model which utilizes a system of three nonlinear coupled ordinary differential equations to successfully model the box-office dynamics of films released theatrically in North America. In this paper we examine the financial performance of film sequels in the context of the existing EBM. We hope to find relationships between the financial performances of original (parent) films and their sequels, particularly in how the former may affect the latter. The ultimate goal is to develop accurate *a priori* predictions of the financial performance of future sequels using a modified version of the EBM. A preliminary report on the progress towards various problems which arise in attempting to mathematically investigate cinematic box-office dynamics will be given. (Received September 21, 2011)

1077-VG-1951 **Joe Latulippe*** (jlatulip@norwich.edu), Mathematics Department, Norwich University, 158 Harmon Dr., Northfield, VT 05663, and **Randy Sierra**. *Modeling Wrist Oscillations Using Perturbation Methods.* Preliminary report.

Wrist dislocations often occur from the tearing of ligaments in the wrist. In order for the wrist to heal, surgery is often performed. During the postoperative healing process the repaired ligament will stretch causing the range of motion of the wrist to vary with time. To better understand the recovery process, a mathematical model that treats the wrist as an oscillator is developed. A corresponding weakly nonlinear differential equation is investigated using perturbation methods. To find a leading order approximation, a multiple scales procedure is used. Under different parameter regimes, the model predicts different recovery scenarios. (Received September 21, 2011)

1077-VG-1988 **Catherine Rose O'Doherty*** (codohert@mail.umw.edu). *Exploration of Stable Distributions.*

We explore stable distributions, noting their occurrence with Cauchy and normal distributions. We examine how stable distributions can be used to model local real estate markets within Virginia. (Received September 21, 2011)

1077-VG-2061 **Zachary M Harrison*** (zharris1@asu.edu), 5135 E. Evergreen St. Unit 1215, Mesa, AZ 85205, and **Peter Derek Bradshaw**. *A Generalization of Contour Advection with Surgery for Three Dimensional Flows.* Preliminary report.

In this talk, I will present a new algorithm based on Contour Advection with Surgery (CAS) for analyzing flow fields in three dimensional space. CAS is a Lagrangian method that simulates the evolution in time of selected contours that are stirred by a moving fluid. This method is excellent for resolving small scale structures that develop in these contours, even when the velocity fields used for advection are finitely resolved. This adaptive method is based on constantly refining a given contour by adding new nodes or particles to the contour or removing old nodes depending on the local curvature of the contour. The main result revealed in this presentation is the generalization of this method to three dimensions. For this purpose, a new algorithm using a new interpolation scheme was developed to maintain the high resolution of the contours based on the continuity of curvature in three dimensions. I will first show how this new computational method works, then I will give examples of applications of this method in an ideal flow and in a real atmospheric flow. (Received September 22, 2011)

1077-VG-2082 **Ardith El-Kareh**, **Leslie Jones*** (lbjones@ut.edu) and **Timothy Secomb**. *An improved mathematical model for dose-response of anticancer drug combinations at fixed schedule.*

Mathematical models to describe cellular dose-response surfaces for drug combinations are an essential component of computational simulations to predict therapeutic response, and are needed as null reference models for synergy tests. The optimal form is unclear, as no systematic comparison across a large sampling of cell lines and drugs has been performed. Here, a number of literature data sets for the case of fixed schedule are considered. The additive damage model is proposed as a generalization of previous damage models, in which survival depends not directly on extracellular concentration but on a quantity denoted cellular damage, a function of the peak concentration of the critical target-bound or metabolite cellular drug species. If cellular damage exceeds a threshold, the cell dies. The key assumption of additive damage is that damage for a combination is a linear superposition of terms for each drug as a single agent. We present the additive damage model and results from comparison to existing models. Generalization to three or more drugs is given. (Received September 21, 2011)

1077-VG-2156 **Erik Lewis*** (elewis@math.ucla.edu) and **George Mohler**. *A Nonparametric Expectation Maximization Algorithm for Multiscale Hawkes Processes.*

Estimating the conditional intensity of a self-exciting point process can be difficult, especially when both exogenous and endogenous effects play a role in clustering. Improving on an expectation-maximization type algorithm propsed by Marsan and Lengline, we employ maximum penalized likelihood estimation to simultaneously estimate the background rate and the triggering density of Hawkes process intensities that vary over multiple time scales. We numerically investigate convergence rates of our algorithm for known examples and then use the model to examine self-excitation in Iraq IED event patterns. (Received September 21, 2011)

1077-VG-2157 **Tim Lai*** (tim.lai@asu.edu). *Lagrangian Transport Patterns for Radioactive Particles after Fukushima.* Preliminary report.

Using data from the Weather Research and Forecasting Model (WRF), which uses real atmospheric data, we analyze Lagrangian transport of inertial particles of different sizes across the Pacific Ocean after the Fukushima disaster. The results allowed us to identify and distinguish features that control transport patterns, known as Lagrangian Coherent Structures for inertial, radio-active particles. We have studied the Lagrangian Coherent Structures associated with realistic aerosols and have found that the evolution of the particles′ trajectories depend on their sizes in a predictable fashion. (Received September 21, 2011)

1077-VG-2158 **Chris G. Wake*** (cgwake@asu.edu). *Skeletons of Lagrangian Transport in Hurricane Katrina.* Preliminary report.

Forecasts for atmospheric hazards are best generated by high resolution regional atmospheric models such as the Weather Research and Forecasting system (WRF). In this talk, we discuss the modeling of Hurricane Katrina using real data from WRF. This data allows the use of Lagrangian analysis on the hurricane, locating Lagrangian Coherent Structures (LCS) which characterize particle motion within the flow. LCS are revealed with Finite Time Lyapunov Exponents. The Lagrangian skeleton of the flow is then outlined by locating the ridges of maximum FTLE value. (Received September 21, 2011)

1077-VG-2162 **Rachel Anne Hegemann*** (Rachel.a.hegemann@gmail.com), **Erik Lewis** and **Andrea L. Bertozzi**. *Inferring gang affiliation for violent events with incomplete data.*

Data sets are often plagued with portions of missing or incomplete data. In this case, the data are assumed to be associated with one of N self-exciting point processes. This creates a network of processes such that each edge is associated with an independent self-exciting point process. The time and geographical location for all events are known, however the process affiliation is not known for some events. Previous work successfully used clustering in time resulting from the self-excitation to maximize the weights of the unknown events for each process. However, the authors assumed that the parameters of the process were known. Further, the maximization of the weights can be computationally costly. This work proposes a novel iterative method with a directly calculable score function assigning appropriate weights for process affiliation and approximating the crucial parameters needed to approximate the underlying point process. After testing this method on simulated data, it is applied to data on gang violence obtained from the LAPD. Gang violence perpetrated against rivals and the subsequent retaliations has been successfully described by self-exciting point processes and therefore fits ideally into this mathematical framework. (Received September 21, 2011)

1077-VG-2241 **Rebecca M Vandiver*** (vandiver@stolaf.edu). *The Mechanical Stability of Growing Arteries.*

In many cylindrical structures in biology, residual stress fields are created through differential growth. In particular, if the outer and inner layers of a cylinder grow at different rates, parts of the cylinder will be in a state of axial compression and other parts will be in tension. These tissue tensions play a fundamental role in the overall rigidity and stability of the cylinder. In this talk I will discuss the possible role of axial residual stress in regulating stress in arteries and preventing buckling instabilities. It is shown that axial residual stress lowers the critical internal pressure leading to buckling and that a reduction of axial loading may lead to a buckling instability which may eventually lead to arterial tortuousity. (Received September 21, 2011)

1077-VG-2510 **Eric P Choate***, echoate@nps.edu. *Laser propagation in biaxial liquid crystal polymers.*

We examine the propagation of a laser beam through a liquid crystal polymer (LCP) layer using the finite-difference time-domain (FDTD) method. Anchoring conditions on two supporting glass plates induce an orientational sturcture in the LCP between the plates. This orientation can deflect energy away from the direction of propagation of the incident beam when the optical axis or major director of a uniaxial medium is neither parallel nor orthogonal to the incident beam. The maximum energy deflection occurs when the angle between the indicent beam and the major director of the orientation is 45 degrees, but for spatially uniform orientations, polarization orthogonal to the plane containing the major director and the propagation direction is unaffected. We investigate how to overcome this by twisting the anchoring aligment on the plates with respect to each other to generate a helical structure in the orientation across the gap. We also examine the difference between the commonly used Leslie-Ericksen theory for the LCP, which assumes a uniaxial orientation, and the more general Doi-Marrucci-Greco orientation tensor model, which allows for both biaxial structures and oblate defect phases. (Received September 22, 2011)

1077-VG-2617 **Edmond Nadler*** (nadler@alum.mit.edu) and **Tae-wan Kim**. *Singularity of Cubic Bézier Curves and Surfaces.*

Parametric cubic polynomial curves and surfaces are useful in applications, being of relatively low dimension, and yet, flexible in their shape. To use these curves and surfaces fully, one must completely understand the cases of singularity. A parametric curve is singular where its derivative is zero, and a parametric surface, where its normal vector is zero.

These singularities are described here in terms of the Bézier form, a representation of parametric polynomial curves and surfaces employing the Bernstein polynomials as basis functions, in which the coefficients have geometric significance. Bézier curves and surfaces, which are used extensively in computer graphics, computer-aided design, and related fields, were first developed in the 1950s and 60s in the French automobile industry. (Received September 22, 2011)

1077-VG-2661 **Lee R Gibson*** (mathdoctorg@gmail.com), KY , and **Mary E Bradley** (mebrad01@gwise.louisville.edu). *Cannibals and Mosquitos: Using a predator-prey epidemic model to search for a Dengue fever reservoir.* Preliminary report.

Rudolf and Antonovics (2007) combined classical epidemic and predator-prey models to demonstrate the critical importance of the number of individuals feeding on a single carcass to the spread of a disease within a cannibalistic population. Mosquito larvae engage in a similar behavior, scavenging of conspecifics, which may play a key role in determining whether mosquitos may act as a reservoir for Dengue fever between human outbreaks. But if too many larvae partake of a single carcass, disease transmission may actually decrease. We will discuss a new ODE model involving this non-monotonically density dependent transmission rate, with some preliminary results. (Received September 22, 2011)

1077-VG-2815 **Janine M. Haugh*** (jhaugh@unca.edu), 1 University Heights, CPO #2350, Asheville, NC 28804. *Modeling Articular Cartilage Regeneration: A Phenomenological Approach.* Preliminary report.

Each year, millions of Americans suffer from joint pain due to cartilage damage caused by trauma, injury, or diseases such as osteoarthritis. Articular cartilage, which lines the surface of bones in joints such as the hips and knees, is regulated by cells called chondrocytes and has a limited ability to repair itself. One possible solution for cartilage repair that has been studied in recent years is the use of nutrient-rich scaffolds seeded with these chondrocytes. In this study, dynamic phenomenological models for cartilage regeneration will be examined. These models capture the "linking" of the major components of the extracellular matrix, collagen and glycosaminoglycan, during regeneration and the effects different scaffolds have on this process. (Received September 22, 2011)

1077-VG-2918 **Emek Kose***, ekose@smcm.edu. *Computational Sensors As Mathematical Models.*

We investigate various problems in imaging and introduce computational sensors to address the problems. These systems are described by a set of ODEs or PDEs, whose numerical solutions yield the resulting sensors. (Received September 23, 2011)

General Session on Interdisciplinary Topics in Mathematics

1077-VH-657 **Colleen Duffy*** (duffycm@uwec.edu). *A course on pre-Hispanic Latin American mathematical ideas.* Preliminary report.

A professor from Latin American Studies (LAS) and I co-teach a general education mathematics (Introduction to Mathematical Thinking)/LAS major course. The course discusses mathematics and mathematical ideas used by the Inca, Maya, and Nazca, their historical and cultural contexts, and how they relate to mathematics today. I will give an overview of the course as well as reflect on the students' reactions and course content. (Received September 09, 2011)

1077-VH-1396 **C. A. Marx*** (cmarx@uci.edu), Department of Mathematics, Univ. of California, Irvine, Irvine, CA 92697-3875. *On the intersection spectrum conjecture.*

Consider a quasi-periodic Schrödinger operator with analytic potential and Diophantine frequency α. We show that up to sets of zero Lebesgue measure, the essential support of the absolutely continuous spectrum can be obtained asymptotically from the intersection spectrum of the periodic operators associated with rational approximations of α. The result is a joint work with S. Jitomirskaya. (Received September 19, 2011)

1077-VH-1708 **Marshall A Whittlesey*** (mwhittle@csusm.edu), Department of Mathematics - CSUSM, 333 South Twin Oaks Valley Road, San Marcos, CA 92078. *A course in spherical geometry and its applications for math majors.* Preliminary report.

Spherical geometry is a subject that gets much less attention in high school and collegiate education now than it did 50 or 100 years ago. In this talk I will scan a number of traditional theorems of spherical geometry - some of which are well-known and some of which are not. Then I will discuss some of the interesting applications in other fields: astronomy, plate tectonics and crystallography. While the subject material is something all mathematicians should know something about, I believe this subject as a course works very well for students who are not going on to graduate school - e.g., for those who may be considering a career in high school teaching. For such students, a broad knowledge of applications of mathematics may be just as important as a knowledge of modern mathematics. I will also illustrate how there are opportunities in studying spherical geometry to motivate some of the ideas of more modern abstract mathematics. (Received September 20, 2011)

1077-VH-1711 **Candace Ohm*** (cao07c@fsu.edu), 1816 Meriadoc, Tallahassee, FL 32303. *The mechanisms behind the evolution of cooperation.*

In this talk, I will give a brief overview of dynamical models of the evolution of cooperation. Among mechanisms that drive cooperation in nature are kin selection, direct reciprocity, indirect reciprocity, group formation, and network formation. I will explain these mechanisms and describe some current models of them. (Received September 20, 2011)

1077-VH-1789 **Jeffrey Remmel** and **Alex Brik*** (abrik@math.ucsd.edu), Department of Mathematics, University of California, San Diego, 9500 Gilman Drive # 0112, La Jolla, CA 92093-0112. *Computing Stable Models of Logic Programs Using Metropolis Type Algorithms.*

The talk will describe a novel Monte Carlo type algorithm, which we call the Metropolized Forward Chaining (MFC) algorithm to find a stable model of a normal propositional logic program P if P has a stable model or to find a maximal subprogram P0 of P and a stable model M0 of P0 if P does not have a stable model. Our algorithm combines the forward chaining algorithm of Marek, Nerode, and Remmel with the Metropolis-Hastings algorithm of Metropolis et al. and Hastings. To demonstrate the feasibility of MFC we conducted computer experiments on logic programs to find (2, 6) van der Waerden's certificates. Logic programming with stable model semantics is a formalism for declarative programming that is well suited for solving search problems. In it a problem is modeled as a theory in some formal language, and solutions to the problem correspond to the stable models of the theory. Thus the talk combines the results of research from logic, computer science, probability theory and combinatorics. MFC can also be used with other Monte Carlo algorithms. A version of MFC that uses Stochastic Approximation Monte Carlo algorithm of Liang et al. is discussed. (Received September 20, 2011)

1077-VH-1962 **Eva Czabarka**, **Peter Erdos**, **Virginia Johnson*** (johnsonv@mailbox.sc.edu), **Anne Kupczok** and **Laszlo Szekely**. *Asymptotically normal distribution of some tree families relevant for phylogenetics.*

P.L. Erdős and L.A. Székely gave a bijection between leaf-labeled trees and partitions. This, together with the asymptotic normality of the Stirling numbers of the second kind (L.H. Harper) translates to the asymptotic normality of rooted leaf-labeled trees with fixed number of vertices (and varying number of leaves). We extend these results to obtain asymptotic normality of certain categories of phylogenetic trees. (Received September 21, 2011)

1077-VH-2024 **Mohamed Allali*** (allali@chapman.edu), 545 W. Palm Ave, Von Neuman Hall, Orange, CA 92866. *Mathematics in Computed Tomography.* Preliminary report.

In this talk, I will show through the medical imaging technique of computed tomography (CT) how we can incorporate a practical and interesting problem into mathematics courses. This approach makes the courses more visual and interesting for instructors and students. (Received September 21, 2011)

1077-VH-2319 **Gerald Kobylski*** (Gerald.Kobylski@usma.edu) and **Hilary DeRemigio Fletcher** (Hilary.Fletcher@usma.edu). *Creating an Institutional Interdisciplinary Culture with Mathematicians at the Lead.*

Recently our institution's leadership asked faculty leaders, including several mathematicians, to study how our academic program could become more interdisciplinary. We are seeking to integrate our curriculum in more meaningful ways and expose our students to large-scale interdisciplinary issues. Our national leaders have declared energy management an important issue for the future. As educators, we have a responsibility and a wonderful opportunity to introduce our students to this issue and to use it in our learning model to develop them as better interdisciplinary problem solvers who are able to think both critically and creatively. In this effort students will study energy science and policy using modules and case studies that will allow them to recognize and appreciate diverse perspectives on complex situations. They will employ an interdisciplinary approach to understanding the challenges and consequences of energy science. During this session we will briefly discuss our interdisciplinary planning process and then focus on how mathematics will play a leading role in this challenging but very exciting endeavor. We will discuss several modeling and calculus examples that address energy issues and that will play a significant role in this institutional effort. (Received September 22, 2011)

1077-VH-2415 **Emma Previato***, Department of Mathematics and Statistics, Boston University, Boston, MA 02215-2411. *Boston University Students' Interdisciplinary Activities.*

The BU MAA Chapter was founded by the speaker in the late 1980s. Attracting students to professional mathematics activities was a challenge: what worked was an interdisciplinary approach. Students discovered geometry through origami and tessellations, modular arithmetic and number theory through music, projective geometry through Renaissance painting and satellite imaging; they researched relations between literature and logic (through the concept of paradox), religion and geometry (through the concept of infinity), juggling and graph theory; they researched the cultural significance of positional number systems through "finger counting" and the Quipu; they designed Geodesic Domes based on other regular polygons than used by R. Buckminster Fuller. This talk will focus on the social activities that showcased such projects: the Math Masterclasses and the annual symposium Without Number: Mathematics and Culture, as well as the application process which secured funding, both internal and external to Boston University. At the end, open questions about interdisciplinary undergraduate research and institutional funding policies will be posed. (Received September 22, 2011)

1077-VH-2851 **Urmi Ghosh-Dastidar*** (ughosh-dastidar@citytech.cuny.edu), **Margaret Cozzens**, **Steven Lora** and **Alma Cabral-Reynoso**. *A Study of Hudson Food Web and its Competition Graph.* Preliminary report.

Food web analysis provides important information regarding the nature of competition among species. In this paper we use a graph theory approach to develop digraphs, competition graphs and weighted competition graphs to analyze relationships of competition among various Hudson River species. Investigation of this food web based on species richness, connectance, and links per species showed strong negative correlation between the change in normalized connectance and number of links lost. Loss of poorly connected species (i.e. species that have relatively fewer links to the other species in the food web) results in positive change in connectance. The loss of highly connected species results in a negative change in the normalized connectance. Furthermore an analysis of Laplacian eigenvalues showed connectivitymarsh > connectivityfreshwater shallows > connectivitybrackish > connectivityfreshwaterchannel. Partitions are also obtained based on spectral clustering to separate each competition graph in two separate groups such that the edges between these two groups have very low weights and the edges within the same group have high weights. (Received September 22, 2011)

1077-VH-2882 **Falko Ziebert** and **Sumanth Swaminathan*** (sovereign620@gmail.com), 3513 N Sheffield Ave, Chicago, IL 60657, and **Igor Aronson**. *Model for self-polarization and motility of keratocyte fragments.*

Computational modeling of cell motility on substrates is a formidable challenge; regulatory pathways are intertwined and forces that influence cell motion are not fully quantified. Additional challenges arise from the need to describe a moving deformable cell boundary. Here, we present a simple mathematical model coupling cell shape dynamics, treated by the phase field approach, to a vector field describing the mean orientation (polarization) of the actin filament network. The model successfully reproduces the primary phenomenology of cell motility: discontinuous onset of motion, diversity of cell shapes, and shape oscillations. The results are in qualitative agreement with recent experiments on motility of keratocyte cells and cell fragments. The asymmetry of the shapes is captured to a large extent in this simple model, which may prove useful for the interpretation of experiments. (Received September 22, 2011)

General Session on Mathematics and Technology

1077-VI-43 **Jay Lawrence Schiffman*** (schiffman@rowan.edu), 201 Mullica Hill Road, Glassboro, NJ 08028-1701. *Exploring Graph Theory Utilizing The OEIS, Wolfram Alpha, and Mathworld.* Preliminary report.

The On-Line Encyclopedia of Integer Sequences and the websites Mathworld and Wolfram Alpha will be utilized together with MATHEMATICA 8.0 as we journey through a subset of the catalogue of graphs (depicted by isomorphism classes)of small order that are featured in the index of Frank Harary's classic textbook Graph Theory. Among the integer sequences discussed are the number of distinct isomorphism classes for undirected graphs of small order as well as those which are connected together with the number of simple trees on a small number of vertices. Snap shots taken from Mathematica, MathWorld, and Wolfram Alpha will be illustrated to present a detailed analysis of the graphs and trees discussed. Our enhanced technology enables one to explore a world of possibilities and can serve as motivation and enrichment for students and faculty partaking of courses in discrete mathematics and graph theory. (Received July 01, 2011)

1077-VI-164 **Carla A Romney*** (romney@bu.edu), **Juan Pedro Paniagua** (jpp@bu.edu) and **Fabian Torrres-Ardila** (fatorres@bu.edu). *Increasing Student Engagement in Undergraduate Mathematics with Tablet PCs.*

Tablet PCs have unique characteristics that make them effective tools to bolster student participation in math classes. A tablet PC uses a stylus so an instructor can write directly on slides during a class session. This real-time writing allows students to participate in the mathematical concept development process since they can watch the lecture unfold before their eyes. Lecture notes and practice problems can be projected on a screen and students can work on their own tablet PCs if the classroom is networked. Student work can be shared via projection to stimulate class discussion. Students' active participation in problem-solving promotes collaboration and moves them away from their roles as passive receptors of information. Further, tablet PC-facilitated participation gives the instructor real-time feedback about students' understanding of the material and provides opportunities to address any difficulties or misconceptions that may impede progress.

We have assessed the impact of using networked tablet PCs to teach introductory mathematics to freshmen who are prospective STEM majors. Students in the tablet PC courses demonstrated increased class engagement, as measured by attendance and website use. STEM retention also improved for students in the tablet PC classes. (Received August 04, 2011)

1077-VI-199 **Ellen M Ziliak***, eziliak@ben.edu. *Clickers in the Calculus II Classroom.* Preliminary report.

One of the issues with the Calculus II course is that students come to my class with misunderstandings of the goal of the course. They think that our goal is to teach them how to be a good calculator, rather than to be individuals who can go into the world and be good problem solvers. Part of this misconception stems from the fact that the material in this course tends to be taught differently than the other two courses in the Calculus sequence. Often Calculus II tends to be the course that picks up the remaining material that did not fit in to Calculus I. I want my students to learn in my class a useful way to apply their mathematical knowledge to the types of problems they will face in their everyday lives, and previous studies have shown that Clicker questions are a way to do this. The goal of this talk is to discuss my preliminary results of using my Clicker Questions in an attempt to motivate my students to gain a deeper understanding of the concepts covered in a Calculus II course. (Received August 11, 2011)

1077-VI-273 **Timothy Hall*** (info@pqic.com), P. O. Box 425616, Cambridge, MA 02142-0012. *A Nomograph For The Trigonometric Functions.*

In the early part of the twentieth century, engineering sciences conscripted the seventeenth-century inventions of Napier/Gunter logarithm scales and the Oughtred slide rule to produce a stratagem that simplified complicated floating-point multiplication and division tasks, and could be used to calculate trigonometric functions. Reliance on electronic-based calculators quickly replaced the skill needed to effectively use a slide rule, with the beguiling promise of "highly precise results" (in contexts where, more often than not, such precision was completely unjustified).

This paper presents a nomograph for the trigonometric functions that represents a return to the limited, but arbitrary, precision capabilities of the slide rule. The nomograph is a two-dimensional, hand-held, graphical calculation artifice that allows a user to quickly, easily, and simultaneously calculate twelve different trigonometric function values by finding the intersection of two straight lines that meet at right angles.

The nomograph may also be physically implemented as depicted in this paper in digital logic hardware as an Embedded Calculation Microprocessor Subsystem for arbitrarily-precise trigonometric calculation results. (Received August 17, 2011)

1077-VI-756 **Alexander Y Vaninsky*** (avaninsky@hostos.cuny.edu), 500 Grand Concourse, Room B-409, Mathematics Department, Hostos CC, CUNY, Bronx, NY 10451. *Neuro Mathematics Education and Technology.*

Teaching and learning mathematics may be viewed as an interactive process of creation of specific domains in the human brains. The domains act later as mathematics knowledge centers. Learning mathematics may be regarded as a development of connections among them and other centers. We refer to this approach as Neuro Mathematics Education (NME) and focus on the role of technology. The NME approach paves the way for development of original teaching tools, strategies, and techniques. In particular, it stresses the principal importance of elimination of mathematics anxiety - the main barrier for success in mathematics. Among the new tools for teaching mathematics are active development of mathematical intuition, using hypnopedia and hypnosis, and instruction delivery in the multifaceted interactive environment, to name a few. The goal of the NME is the creation of a confident mental environment for perception and storage of mathematical information: concepts, notions, rules, techniques, etc. We present evidence that using technology contributes to the implementation of the NME in practice and has a positive impact on perception of mathematics and its applications. (Received September 12, 2011)

1077-VI-999 **Steven D. Wallace*** (steven.wallace@maconstate.edu), 100 College Station Drive, Mathematics Department, Macon, GA 31206. *Time management and student success using the computer-based instructional system Aleks.* Preliminary report.

"Aleks" is an artificial intelligence based instructional system which uses periodic assessments to dynamically assign the course objectives at a pace that is specific to each student. Although research has shown that a learner-centered evironment yields high student success and retention rates, there are exceptions to the positive correlation between the completion of the topics in Aleks and student success. A student must answer an algorithmically generated problem type correctly three times in a row before moving on to the next topic so the onus is on the student herself to learn the material in a timely fashion. In this talk we will show that poor time management and procrastination are main reasons why students who complete the objectives still fail to pass the corresponding exams. Instructors must coach their students in the discipline and study habits required to conteract this phenomenon. We will present data collected from several hybridized College Algebra and Precalculus courses at Macon State College. (Received September 15, 2011)

1077-VI-1043 **Barbara E. Reynolds** (breynolds@stritch.edu), Dept. of Mathematics & Computer Science, Cardinal Stritch University, 6801 N. Yates Road, Milwaukee, WI 53217, and **William E. Fenton*** (wfenton@bellarmine.edu), College of Arts & Sciences, Bellarmine University, 2001 Newburg Road, Louisville, KY 40205. *Exploratory Activities for College Geometry.* Preliminary report.

This talk will demonstrate a sequence of related activities using dynamic geometry software that allows students to develop an intuitive foundation for the geometric concept of power of a point with respect to a circle and to discover alternative definitions for this concept. This leads naturally to the radical axis of two circles. We also will discuss our students' reactions to this style of learning.

These activities come from the newly revised edition of College Geometry Using The Geometer's Sketchpad, a textbook that emphasizes exploration and discovery. Each chapter begins with computer-based activities that introduce the concepts. Building on this foundation, the discussion presents terminology, notation, and important theorems. The chapter then closes with exercises to assess the students' understanding. (Received September 15, 2011)

1077-VI-1127 **Philip B. Yasskin*** (yasskin@math.tamu.edu), Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77845-3368, and **Douglas B. Meade** (meade@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *Building Intuition and Computational Skills with Maplets for Calculus.*

Many calculus courses incorporate a computer lab component using Maple, Mathematica or Matlab. Unfortunately much of the time is spent learning how to program rather than learning calculus. It would be much better if the time were spent on activities which enhance the learning of calculus. Several schools are now using the Maplets for Calculus (M4C) in their labs to build intuition and computational skills which are reinforced by weekly quizzes. The M4C is an electronic study guide that consists of 129 applets which present algorithmically-generated problems, require correct intermediate responses before moving on to the next step, employ computer algebra to analyze student responses and provide customized hints and feedback. Algebraic, graphic (2D, 3D, animation and stereo), numeric and verbal approaches support diverse learning styles. Instructors comment that the intuitive introduction to limits, derivatives and integrals in lab makes it easier to introduce these concepts in class and frequently use the applet graphics as lecture demonstrations. They also like the interactions that arise when students in a lab have different versions of similar problems. Initial assessment of M4C's effectiveness shows that students prefer M4C over a computer algebra or numeric system. (Received September 17, 2011)

1077-VI-1337 **Shay Fuchs*** (s.fuchs@utoronto.ca). *Calculus Video Clips.*

In the last few years, we have created several video clips, on topics covered by our first year calculus courses. Each clip is 12-15 minutes long. In each of the videos, the relevant concepts and ideas are being reviewed, and then two or three examples are being discussed and solved. The videos use high quality electronic slides, often accompanied by graphs, diagrams and/or animations. The videos are not attached to a specific calculus course or to a textbook, and therefore can be used in almost any first year calculus course, and by any college or university. A list of practice problems with answers is available at the end of each clip. In my presentation, I will talk about the rational behind the clips and the tools we used to create them. We will watch parts of the videos to demonstrate their main features.
(Received September 19, 2011)

1077-VI-1620 **Brian Katz*** (briankatz@augustana.edu) and **Elizabeth Thoren**. *Wiki Technology Supporting Learning (II).* Preliminary report.

A growing body of evidence is showing that blended courses (those having both in person and online components) offer advantages over traditional classroom-based courses by providing opportunities for asynchronous, collaborative writing. We have been blending some of our courses by using wiki technology to support the students in creating a hyper-linked reference text, which we are calling a WikiTextbook.

We believe that this activity helps students build a deeper and more connected understanding of the material while transforming the flow of feedback in the course. We also believe that a WikiTextbook can mitigate some of the extra challenges posed by inquiry-based course design. We will share some of our experiences using wikis in a variety of courses from an Honors Calculus III class at a large university to Modern Geometry at a small college. (Received September 20, 2011)

1077-VI-1622 **Elizabeth Thoren***, ethoren@math.ucsb.edu, and **Brian Katz**, briankatz@augustana.edu. *Wiki Technology Supporting Learning (I).* Preliminary report.

A growing body of evidence is showing that blended courses (those having both in person and online components) offer advantages over traditional classroom-based courses by providing opportunities for asynchronous, collaborative writing. We have been blending some of our courses by using wiki technology to support the students in creating a hyper-linked reference text, which we are calling a WikiTextbook.

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1077-VI-1652 **Daniel Kiteck*** (`daniel.kiteck@indwes.du`). *Virtual Pin Board Pinterest.com Motivating Gen Ed Group Project and Connecting Math Majors.* Preliminary report.

Pinterest.com is a relatively new website where one can "pin" or display their favorite images from the internet. Since I excitedly created a "board" named "Mathematics," I wondered if I could somehow allow interesting math images to motivate a group project in a gen-ed "math for liberal arts" class. I further wondered if math majors could be further connected socially in a mathematically motivated way if enticed with a little extra credit if they create their own "Mathematics" boards.

In this presentation, I will share my first experience experimenting with both of these ideas. (Received September 20, 2011)

1077-VI-1955 **Eric Thornburg***, Department of Mathematical Sciences, Thayer Hall, West Point, NY 10996, and **Benjamin Hung** and **John Jackson**. *Learning with the iPad: Does this technology help or hinder student understanding?*

Traditionally, technological advancements in the classroom have been restricted to computational aids like the graphing calculator or computer algebra system. The iPad provides an outlet like no other in terms of integrating the entire student experience in the classroom: computing, text referencing, note taking and the ease of sharing information and communicating between classmates and the instructor. In this presentation, we share our observations and insights on teaching an introductory college mathematics course using the iPad. In particular, we address how we implemented particular iPad applications to allow the student to: (1) use the course text as an electronic reference; (2) take course notes; (3) exchange information in and out of the classroom; and (4) organize their learning. (Received September 21, 2011)

1077-VI-2059 **Robert Talbert*** (`talbertr@gvsu.edu`), Grand Valley State University, Department of Mathematics, MAK A-2-178, 1 Campus Drive, Allendale, MI 49401-649. *Making proofs click: Classroom response systems in transition-to-proof courses.*

Transition-to-proof courses, designed to prepare students from calculus and other lower-level courses for the methodology of upper-level mathematics, are often difficult for students in several ways. Students who are used to purely algorithmic approaches to mathematics experience culture shock at the more open-ended and uncertain mathematical world that such courses introduce. The elements of communication and writing often play a much larger role in these courses than in earlier ones. And generally, these courses signal a major change in the way students conceive of the study of mathematics, which can make further study of mathematics stressfully forbidding.

Technology can help students make this transition. In particular, classroom response systems, or "clickers", open up the classroom to a range of pedagogical approaches that can help students learn mathematical abstraction and good mathematical writing practice. In this talk, we discuss some instances of clicker-enabled pedagogy in the author's Communicating in Mathematics class, including peer instruction, informal quizzing, and peer review of writing samples as forms of formative assessment. (Received September 21, 2011)

1077-VI-2406 **Jason Samuels*** (jsamuels@bmcc.cuny.edu). *An Innovative Approach to Derivative Instruction Using Technology to Explore Local Straightness.*

Many students taking calculus for the first time are perplexed by the use of limits and the role of infinity in developing the derivative. As a result, they implement symbolic procedures with no understanding. I will present an approach to first semester calculus instruction which allows students to build on previous knowledge of rate and slope. In this approach, the derivative is introduced by focusing on its essential geometric property, local straightness. I have designed a mathlet to help students discover the derivative in this context. This novel sequence of instruction begins with guided discovery and leads to techniques of differentiation and the familiar symbolic definition using limits. The presentation will include a summary of the approach from the initial intuitive introduction to the extension to formal techniques, a demonstration of the mathlet, and examples of student learning. (Received September 22, 2011)

1077-VI-2534 **Nathan C Carter*** (ncarter@bentley.edu), Bentley University, 175 Forest St., Waltham, MA 02452, and **Kenneth G Monks**. Lurch*, a free math word processor that can check your work.*

Lurch is a free math word processor that aims to check the steps of students' work, from simple arithmetic to complex proofs. Unlike the computational software most of us are familiar with, *Lurch* does no work on the student's behalf, but instead provides frequent and immediate feedback on each step of mathematical work the student includes in a document. This talk will showcase the vast improvements in the software's capabilities (particularly the user interface) over the past year, discuss where the project is going next, and show its potential for transforming the way students learn from homework. Supported in part by NSF DUE grant #0736644. (Received September 22, 2011)

1077-VI-2620 **Michelle DeDeo***, mdedeo@unf.edu. *A Decade of Improving Pass Rates in Mathematics using Interactive Software.*

In 2001, my paper entitled Improving Pass Rates in Mathematics using Interactive Software was published in Selected Papers from the Twelfth National Conference on College Teaching and Learning. This paper gave a positive assessment of the use of software as a component in the teaching of College Algebra. It supported the idea that interactive mathematics software promotes increased retention and success for students in College Algebra courses and that those students were engaged in learning both at school and at home.

Not only has this initial data been confirmed over the past decade, one system proved to be more successful, more flexible, and a better fit than the others that were tested. This talk updates those results and discusses the continued success.

We will evaluate a decade's worth of study, present student and instructor feedback, and compare how well the students performed in sections that utilized software versus: (1) those instructors who made use of the system optional, (2) those who used another system, and (3) those that did not use any system at all. (Received September 22, 2011)

1077-VI-2641 **Heba Bakr Khoshaim*** (hkhoshaim@gmail.com), 366 Richland Ave., Apt. # 5118, Athens, OH 45701. *Perspectives on the Use of Dynamic Mathematical Software in Classrooms.* Preliminary report.

The call for integrating mathematical software in collegiate mathematics started more than 20 years ago. However, recent research has shown that academic mathematicians' opinions are divided when it comes to using software in classrooms. Some mathematicians argue that the use of software will hinder students' thinking, although others believe that it will improve it. Still other collegiate mathematics instructors take a balanced view and argue that technology has both benefits and limitations, and that those who teach have to be aware and considerate of both. The purpose of the presented study is to explore academic mathematicians' dispositions toward software use in teaching. Qualitative interviews have been conducted with 11 mathematicians who are currently teaching undergraduate courses in the U.S. This session will present the findings of this qualitative investigation, which will inform a second phase in a dissertation study that will address mathematicians' dispositions on a larger scale. (Received September 22, 2011)

1077-VI-2670 **Thomas E Leathrum*** (leathrum@jsu.edu). *Mobile Mathlets with Google Web Toolkit.* Preliminary report.

Google Web Toolkit (GWT) is a programming platform which compiles Java source code to JavaScript output, in particular output which (unlike standard Java) runs on mobile devices like tablets and smart phones. Available libraries for GWT provide significant compatibility with legacy Java libraries. This presentation will report on an ongoing project to port a set of approximately 50 legacy Java math applets ("mathlets") to GWT. As part of this project, the author has written a set of GWT libraries which facilitate writing new math visualization applets in GWT. The presentation will include future directions for disseminating some of the techniques and libraries used in this project. (Received September 22, 2011)

1077-VI-2725 **Aldo R. Maldonado*** (aldo.maldonado@gmail.com), 15300 Cadoz Dr, Austin, TX 78728. *Teaching mathematics online, is it even possible?*

Many old timers and some not so old timers believe that online teaching and learning is not as effective as traditional face-to-face mathematics teaching and learning. What does the evidence say? I will emphasize the biggest difficulties online teachers and online students face and their possible solutions. Some tried and proved strategies for online teaching will be offered. (Received September 22, 2011)

1077-VI-2779 **Terrence R Blackman*** (tblackman@mec.cuny.edu), 1365 E 99th St, Brooklyn, NY 11236. *An assessment of the use of an Interactive Electronic Text on student engagement and learning in Pre-Calculus and Calculus at Medgar Evers College, CUNY.* Preliminary report.

The author offers a preliminary report on the challenges and opportunities of integrating the MathLynx text in Pre-calculus and Calculus section at Medgar Evers College, CUNY. Two questions are explored: Do these tools have the potential to positively affect student engagement in the classroom? To what extent do these tools aid in the long term development of a deep conceptual understanding of mathematics? The analysis, primarily based on observations and on interviews with the students, will focus on students' perceptions of this mode of teaching and learning and its potential impact on their success in mathematics. (Received September 22, 2011)

1077-VI-2817 **Arthur J Rosenthal*** (arosenthal@salemstate.edu), Salem State University, 352 Lafayette St., Math Dept., Salem, MA 01970-5353. *Using Octave (a freeware version of Matlab) to generate close calls for Fermat's last theorem.* Preliminary report.

This talk will demonstrate how a program written in Octave (a freeware version of Matlab) can be used to generate natural numbers $n > 2$, a, b and c such that $\mathrm{fl}(a^n + b^n) = \mathrm{fl}(c^n)$, where $\mathrm{fl}(x)$ is the floating-point representation of x on a computer. Although Fermat's Last Theorem has been proven by Wiles to show that there are no natural number solutions for $n > 2$, a, b and c such that $a^n + b^n = c^n$, this Octave program shows there are many "close calls" such as the example $\mathrm{fl}(18494^5 + 33025^5) = \mathrm{fl}(33381^5)$ on a TI-84 graphing calculator. This talk will also discuss the conjecture that for any $\epsilon > 0$ and natural number $n > 2$, there exist natural numbers a, b and c such that $|a^n + b^n - c^n|/c^n < \epsilon$. (Received September 22, 2011)

1077-VI-2847 **Beth Cory*** (bcory@shsu.edu), Huntsville, TX 77340, and **Ken W. Smith**, Huntsville, TX 77340. *Using Dynamic Sketches to Help Calculus Students Develop and Integrate Coherent Mental Models of the Formal Definition of the Limit of a Sequence.*

The purpose of this research was to investigate the understanding of calculus students as they explored the formal epsilon-N definition of the limit of a sequence using interactive, dynamic sketches which embodied the formal definition. According to Theory of Multimedia Learning put forth by R.E. Mayer, learners construct two mental models as they learn a new concept: a visual model and a verbal model. A crucial step in learning occurs when students map elements of one model onto the other to create an integrated model. This presentation includes a demonstration of the sketches, created using The Geometers Sketchpad, and focuses on how the sketches and supporting activities were used to help calculus students develop an integrated model of the formal definition. Results indicated that the ability to manipulate the visual features of a sketch corresponding to key aspects of the verbal definition, in response to careful guidance, likely facilitated the processing necessary for students to develop coherent visual models of the definition and to connect it to formal symbolism. After developing their visual models in this way, many calculus students were able to construct a coherent symbolic definition on their own. (Received September 22, 2011)

1077-VI-2932 **Kimberly Arp*** (kim.arp@cabrini.edu), 610 King of Prussia Rd, Radnor, PA 19087, and **Ellen Panofsky**, 610 King of Prussia Rd, Radnor, PA 19087. *Motion Sensor Activities for Middle School Algebra.*

Too often algebra concepts seem abstract to middle school students. Combining graphing calculators with motion sensors can help bring life to these concepts. With funds provided by a Dolciani Mathematics Enrichment Grant and matching funds through the College, we were able to purchase TI-73 graphing calculators and Vernier Motion Sensors for Eisenhower Science and Technology Leadership Academy in Norristown, PA. Over the summer we provided hands on training for the teachers and our college students during a one day workshop. In this talk, we will share several of the activities and the feedback we received. (Received September 23, 2011)

General Session on Research in Pure Mathematics

1077-VJ-369 **Stephen Lovett*** (stephen.lovett@wheaton.edu). *Sequences preserving GCD, Cyclotomic Polynomials, and Iterated Polynomials.*

In almost all algebra texts define cyclotomic polynomials in reference to the primitive n'th roots of unity. However, as we will show, the property that $\gcd(x^n-1, x^m-1) = x^{\gcd(m,n)}-1$ is sufficient to uniquely define the cyclotomic polynomials. In this talk, we present a factorization property about sequences that preserve the greatest common divisor. We illustrate the property with sequences already known to possess this property and present some new sequences. As applications, we show how one can define cyclotomic polynomials without reference to roots of unity. Then we generalize the concept of cyclotomic polynomials to iterated polynomials and present a connection with discrete dynamical systems of polynomial functions. (Received August 26, 2011)

1077-VJ-450 **George A Anastassiou** (ganastss@memphis.edu), University of Memphis, Memphis, TN 38152, and **Razvan A Mezei*** (rmezei@lander.edu), Department of Mathematics and Computing, Lander University, 320 Stanley Avenue, Greenwood, SC 29649. *Quantitative Approximation by Fractional Smooth General Singular Operators.*

In this article we study the fractional smooth general singular integral operators on the real line, regarding their convergence to the unit operator with fractional rates in the uniform norm. The related established inequalities involve the higher order moduli of smoothness of the associated right and left Caputo fractional derivatives of the engaged function. Furthermore we produce a fractional Voronovskaya type result giving the fractional asymptotic expansion of the basic error of our approximation.

We finish with applications to fractional trigonometric singular integral operators. Our operators are not in general positive. (Received September 01, 2011)

1077-VJ-479 **Jonathan Weisbrod*** (weisbrodj1@verizon.net). *Examining the Dynamical Systems of Various Polynomials over Finite Fields Using Mathematica.*

Using Wolfram Mathemtica 8.0, we will examine various dynamical system maps for various polynomials modulo n. Using the program, we can quickly determine any points of interest (periodic, strictly preperiodic, or fixed points) and display the orbit, period, and preimageso of any point in any finite polynomial dynamical system. Our results produce many patterns and sequences we can use for further analysis. (Received September 03, 2011)

1077-VJ-552 **Jay R. Stine*** (jstine@misericordia.edu). *Creating Separation in Topological Spaces.*

We give an explicit description of three functors L_0, L_1, and L_2 which create T_0, T_1, and T_2 (resp.) spaces from a given topological space. These functors have equivalent alternative formulations in certain special cases, which we mention. Finally we employ these new T_i spaces to manufacture spaces with other separation properties. (Received September 12, 2011)

1077-VJ-553 **Steven J. Tedford*** (stedford@misericordia.edu). *The Characteristic Polynomial for Bi-Rooted Trees.*

Developed in the 1980's, the characteristic polynomial for rooted graphs and rooted digraphs is defined using a recursive procedure with edge deletions and edge contractions. We extend this polynomial to bi-rooted trees and give a non-recursive characterization of the characteristic polynomial for these trees. (Received September 07, 2011)

1077-VJ-601 **Karen Shen*** (shenk@stanford.edu), PO Box 12502, Stanford, CA 94309, and **Olivia Beckwith** and **Steven J Miller**. *Distribution of Eigenvalues of Weighted, Structured Matrix Ensembles.*

The study of the distribution of eigenvalues of large random matrices has many applications (nuclear physics, number theory). Previous work has determined the limiting spectral measures for many matrix ensembles, famously the semicircle for the real symmetric matrices, but also more structured ensembles such as the Toeplitz and circulant matrices. We introduce a parameter p to continuously interpolate between such structured ensembles and the real symmetric ensemble by multiplying each entry by $\epsilon_{ij} = \epsilon_{ji} = \pm 1$ where $p = \mathbb{P}(\epsilon_{ij} = 1)$. For $p = 1/2$, we prove the limiting measure is the semicircle. For all other p, we prove the measure has unbounded support. The proofs are by Markov's Method of Moments where the moment analysis involves analyzing pairings of vertices on a circle. We prove that the contribution of each pairing is weighted by a factor depending on p and m, the number of vertices in crossing pairs. The number of pairings with no crossings ($m = 0$) is well-known as the Catalan numbers; we discover and prove similar formulas for $m = 4, 6, 8$ and 10 and find closed-form expressions for the expected value and variance. As the variance converges to 4, these results yield significant information about the limiting measure. (Received September 08, 2011)

1077-VJ-636 **Michael Cap Khoury*** (mjkhoury@umich.edu) and **Steven J Miller**. *On the Limiting Distribution of Eigenvalues of Large Random d-Regular Graphs with Weighted Edges.*

Random matrix ensembles model many phenomena, from nuclear energy levels to L-function zeros. The idea is to generate NxN matrices from some nice distribution and look at their spectra. For large N, the behavior of the eigenvalues of a typical matrix is close to the ensemble average. McKay determined the limiting spectral measure for adjacency matrices of d-regular graphs. While the family of real symmetric matrices has the semi-circle as its limiting spectral measure, new distributions govern the behavior for finite d.

Here we consider weighted d-regular graphs, where each non-zero entry of the adjacency matrix is weighted by a random variable. While numerical simulations and a computation of the first 6 moments supported the conjecture that the weighted ensemble would have the semi-circle as its limiting measure iff the weights were drawn from a semi-circle, we show this is not true. If c_{2k} is the 2k-th moment of the semi-circle, then the 2k-th moment of this ensemble is $c_{2k} + O(1/d^2)$. The proofs involve a combinatorial analysis of acyclic paths on trees. (Received September 09, 2011)

1077-VJ-660 **Bei Zhang*** (zbtai@math.northwestern.edu) and **Matthew Emerton**. *p-adic L-functions of GL_2 automorphic representations.* Preliminary report.

Modular symbol method can be used to construct p-adic L-functions associated to modular forms with non-critical slopes. In the joint work with Matthew Emerton, we seek to generalize this method when replacing modular forms by GL_2 automorphic forms over a number field. To do this, we give the variant of the classical results of Amice-Velu and Vishik on tempered distributions in a more general context using the representation theory of parabolically induced representations. The tempered distributions enable us to give a construction of p-adic L-function attached to p-stabilized newforms of non-critical slope of GL_2. (Received September 09, 2011)

1077-VJ-739 **Brice Merlin Nguelifack*** (bmn0003@auburn.edu), 316 West Glenn Ave, Auburn, AL 36830, **Huhua Liu** (xzl0002@auburn.edu), 221 Parker Hall, Auburn, AL 36849, and **Tin-Yau Tam** (tamtiny@auburn.edu), 221 Parker Hall, Auburn, AL 36849. *Unitary Similarity To a Complex Symmetric Matrix And Its Extension to Orthogonal Symmetric Lie Algebra.*

Some characterizations of a square complex matrix being unitarily similar to a symmetric matrix are given. Our ap- proach uses singular value decomposition. A result of Vermeer is extended in the context of orthogonal symmetric Lie algebra of the compact type. (Received September 11, 2011)

1077-VJ-740 **Liyang Zhang*** (lz1@williams.edu), 3090 Paresky Center, 39 Chapin Hall Drive, Williamstown, MA 01267, and **Steven J Miller**, **Oleg Lazarev**, **Geoffrey Iyer** and **Nadine Amersi**. *Low-lying zeros of cuspidal Maass forms.*

Maass forms are smooth functions on the upper half plane, are invariant under the action of $\mathrm{SL}_2(\mathbb{Z})$, are eigenfunctions of the non-Euclidean Laplacian, and are a natural generalization of the Riemann zeta function. While they arise in a variety of problems in number theory, they are significantly harder to work with then their cousins (the holomorphic cusp forms) as the averaging formula here is significantly more unwieldy. We study the distribution of zeros near the central point of L-functions of level 1 Maass forms; this is essentially summing a smooth test function whose Fourier transform is compactly supported over the scaled zeros.

Using the Petersson formula, Iwaniec, Luo and Sarnak proved that the zeros near the central point of holomorphic cusp forms agree with the eigenvalues of orthogonal matrices for suitably restricted test functions. We prove a similar result for Maass forms. We derive an explicit formula, and use the Kuznetsov trace formula to average over the family. There are numerous technical obstructions in handling the terms in the trace formula, which are surmounted through the use of smooth weight functions and results on Kloosterman sums and Bessel and hyperbolic functions. (Received September 11, 2011)

1077-VJ-845 **Michael A Brilleslyper*** (mike.brilleslyper@usafa.edu) and **Bradley A Warner** (brad.warner@usafa.edu). *How Fast does a Sequence of Positive Integers Grow? An Elementary Perspective based on Multiplication.* Preliminary report.

Let $a_1, a_2, \ldots, a_j, \ldots$ be an increasing, infinite sequence of positive integers. For example, we may have $a_j = j$, or $a_j = 2^j$. Other examples include the even or odd integers, or the sequence of prime numbers. We are interested in how such sequences grow relative to the notion of how rapidly the product of consecutive terms grows. In particular, we define the following terms: For a given sequence $\{a_j\}$, we let

$$P^{(n)} = \prod_{j=1}^{n} a_j.$$

Then, for each value of n, there exists a unique integer $k \geq 0$, such that the product

$$Q^{(k)} = \prod_{j=n+1}^{n+k} a_j$$

satisfies the following properties: $P^{(n)} \geq Q^{(k)}$ and $P^{(n)} < Q^{(k+1)}$. Thus k is a funtion of n that we denote by $k = f(n)$. This talk will outline properties of f for various integer sequences and also consider the existence of sequences that result in f having particular characteristics. (Received September 13, 2011)

1077-VJ-924 **Keegan C. Gary*** (`kgary2@students.kennesaw.edu`), **Mari Castle** (`mfc7379@kennesaw.edu`) and **Joe DeMaio** (`jdemaio@kennesaw.edu`). *Total Efficient Domination in Cayley Graphs.* Preliminary report.

A set $S \subseteq V$ is a **dominating set** of $G = (V, E)$ if each vertex in V is either in S or is adjacent to a vertex in S. A set $S \subseteq V$ is a **total efficient dominating set** (or **TEDS**) of a graph $G = (V, E)$ if each vertex in V is adjacent to exactly one vertex in S. While the problem of domination is one of optimization, the question surrounding a TEDS is that of existence. In 2002, Gavlas and Schultz showed that a TEDS S exists for the path graph P_n if and only if $n \not\equiv 1 \bmod 4$, and that a TEDS S exists for the cycle graph, C_n, if and only if $n \equiv 0 \bmod 4$. The cycle graphs are a special class of circulant graphs, which in turn, are a special class of Cayley graphs. The **Cayley graph** $C(A, X)$ for a group A with generating set X has the elements of A as vertices and has an edge directed from a to ax for every $a \in A$ and $x \in X$. In this talk we will classify all circulant graphs that admit a TEDS, and begin to investigate the existence of a TEDS in Cayley graphs. (Received September 14, 2011)

1077-VJ-946 **Geoffrey S Iyer***, geoff.iyer@gmail.com, and **Oleg Lazarev** and **Liyang Zhang**. *Constructing Generalized Sum-Dominant Sets.*

Many of the biggest problems in additive number theory (such as Goldbach's conjecture and Fermat's last theorem) can be recast as understanding the behavior of sums of a set with itself. A sum-dominant set is a finite set $A \subset \mathbb{Z}$ such that $|A + A| > |A - A|$. It was initially believed that the percentage of subsets of $\{0, \ldots, n\}$ that are sum-dominant tends to zero, however, in 2006 Martin and O'Bryant proved a positive percentage are sum-dominant.

We generalize their result to deal with many different ways of taking sums and differences of a set. We first prove that $|\epsilon_1 A + \cdots + \epsilon_k A| > |\delta_1 A + \cdots + \delta_k A|$ a positive percent of the time for all nontrivial choices of $\epsilon_j, \delta_j \in \{-1, 1\}$. Previous approaches proved the existence of many such sets given the existence of one; however, no method existed to construct such a set.

Extending this result, we find sets that exhibit different behavior as more sums/differences are taken. For example, we say A is k-generational if A, $A+A$, $\ldots$, kA are all sum-dominant. Numerical searches were unable to find even a 2-generational set, however, we prove that for any k a positive percentage of sets are k-generational, and no set can be k-generational for all k. (Received September 14, 2011)

1077-VJ-949 **Yuanyou F. Cheng*** (`cfy1721@gmail.com`), Waltham, MA. *Proof of the density hypothesis.*

The Riemann hypothesis, conjectured by Bernhard Riemann, claims that all nontrivial zeros of $\zeta(s)$ lie on the line $\Re(s) = \frac{1}{2}$. The density hypothesis is a conjectured estimate $N(\lambda, T) = O\big(T^{2(1-\lambda)+\epsilon}\big)$ for any $\epsilon > 0$, where $N(\lambda, T)$ is the number of zeros of $\zeta(s)$ when $\Re(s) \geq \lambda$ and $0 < \Im(s) \leq T$, with $\frac{1}{2} \leq \lambda \leq 1$ and $T > 0$. The Riemann-von Mangoldt Theorem confirms this estimate when $\lambda = \frac{1}{2}$, with T^ϵ being replaced by $\log T$. In an attempt to transform Backlund's proof of the Riemann-von Mangoldt Theorem to a proof of the density hypothesis by convexity, we discovered a slightly different approach utilizing a *pseudo Gamma function*. This function is devised to be symmetric with respect to $\Re(s) = \frac{1}{2}$. It is about the size of the Euler Gamma function on the right side of the line $\Re(s) = \frac{1}{2}$. Moreover, it is analytic and does not have any zeros and poles in the concerned open region. Aided by this function, we are able to establish a proof of the density hypothesis. Actually, our result is even stronger, when $\frac{1}{2} < \lambda < 1$, $N(\lambda, T) = O(\log T)$. (Received September 20, 2011)

1077-VJ-992 **Sean P Howe*** (seanpkh@gmail.com). *The Log-Convex Density Conjecture and vertical surface area in warped products.*

We examine the vertical component of surface area in the warped product of a Euclidean interval and a fiber manifold with product density. We determine general conditions under which vertical fibers minimize vertical surface area among regions bounding the same volume and use these results to conclude that in many such spaces vertical fibers are isoperimetric. Our main hypothesis is that the surface area of a fiber be a convex function of the volume it bounds. We apply our results in the specific case of $\mathbb{R}^n - \{0\}$ realized as the warped product $(0, \infty) \times_r S^{n-1}$, providing many new examples of densities where spheres about the origin are isoperimetric, including simple densities with finite volume, simple densities that at the origin are neither log-convex nor smooth, and non-simple densities. We also generalize the results of Kolesnikov and Zhdanov on large balls in $\mathbb{R}^n$ with increasing strictly log-convex simple density. We situate our work in relation to the Log-Convex Density Conjecture of Rosales et al. and the recent work by Morgan, Ritoré, and others on formulating a generalized log-convex density/stable spheres conjecture. (Received September 15, 2011)

1077-VJ-1077 **Michael Fulkerson** and **Kristi Karber*** (kkarber1@uco.edu). *Existence of Solutions for Nonconvex n^{th} Order Differential Inclusions.*

We prove an existence result for the nth order differential inclusion $x^{(n)} \in F\left(x, x', x'', \ldots, x^{(n-1)}\right) + f\left(t, x, x', \ldots, x^{(n-1)}\right)$, with initial conditions $x(0) = a_0,\ x'(0) = a_1, \ldots, x^{(n-1)}(0) = a_{n-1}$, where f is a Carathéodory function and where F is a compact valued upper semicontinuous multifunction such that $F(x_0, x_1, ..., x_{n-1}) \subset \partial V(x_{n-1})$ for some lower semicontinuous proper convex function V. (Received September 16, 2011)

1077-VJ-1164 **Olivia Beckwith*** (obeckwith@gmail.com) and **Steven J Miller** (Steven.J.Miller@williams.edu). *Gaps between summands in generalized Zeckendorf decompositions.*

Zeckendorf proved any integer can be written uniquely as a sum of non-adjacent Fibonacci numbers. This was recently generalized by Miller-Wang, who replaced the Fibonacci numbers with the terms of any recurrence relation of the form $A_n = c_1 A_{n-1} + c_2 A_{n-1} + \cdots + c_L A_{n+1-L}$ (under suitable restrictions on the c_i's). They proved that the number of summands in these generalized Zeckendorf decompositions for integers in $[A_n, A_{n+1})$ converges to a Gaussian as $n \to \infty$.

We examine the distribution of gaps between the indices of the summands in these decompositions, specifically for the base B expansions ($H_n = BH_{n-1}$), and the Fibonacci numbers ($F_n = F_n + F_{n-1}$). We prove many results about the gaps. For example, in the base B case we derive formulas for the largest expected gap and prove that the probability of a gap being of length k is $c_B B^{-k}$ where $c_B = \frac{2(B-1)}{B}$, and for the Fibonacci case prove that the probability of a gap being of length m ($m \geq 2$) is $(\phi - 1)\phi^{-m}$, with ϕ the golden mean. Our methods are combinatorial, involving generating functions and recurrences. (Received September 17, 2011)

1077-VJ-1335 **Bruce R. Ebanks*** (bre13@msstate.edu). *Looking for a few good means.*

The mean value theorem of integral calculus states that for any continuous real-valued function f on an interval I, and for any two distinct real numbers $a, b \in I$, there exists a value $V(a, b)$ in the open interval between a and b for which

$$f(V(a,b)) = \frac{1}{b-a} \int_a^b f(x)\, dx.$$

If in addition f is strictly monotonic, then the function V_f defined by

$$V_f(s,t) = f^{-1}\left(\frac{1}{t-s} \int_s^t f(x)\, dx\right)$$

(and $V_f(s, s) = s$) can be viewed as a two-variable mean on the interval I. We discuss which of these means are homogeneous. (Received September 19, 2011)

1077-VJ-1360 **Joshua P. Bowman*** (joshua.bowman@gmail.com), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *Dynamical deltoids.* Preliminary report.

Polynomial self-maps of $\mathbb{C}$ have been well studied, along the way producing many familiar images of Julia sets and the Mandelbrot set. Polynomial maps of $\mathbb{C}^2$ are natural higher-dimensional analogues. One such map may be defined purely from the geometry of the classical deltoid curve. I will describe a complex one-dimensional family of polynomial maps of $\mathbb{C}^2$ that are linear perturbations of this "deltoid map" and state some of their dynamical properties. (Received September 19, 2011)

1077-VJ-1409 **Oleg Lazarev*** (olazarev@princeton.edu). *Distribution of Missing Sums in Sumsets.*
For any finite set of integers A, define its sumset $A+A$ to be $\{x+y : x, y \in A\}$. In a recent paper, Martin & O'Bryant studied sum-dominant sets, where $|A+A| > |A-A|$. They prove a positive percentage of all sets are sum-dominant, and investigate the distribution of $|A+A|$ given the uniform distribution on subsets $A \subseteq \{0, 1, \dots, n-1\}$. They also conjecture the existence of a limiting distribution for $|A+A|$ and show that the expectation of $|A+A|$ is $2n-11+O((3/4)^{n/2})$.

Using a graph-theoretic framework, we derive an explicit formula for the variance of $|A+A|$ in terms of Fibonacci numbers. We also prove exponential upper and lower bounds (independent of n) for the distribution of $|A+A|$. These bounds are based on bounds on probabilities like $P(k+a_1, \cdots,$ and $k+a_m \notin A+A)$, which we show are approximately exponential in k for fixed $a_1, \cdots, a_m$. Finally, we show that $P(k, k+1, \cdots, k+m \notin A+A)$, the probability of $A+A$ missing a block of consecutive elements, is approximately $(1/2)^{(k+m)/2}$ for large m, k. This approximation implies that essentially the only way for $A+A$ to miss a consecutive block of $m+1$ elements starting at k is to miss all elements up to $k+m$. (Received September 19, 2011)

1077-VJ-1449 **Nadine Amersi**, **Olivia Beckwith**, **Steven J Miller** and **Ryan Ronan***
(ronan2@cooper.edu), 32-52 41st Street, Apartment #2A, Queens, NY 11103, and
Jonathan Sondow. *The Distribution of Generalized Ramanujan Primes.*
In 1845, Bertrand conjectured that for all integers x greater than or equal to 2, there exists at least one prime in $(x/2, x]$. This was proved by Chebyshev in 1860, and then generalized by Ramanujan in 1919, who showed for any integer n there is a prime R_n such that $\pi(x) - \pi(x/2) \geq n$ for all $x \geq R_n$. We generalize the interval of interest by introducing a parameter $c \in (0, 1)$ and defining the n-th c-Ramanujan prime $R_{c,n}$ as the smallest integer such that for all greater integers x, there are at least n primes between cx and x. Using consequences of strengthened versions of the Prime Number Theorem, we prove the existence of $R_{c,n}$ for all n and all c, that the asymptotic behavior is $R_{c,n} \sim p_{\frac{n}{1-c}}$ (where p_m is the m-th prime), and that the percentage of primes that are c-Ramanujan converges to $1-c$. We then study finer questions related to their distribution among the primes, and see that the $c-$Ramanujan primes display striking behavior, deviating significantly from a probabilistic model based on biased coin flipping. This model is related to the Cramer model, which correctly predicts many properties of primes on large scales but has been shown to fail in some instances on smaller scales. (Received September 19, 2011)

1077-VJ-1695 **Daniel P. Biebighauser*** (biebigha@cord.edu). *The Firefighter Problem for Directed Grids.*
Given a graph G, a fire breaks out at one or more vertices of G. Then we are able to place defenders on other vertices of G that are not currently burning. After this, the fire spreads to all undefended neighbors of burning vertices. This process continues until the fire can no longer spread.

We investigate this problem for directed rectangular and triangular grids. This is joint work with Michael Dyrud, Lise Holte, Nicole Rutt, and Ryan Wagner. (Received September 20, 2011)

1077-VJ-1706 **Jose L. Lugo***, Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907-2067. *On quasi-diagonality of continuous fields.* Preliminary report.
Quasi-diagonal C*-algebras form a large class of C*-algebras and arise naturally in many contexts. Dan Voiculescu has shown that quasi-diagonality is a homotopy invariant, and consequently, that the cone of a C*-algebra is always quasi-diagonal. In this talk we discuss an extension of this result for exact continuous fields of C*-algebras. As an application, we obtain that the group C*-algebras of certain central group extensions are always quasi-diagonal. (Received September 20, 2011)

1077-VJ-1737 **Carlos M. Nicolas*** (cmnicola@uncg.edu). *Minimum-size convex decompositions in d dimensions.*
For a set V of points in general position in the d-dimensional Euclidean space, a convex decomposition of V is a set of polytopes with disjoint interiors such that their union is the convex hull of V and the union of their vertex-sets is V. Let $G(V)$ be the minimum number of polytopes in a convex decomposition of V and let $g(n)$ be the maximum value of $G(V)$ among all sets V with n elements in general position. The problem of finding lower and upper bounds for $g(n)$ has been considered only for the plane ($d=2$). In this talk I will present a construction that yields the first non-trivial lower bound for $g(n)$ in d dimensions for any $d > 1$. (Received September 20, 2011)

1077-VJ-1903 **Steven J Miller*** (sjm1@williams.edu), Department of Mathematics and Statistics, Williams College, Williamstown, MA 01267-2680, and **Geoffrey S Iyer** (geoff.iyer@gmail.com), Department of Mathematics, Ann Arbor, MI. *Moment Formulas for Ensembles of Classical Compact Groups.*

As many problems in number theory are connected to the zeros of the Riemann zeta function, as well as more general L-functions, it is important to be able to predict their behavior. Random Matrix Theory has successfully modeled many of their properties. The Katz-Sarnak philosophy says that the behavior of L-functions near the central point (as conductors tend to zero) agrees with the behavior of eigenvalues near 1 of a classical compact group (as the matrix size tends to infinity).

Katz and Sarnak found a determinantal expansion that gives the exact behavior of eigenvalues near 1; however, this expansion is intractable for some statistics, and not useful for some advanced comparisons with number theory. Using combinatorics, generating functions and analysis we expand earlier work on orthogonal groups to symplectic and unitary, correcting an error in the literature and increasing the region where number theory and random matrix theory can be shown to agree. (Received September 21, 2011)

1077-VJ-1961 **Huilan Li*** (hl377@drexel.edu), Department of Mathematics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, and **Jennifer Morse**, Department of Mathematics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104. *An inverse approach to the Littlewood-Richardson Rule for the K-theoretic coproducts.*

The Littlewood -Richardson Rule is a combinatorial description of the coefficients that arise when decomposing a product of two Schur functions as a linear combination of Schur functions. Buch studies the Littlewood-Richardson Rule for the K-theoretic coproducts. Here we present a proof of this by using sign-reversing involutions. (Received September 21, 2011)

1077-VJ-2096 **Garry S. Bowlin*** (bowlings@oneonta.edu), Garry Bowlin, 20 Gardner St, Apt 20, Oneonta, NY 13820. *Thompson's Group and the Four Color Theorem.*

The Four Color Theorem was first proved by Appel and Haken in 1977 with the aid of a computer. Later a simplified proof was given by Robertson, Sanders, Seymour, and Thomas. While the proof was simplified, it still relies on a computer in a significant way. In 1990, Kauffman proved that the Four Color Theorem is equivalent to the ability to find an assignment of the vectors $\hat{\imath}$, $\hat{\jmath}$, and $\hat{k}$ to the variables of two associations of the product $v_1 \times v_2 \times \cdots \times v_n$, such that the evaluations of both associations are equal and non-zero. Since elements of Thompson's group F represent forms of the associative law, one can prove that the Four Color Theorem is equivalent to every element of F having an assignment of the vectors $\hat{\imath}$, $\hat{\jmath}$, and $\hat{k}$ for which that associative law holds. In this talk, I will prove that every positive element of F has such an assignment. (Received September 21, 2011)

1077-VJ-2118 **Matthew L. Bennett*** (mbenn002@gmail.com), CA, and **Nathaniael J. Manning** and **Vyjayanthi Chari**. *BGG reciprocity for the current algebra of $\mathfrak{sl}_2$.*

We study the category $\mathcal{I}$ of graded representations with finite–dimensional graded pieces for the current algebra $\mathfrak{g} \otimes \mathbf{c}[t]$ where $\mathfrak{g}$ is a simple Lie algebra. This category has many similarities with the category $\mathcal{O}$ of modules for $\mathfrak{g}$ and in this paper, we formulate and study an analogue of the famous BGG duality. We recall the definition of the projective and simple objects in $\mathcal{I}$ which are indexed by a dominant integral weight and an integer. The role of the Verma modules is played by a family of modules called the global Weyl modules. We show that in the case when $\mathfrak{g}$ is of type $\mathfrak{sl}_2$, the projective module admits a flag in which the successive quotients are finite direct sums of global Weyl modules. The multiplicity with which a particular Weyl module occurs in the flag is determined by the multiplicity of a Jordan–Holder series for a closely associated family of modules, called the local Weyl modules. We conjecture that the result remains true for arbitrary simple Lie algebras. We also prove some combinatorial product–sum identities involving Kostka polynomials which arise as a consequence of our theorem. (Received September 21, 2011)

1077-VJ-2130 **Mark Wissler*** (Mark.Wissler@gmail.com), 100 N University Drive, Edmond, OK 73034, and **Lavinia Ciungu**. *A Variation of the ElGamal Encryption Method.* Preliminary report.

In cryptography, the discrete log problem is a well-known encryption tool. It is useful due to the difficulty, given the values of a, y, and n in the equation $a^x = y (mod\, n)$, of solving for x. We try to take this problem one step further and examine the substitution by the integer part of the exponential mod 26. For example: the letter f would encrypt to $[e^5] = 18 (mod\, 26)$ which corresponds to Q. This is hypothesized to increase the difficulty by not encrypting directly to integer values. (Received September 21, 2011)

1077-VJ-2131 **Lavinia Ciungu*** (LCiungu@uco.edu), 100 N University Drive, Edmond, OK 73034, and **Mark Wissler**. *Encrypting into Polynomials.* Preliminary report.

In cryptography, two well-known problems are the RSA algorithm, whose core difficulty resides in factorizing a large integer into a product of primes, and the ElGamal algorithm, which is based off of the difficulty that arises while trying to solve the discrete log problem. In the vein of the Jacobian conjecture, this study examines the cryptographic implications of encrypting messages into polynomials based off of a function, $F(x, y)$, whose inverse exists. Utilizing this function, each element of a message is placed into a polynomial mapping family and evaluated by F. Each element is then evaluated and output into a polynomial. Using this method, the encryption of messages is a fairly easy process, while the decryption requires finding the inverse of the decryption function, which is a difficult task. (Received September 21, 2011)

1077-VJ-2133 **Nathaniael J Manning*** (nmanning@math.ucr.edu), Riverside, CA, and **Ghislain Fourier** (gfourier@math.uni-koeln.de) and **Prasad Senesi** (senesi@cua.edu). *Global Weyl modules for twisted loop algebras.*

We define global Weyl modules for twisted loop algebras and analyze their highest weight spaces, which are in fact isomorphic to Laurent polynomial rings in finitely many variables. We are able to show that the global Weyl module is a free module of finite rank over these rings. Furthermore, we prove that there exist injective maps from the global Weyl modules for twisted loop algebras into a direct sum of global Weyl modules for untwisted loop algebras. Relations between local Weyl modules for twisted and untwisted generalized current algebras are known; we provide for the first time a relation on global Weyl modules. (Received September 21, 2011)

1077-VJ-2175 **Alexander Greaves-Tunnell*** (ahg1@williams.edu), **Thealexa Becker**, **Aryeh Kontorovich**, **Steven Miller**, **Pradeep Ravikumar** and **Karen Shen**. *Virus Dynamics in Star Graphs.*

The field of epidemiology has presented fascinating and relevant questions for mathematicians, primarily concerning the spread of viruses in a society. The importance of this research has greatly increased over time as its applications have expanded to include studies of electronic and social networks and the spread of information and ideas. We study the SIS (Susceptible Infected Susceptible) model for virus propagation on star graphs. These graphs feature a single hub with n spokes, and model well many systems, such as certain airline networks.

We determine the long-term behavior as a function of the cure and infection rates, as well as the number of spokes n. For each n we prove the existence of a critical threshold relating the two rates. Below this threshold, the virus always dies out; above this threshold, all non-trivial initial conditions iterate to a unique non-trivial steady state. We discuss generalizations to other networks. (Received September 21, 2011)

1077-VJ-2191 **Casey L Sherman*** (Casey_Sherman@baylor.edu). *A Characterization of Homeomorphisms on Cantor Sets by Orbit Structures.*

We consider the following problem: Given a set X and a function $T : X \to X$, does there exist a topology on X for which T a homeomorphism and X a Cantor set? This question is answered in terms of the orbit structure of the functions. (Received September 21, 2011)

1077-VJ-2199 **Lee Stemkoski*** (stemkoski@adelphi.edu), Adelphi University, 1 South Ave., Garden City, NY 11530. *The Coefficient Space of Polynomial Knots.*

Polynomial knots are embeddings of $\mathbb{R}$ in $\mathbb{R}^3$, where the coordinate functions of the embedding are polynomials. The one-point compactification of such curves are topological knots. For a parametrization with polynomials of fixed degree, we investigate the space of coefficients of the polynomials. In particular, we find algebraic equations for the boundaries of regions corresponding to various knot types. (Received September 21, 2011)

1077-VJ-2236 **Jacob Hughes*** (jthughes@math.ucsd.edu). *Randomly Altering Graphs via Vertex Switching.*

We consider a random process of vertex-switching on a finite graph. At each step, a random vertex of a given graph is selected and the graph is altered by removing all edges incident to the vertex and inserting all non-edges that would be incident to the vertex. We study the behavior of a sequence of altered graphs by examining the associated random walk on the state graph of all possible configurations. Using spectral and algebraic methods, we identify the stationary distribution and bound convergence times of this random process. We also explore generalizations where there are multiple states for each edge, and connections to related processes such as the "lights-out" puzzle. (Received September 21, 2011)

1077-VJ-2247 **Alice Rizzardo*** (rizzardo@math.columbia.edu). *On Fourier-Mukai type functors.* Preliminary report.

Orlov showed in 1997 that all exact, fully faithful functors $F : D^b_{Coh}(X) \to D^b_{Coh}(Y)$ with X and Y smooth projective are isomorphic to a Fourier-Mukai transform $Rp_{2*}(E \overset{L}{\otimes} (\cdot))$, where $E \in D^b_{Coh}(X \times Y)$. In this talk we will discuss a class of functors $D^b_{Coh}(X) \to D^b_{Coh}(Y)$ that are not full or faithful and still satisfy the above result. (Received September 21, 2011)

1077-VJ-2337 **Peter Staab*** (pstaab@fitchburgstate.edu), Dept. of Math, Fitchburg State University, Fitchburg, MA 02130, and **Jared Weed**. *How Many Unique 4 by 4 Natural Magic Squares are There?* Preliminary report.

If we think of a magic squares as matrices, there are 7040 unique natural magic squares that are often classified into one of 12 types, called Dudeney types. Historically, two magic squares are considered equal if you can rotate or reflect one to get the other. In this light each magic square has another 7 related ones, which reduces the total number of unique ones 880. We seek to reduce this number further by finding families of magic squares that are formed by multiplication by permutation matrices. Depending on the Dudeney type of a magic square, there are between 16 and 384 in its family. The determination of the family of every magic square can determine the total number of unique magic squares. Come join us to find the answer to the title question. (Received September 22, 2011)

1077-VJ-2384 **Ryan Stuffelbeam*** (rstuffelbeam@transy.edu). *Counting the Number of Invalid Reductions of Fractions - How "Weird" are "Weird" Fractions?*

An invalid reduction of a fraction consists of deletions of like digits from both the numerator and denominator. A "weird" fraction is a fraction which enjoys a "correct" invalid reduction; an example is deleting the sixes in 26/65. In this talk, a result concerning the construction of weird fractions will be used to discuss their prevalence. In particular, the question of representing a fraction by a weird fraction will be addressed. (Received September 22, 2011)

1077-VJ-2398 **David Offner***, Department of Math and CS, Westminster College, New Wilmington, PA 16172. *Cops and Robber on the hypercube.* Preliminary report.

The game of Cops and Robber is a two-player, perfect-information game played on an undirected graph G. A robber and a fixed number of cops each occupy vertices of G, and take turns moving to adjacent vertices. The cops win if a cop ever occupies the same vertex as the robber. The cop number is the minimum number of cops required to guarantee a winning strategy for the cops, and this number can be interpreted as a measure of the difficulty of searching the graph. We investigate the cop number for variations of this game on the hypercube and related graphs. (Received September 22, 2011)

1077-VJ-2404 **George E Andrews**, **Frank G Garvan** and **Jie L Liang*** (jiel@knights.ucf.edu), McNair Program, P.O. Box 162001, Orlando, FL 32816. *Combinatorial Interpretations of Congruences for the spt-function.*

Let $spt(n)$ denote the total number of appearances of the smallest parts in all the partitions of n. In 1988, the second author gave new combinatorial interpretations of Ramanujan's partition congruences mod 5, 7 and 11 in terms of a crank for weighted vector partitions. In 2008, the first author found Ramanujan-type congruences for the *spt*-function mod 5, 7 and 13. We give new combinatorial interpretations of the *spt*-congruences mod 5 and 7. These are in terms of the same crank but for a restricted set of vector partitions. The proof depends on relating the *spt*-crank with the crank of vector partitions and the Dyson rank of ordinary partitions. We derive a number of identities for *spt*-crank modulo 5 and 7. We prove a surprising result that all the *spt*-crank coefficients are nonnegative. (Received September 22, 2011)

1077-VJ-2416 **Jonathan Sondow*** (jsondow@alumni.princeton.edu). *Evaluation of infinite products involving Fibonacci and Lucas numbers.*

The *Fibonacci numbers* F_k are defined by the recurrence $F_k = F_{k-1} + F_{k-2}$ with $F_0 = 0$ and $F_1 = 1$; the first few terms are $0, 1, 1, 2, 3, 5, 8, 13, 21, 34, \ldots$. The *Lucas numbers* L_k satisfy the same recurrence, but with $L_0 = 2$ and $L_1 = 1$; the sequence begins $2, 1, 3, 4, 7, 11, 18, 29, 47, 76, \ldots$.

In this talk, I will begin by recalling formulas for F_k and L_k in terms of the *golden ratio* $\varphi = (1 + \sqrt{5})/2$. Then I will explain how to evaluate the infinite products

$$\prod_{n=1}^{\infty}\left(1 + \frac{1}{F_{2^n+1}}\right) = \frac{3}{2}\frac{6}{5}\frac{35}{34}\cdots = \frac{3}{\varphi}, \qquad \prod_{n=1}^{\infty}\left(1 + \frac{1}{L_{2^n+1}}\right) = \frac{5}{4}\frac{12}{11}\frac{77}{76}\cdots = 3 - \varphi.$$

A preprint is available at http://arxiv.org/abs/1106.4246. (Received September 22, 2011)

1077-VJ-2495 **Thealexa G Becker*** (tbecker@smith.edu), **Alec Greaves-Tunnell**, **Ryan Ronan** and **Steven J Miller**. *Benford's Law and Dependent Random Variables.*

Many systems exhibit a digit bias. For example, the firstdigit base 10 of the Fibonacci numbers, or of 2^n, equals 1 not 10% or 11% ofthe time, as one would expect if all digits were equally likely, but about30% of the time. This phenomenon, known as Benford's Law, has many applications, ranging from detecting tax fraud for the IRS to analyzing round-off errors in computer science.

The central question is determining which data sets follow Benford's law. Inspired by natural processes such as particle decay, our work examines two models for the decomposition of conserved quantities. Using results from probability, analysis and combinatorics we find conditions under which the processes conform to Benford's Law, thus increasing the number of systems known to be Benford. The main difficulty is dealing with dependent random variables. One way to further explore the relationship between Benford's Law and dependent random variables is to study the copula class of functions . These functions are widely used in the financial industry. We study the relationship between their parameters, number of variables and convergence to Benford's Law, specifically in the family of copulas called the Archimedeans. (Received September 22, 2011)

1077-VJ-2505 **Manizheh Nafari*** (manizheh@uta.edu), Department of Mathematics, University of Texas at Arlington, P.O.Box 19408, Arlington, TX 76019. *Regular Graded Skew Clifford Algebras of Low Global Dimension.*

M. Artin, W. Schelter, J. Tate, and M. Van den Bergh introduced the notion of non-commutative regular algebras, and classified regular algebras of global dimension 3 on degree-one generators by using geometry (i.e., point schemes) in the late 1980s. Recently, T. Cassidy and M. Vancliff generalized the notion of a graded Clifford algebra and called it a graded skew Clifford algebra.

In this talk, we prove that all classes of quadratic regular algebras of global dimension 3 contain graded skew Clifford algebras or Ore extensions of graded skew Clifford algebras of global dimension 2.

We also prove that some known regular algebras of global dimension 4 can be obtained from Ore extensions of regular graded skew Clifford algebras of global dimension 3.

We also show that a certain subalgebra R of a regular graded skew Clifford algebra A is a twist of the polynomial ring if A is a twist of a regular graded Clifford algebra B. We have an example that demonstrates that this can fail when A is not a twist of B. (Received September 22, 2011)

1077-VJ-2559 **Jody M Sorensen*** (sorensj1@augsburg.edu), Department of Mathematics, Augsburg College, 2211 Riverside Ave., Minneapolis, MN 55454. *Bifurcations of Inverse Functions: A Story of Undergraduate Research.*

This report describes an undergraduate student research project exploring the relationship between the bifurcation diagram for a function and that of its inverse. The story includes vague definitions, black and white video shoots, struggles with Mathematica, and surprising successes. (Received September 22, 2011)

1077-VJ-2564 **Johann A Thiel*** (johann.thiel@usma.edu), 601 Thayer Rd., 239B Thayer Hall, West Point, NY 10996. *A tail of two series.* Preliminary report.

It is virtually an automatic response, for some, to rearrange an infinite double sum to obtain a new identity. In the absence of an absolutely converging series, such a rearrangement must be justified. We will discuss certain double sum rearrangements related to some infinite series identities in an unpublished manuscript of Ramanujan. (Received September 22, 2011)

1077-VJ-2578 **Young Hwan You***, Indiana University East, 2325 Chester Blvd., Richmond, IN 47374. *The Necessary Condition For $\bar{\partial}$-equation in Hölder space in $\mathbb{C}^3$.*

Suppose that a smooth holomorphic curve V has order of contact η at a point z_0 in the boundary of a pseudoconvex domain Ω in $\mathbb{C}^3$. We show that the maximal gain in Hölder regularity for solutions of the $\bar{\partial}$-equation is at most $\frac{1}{\eta}$. The result improves works by Krantz and McNeal in this direction. (Received September 22, 2011)

1077-VJ-2579 **James A Fullwood*** (jfullwoo@math.fsu.edu), 2006 Sheridan Rd., Tallahassee, FL 32303. *On global invariants of fibrations of smooth complete intersections.*

A fibration of smooth complete intersections is a proper surjective map of varieties such that the generic fiber is some fixed smooth complete intersection in projective space. We discuss a program for computing invariants of fibrations of complete intersections as functions of invariants of the base of the fibration. In particular, we introduce a general method which culminated in generating functions for the Euler characteristic and all Hirzebruch invariants of elliptic fibrations of all dimensions. In the case of Calabi-Yau elliptic fibrations we highlight applications to string theory. (Received September 22, 2011)

1077-VJ-2586 **Franklin H.J. Kenter*** (fkenter@math.ucsd.edu), 9500 Gilman Drive, Dept. of Mathematics MC 0112, La Jolla, CA 92093. *Necessary Spectral Conditions for 2-coloring Regular 3-uniform Hypergraphs.*

Hoffman proved that for a simple graph G, the chromatic number, $\chi(G)$, obeys $\chi(G) \leq 1 - \frac{\lambda_1}{\lambda_n}$ where λ_1 and λ_n are the maximal and minimal eigenvalues of the adjacency matrix of G respectively. Lovász later showed that $\chi(G) \leq 1 - \frac{\lambda_1}{\lambda_n}$ for any (perhaps negatively) weighted adjacency matrix.

We give a short probabilistic proof of Lovász's theorem. We then extend the technique to derive generalizations of Hoffman's theorem for regular graphs regarding colorings allowing a certain proportion of edge-conflicts. Finally, we derive our main result: If a d-regular 3-uniform hypergraph is 2-colorable, then $-\lambda_{min} \geq \frac{2d}{3}$ where λ_{min} is the smallest eigenvalue of an appropriately-weighted adjacency matrix for the underlying graph. (Received September 23, 2011)

1077-VJ-2605 **Thomas R. Hagedorn*** (hagedorn@tcnj.edu). *Primes of the Form $x^2 + ny^2$ and the Geometry of Convenient Numbers.*

Euler introduced convenient numbers as a useful tool for finding large primes (for his time). He found 65 convenient numbers, the largest being 1848, but could not find another one even though he searched up to 10,000. Gauss rigorously proved that all the numbers on Euler's list were convenient. It is conjectured that Euler's list contains all convenient numbers, and it is known that there are at most two more (with at most one square-free). In this paper, we present an alternative proof that Euler's 65 numbers are convenient using the geometry of numbers. (Received September 22, 2011)

1077-VJ-2632 **Yongsheng Zhang*** (yzhang@math.sunysb.edu), Math Dept, Stony Brook Univ, Stony Brook, NY 11794. *New Results in Calibrated Geometry.*

If a compact connected submanifold M^m is calibrated in (X^n, g), then $[M]$ is non-zero in $H_m(X;\mathbb{R})$. It is quite natural to ask what happens to the reversed direction, i.e., if given a compact connected submanifold M with $[M]$ non-zero in $H_m(X;\mathbb{R})$, is it possible for M to be calibrated by some calibration pair (Φ, g)? The answer is affirmative due to Tasaki.

In my thesis work, I got more nicer results. One of them is: Suppose (X^n, g) is an$n$-dimensional Riemannian manifold without boundary and M^m is a connected oriented closed m-dimensional submanifold with $[M]$ non-zero in $H_m(X;\mathbb{R})$. Then we can construct a new metric $\hat{g}$ in the conformal class of g, such that M can be calibrated with respect to $\hat{g}$. Consequently, M is one mass minimizer among its current homology class in $(X, \hat{g})$. If X is compact, then for any given neighborhood U of M in X, we can make this conformal change essentially occur in U, namely $\hat{g} = g$ on U^c. (Received September 22, 2011)

1077-VJ-2638 **Daniel Joseph Galiffa*** (djg34@psu.edu). *On the Linear Generating Function for the Charlier Polynomials.* Preliminary report.

In this talk, we discuss three ways to obtain the linear generating for the Charlier orthogonal polynomials. We begin by showing how to achieve this generating function using the well-known first principles approach. Then, we discuss how to obtain this generating function using the three-term recurrence relation that defines the Charlier polynomials by constructing and solving a first-order differential equation. From there, we show how to derive an additional three-term recurrence relation for a variation of the Charlier polynomials that also leads to the aforementioned generating function via a first-order differential equation. We conclude our discussion by addressing some results related to bilinear and bilateral generating functions for the Charlier polynomials, as well as generating functions for the q-Charlier polynomials and also consider future research. (Received September 22, 2011)

1077-VJ-2664 **Mary J Riegel*** (riegelmj@mso.umt.edu), Department of Mathematical Sciences, University of Montana, Missoula, MT 59812. *Adding Complexity to Playing Tic-Tac-Toe.* Preliminary report.

Tic-Tac-Toe is a well know, often played, and frequently studied game. As the prototypical positional game, its analysis highlights many of the characteristics that one looks for in the study of positional games. Many variations to the game exist, and in this talk we will explore a new one. It is very rare in a two player game that one player would wish to help his opponent. In this new variation a player will in a single turn be able to improve his own position and forced to improve his opponent's position. It would seem that this would be detrimental to both players; however we will see that playing the variation on the traditional Tic-Tac-Toe board results in the surprising ability of the first player to always win under optimal play by both players. We will also prove the game result on two infinite classes of boards: affine and projective planes. Finally we will describe a second more restrictive variation and some preliminary results for its use. (Received September 22, 2011)

1077-VJ-2717 **Sam Northshield*** (northssw@plattsburgh.edu). *Geometry of cubics.* Preliminary report.

The roots of a cubic polynomial form a triangle T in the complex plane. There is an equilateral triangle in 3-space that projects onto T, and this projection induces a linear map taking the cube roots of unity to the roots of the polynomial. This leads to a short new proof of Marden's theorem: the roots of a complex polynomial are the foci of the ellipse of maximum area inscribed in T. Time permitting, we give a related proof of Cardano's formula. (Received September 22, 2011)

1077-VJ-2736 **McKenzie R Lamb*** (lambm@ripon.edu), 300 Seward Street, PO Box 248, Ripon, WI 54971, and **Philip Foth** (foth@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N. Santa Rita Ave., Tucson, AZ 85721. *The Poisson Geometry of SU(1,1).*

The pseudo-unitary group SU(1,1) admits a natural, multiplicative Poisson structure. This structure is analogous to the canonical Poisson structure on the unitary group SU(2). The Lie algebra of SU(1,1) also admits a natural, linear Lie-Poisson structure, as in the unitary case. These Poisson structures are related to important questions in Hamiltonian and quantum mechanics, dynamical systems, WZW models, etc.

We study two questions concerning the multiplicative and Lie-Poisson structures associated to SU(1,1). First, a theorem of Ginzburg and Weinstein posits the existence of a Poisson isomorphism between the multiplicative and linear Poisson structures for the unitary case. We prove, in two different ways, an analogue of this theorem for the pseudo-unitary case. Second, we establish an analogue of the Thompson Conjecture, which relates singular values in the multiplicative setting to eigenvalues in the linear setting, for the group SU(1,1) - a surprising result in the non-compact setting, which is likely to have further generalizations. (Received September 22, 2011)

1077-VJ-2762 **Sean D Cox*** (sean.cox@uni-muenster.de). *Compactness properties of the second uncountable cardinal.*

Gödel's Compactness Theorem for (finitary) first order logic states: Any inconsistent collection of sentences has a *finite* subcollection which is inconsistent. In modern terminology: the countably infinite cardinal $\aleph_0$—i.e. the least infinite cardinal—is a *strongly compact cardinal*. The next few cardinals—such as the 1st and 2nd uncountable cardinals—can never be strongly compact (assuming the Axiom of Choice). However, it is possible that the 2nd uncountable cardinal (denoted $\aleph_2$) exhibits properties resembling strong compactness. This occurs especially in the presence of *Forcing Axioms*. I will discuss some recent research surrounding Forcing Axioms and compactness properties of the 2nd uncountable cardinal. (Received September 22, 2011)

1077-VJ-2832 **Lena Folwaczny*** (lfolwa2@uic.edu). *Finite Type Knot Invariants.* Preliminary report.

This short talk introduces Finite Type Invariants for Knots (aka Vassiliev Invariants) and explores their connections with other branches of mathematics. We'll discuss recent progress in the area, open problems, and potential research projects for undergraduates. (Received September 22, 2011)

1077-VJ-2838 **Zachary Paul Faubion*** (zfaubion@uci.edu). *Improving the Consistency Strength of Reflection at $\aleph_{\omega+1}$.*

Reflection at $\aleph_{\omega+1}$, the statement that every stationary subset of $\aleph_{\omega+1}$ has a reflection point below $\aleph_{\omega+1}$, was shown to be consistent given the consistency of infinitely many supercompact cardinals by Magidor in 1982. In this talk we will consider improving the known upper bound for the consistency to a quasi-compact cardinal, which is a large cardinal property below any non-trivial instance of a supercompact.

If κ is quasi-compact then every stationary subset of κ^+ has a reflection point of cofinality less than κ. Using a Modified Prikry forcing similar to the one used by Woodin to get the failure of SCH at $\aleph_\omega$ we can turn κ^+ in to $\aleph_{\omega+1}$ while preserving the reflection of stationary sets in the ground model. These results will be presented as well as possible methods for getting reflection for stationary sets which are added by the forcing to also reflect. (Received September 22, 2011)

1077-VJ-2839 **carlos De la Mora*** (carlos-delamora@uiowa.com), 1753 Louis Pl, Iowa City, IA 52245. *Explicit Plancherel Measure for PGL_2 over a p-adic field.*

Computing an explicit Plancherel measure for a reductive group over the p-adic field has been a difficult task. A general theory has been developed in a joint paper by G.Henniart, C.Bushnell and P.Kutzko on computation of the Plancherel measure. The main ideas are to decompose $\hat{G}$ into a union $G = \cup_{\mathfrak{s}\in\mathfrak{B}(G)} G(\mathfrak{s})$ where elements in $\mathfrak{B}(G)$ correspond to Bernstein components. We then know that we can identify each set $G(\mathfrak{s})$ with the unitary dual of a Hecke algebra $\mathcal{H}(G,\lambda)$ where (J,λ) is an $\mathfrak{s}$-type in the sense of Bushnell and Kutzko. Then the Hecke algebras can be seen as Hilbert algebras and they have a corresponding Plancherel measure that is related to the Plancherel measure in $\hat{G}$ in a very explicit way. I will approach the problem of computing the Plancherel measure for $\mathrm{PGL}_2(F)$ using the method described above. (Received September 22, 2011)

1077-VJ-2856 **Juhyung Lee*** (juhylee@math.okstate.edu), MS438 Oklahoma State University, Stillwater, OK 74078. *A functional equation for a prehomogeneous vector space and unitary representations of $GL(2n, R)$.*

To give a realization of an irreducible unitary representation of $G = GL(2n, \mathbf{R})$, we use the usual G-invariant Hermitian form coming from the standard G-intertwining operator between degenerate principal series representations of parameter s. It is known that the zeta distribution is given by the G-intertwining operator and has a meromorphic continuation to all of $\mathbf{C}$.

The formula for the Fourier transformation of $|\det(x)|^s$, as a distribution, gives a functional equation between the zeta distributions which is known as the Fundamental Theorem of prehomogeneous vector spaces. To show that the Hermitian form is positive definite, we need to extend the functional equation, which is well-known for Schwartz functions, to the larger class of functions in the $\bar{N}$-picture $I(s)$ for a degenerate principal series representation. However, there is no range where both integrals of the functional equation converge (except the $n = 1$ case). Therefore, we extend the notion of the zeta distributions so that the functional equation holds for functions in $I(s)$ as meromorphic functions. The extended functional equation can be applied to construct the inner product on the $I(s)$ explicitly. (Received September 22, 2011)

1077-VJ-2869 **Yuping Yang*** (yangyuping@mail.com), Department of Mathematics, MailStop 3368, Texas A&M University, College Station, TX 77843-3368. *a CLT for independent non-identical processes.*

We prove a functional central limit theorem for a sequence of independent non-identical processes with conditions on the distributions of the processes. That is, the empirical process $n^{-1/2}\sum_{j=1}^{n}\big(\mathbf{1}\{X_j(t) \le y\} - \Pr(X_j(t) \le y)\big)$ converges weakly to a gaussian limit on the parameter set $E \times R$. It extends the i.i.d. case in the paper by Kuelbs, J., Kurtz, T. and Zinn, J. (2010). (Received September 22, 2011)

1077-VJ-2933 **Nicholas A Scoville*** (nscoville@ursinus.edu), 153 Regents Rd, Collegeville, PA 19426. *Lusternik–Schnirelmann Category and the connectivity of X.*

We define and study a homotopy invariant called the connectivity weight to compute the weighted length between spaces X and Y. This is an invariant based on the connectivity of A_i, where A_i is a space attached in a mapping cone sequence from X to Y. We use the Lusternik–Schnirelmann category to prove a theorem concerning the connectivity of all spaces attached in any decomposition from X to Y. This theorem is used to compute several examples of the weighted connectivity length between spaces. (Received September 23, 2011)

1077-VJ-2942 **Colin Carroll*** (colin.carroll@rice.edu). *Minimizing the Jacobian Integral.*

We discuss minimizers of the integral of the m-Jacobian of maps $u : \mathbb{R}^n \to \mathbb{R}^m$ where $n \ge m$. This is a highly nonlinear integrand that, in particular, fails to be coercive. If u has a certain amount of regularity, then it will obey the coarea formula of Federer,

$$\int_E |J_m u| = \int_{\mathbb{R}^m} \mathcal{H}^{n-m}(E \cap u^{-1}(y))\, d\mathcal{H}^m(y),$$

for measurable $E \subset \mathbb{R}^n$. This allows a geometric view of the problem, in addition to the variational one. We present a proof of existence for minimizers under certain hypotheses, as well as discussing some properties of these minimizers. (Received September 23, 2011)

General Session on Research in Applied Mathematics

1077-VK-799 **Sridevi Pudipeddi*** (sridevi.pudipeddi@gmail.com), 1920 Lee Boulevard, North Mankato, MN 56003, and **Ravi Chityala** (chityala@msi.umn.edu), 599 Walter Library, 117 Pleasant Street SE, Minneapolis, MN 55455. *Method to extract names of geographical features from images of maps - A theoretical case study.* Preliminary report.

There are thousands of hand drawn maps of Antarctica waiting to be digitized. These maps contain various first-order geographical features like coasts, seas, plateaus, glaciers etc. Due to the extent of these features, their names are spelled over a large area of the map along a contour. A human can perceptually understand that all these letters belong to a word but it is challenging to make the computers perform the same. If the individual letters can be combined to form a word, it can then be transcribed using an Optical Character Recognition (OCR) program, so that text-based queries can be performed. In this paper, we have applied the idea of perceptual grouping to simulated images containing text with letters separated by large distance. The centroid of each of the letter is determined. Finally, the centroids are then grouped based on their proximity to other centroids and also the direction between the pairs of centroid. Once the letters are grouped, the images of the individual letters were given to OCR after appropriate transformation. We applied the technique on many simulated images containing a total of 12 words with 66 letters. The grouping process determined accurately 65 of the 66 letters and assembled them correctly in to a word, giving a close to 100% accuracy. (Received September 12, 2011)

1077-VK-802 **Mark Huber** (mhuber@cmc.edu) and **Sarah Schott*** (schott@math.duke.edu). *TPA: A New Method for Approximate Counting.*

Many high dimensional integrals can be reduced to the problem of finding the relative measures of two sets. Often one set will be exponentially larger than the other. A standard method of dealing with this problem is to interpolate between the sets with a series of nested sets where neighboring nested sets have relative measures bounded above by a constant. Choosing these nested sets can be very difficult in practice. Here a new approach that creates a randomly drawn sequence of such sets is presented. This procedure gives faster approximation algorithms and a well-balanced set of nested sets that are essential to building effective tempering and annealing algorithms. (Received September 12, 2011)

1077-VK-1060 **Dimplekumar N Chalishajar*** (dipu17370@yahoo.com), 417 Mallory Hall, Department of Mathematics and Computer Scienc, Virginia Military Institute (VMI), Lexington, VA 24450, and **Heena D. Chalishajar**. *Trajectory Controllability of Nonlinear Integro-differential System*

A stronger concept of complete (exact) controllability which we call **Trajectory Controllability** is introduced in this paper. We study the Trajectory Controllability of an abstract nonlinear integro-differential system in the finite and infinite dimensional space setting. If we know the trajectory, we can minimize the cost involved in the system and sometimes safe guard the system. These motivated us to study a new notion of control called trajectory control.

(Received September 15, 2011)

1077-VK-1216 **Daniel Maxin*** (daniel.maxin@valpo.edu), **Ludek Berec** (berec@entu.cas.cz), **Michael Covello** (mcovello@luc.edu), **Jill Jessee** (jill.jessee@my.simpson.edu) and **Matthew Zimmer** (mdzimmer@csbsju.edu). *The logistic gender-structured model with ephemeral pair bonds and isolation from reproduction (report on an REU project at Valparaiso University).*

In this paper we analyze a logistic two-sex population model in which individuals do not form stable pairs (appropriate for certain animal populations). Using this model, we study the impact of sexually abstaining groups on persistence of a mild sexually transmitted infection(STI). In addition to presenting the main results of our paper, I will give a brief summary on how this REU project was born from earlier work done by the first author on population models with stable pairs. I will describe how switching from stable pairs to ephemeral pairs made the models suitable to certain mathematical techniques accessible to undergraduate students with minimal background. (Received September 18, 2011)

1077-VK-1366 **Anna M. Barry*** (annab@bu.edu), **Glen R. Hall** and **C. Eugene Wayne**. *The $(1+N)$-vortex problem: a study of inviscid and weakly viscous vortex relative equilibria.*

We study relative equilibria of the n-vortex problem where N vortices have small, equal circulation and one vortex has large circulation. In the limit, the problem reduces to seeking critical points of a particular potential function. In contrast to the Newtonian $(1+N)$-body problem, there are typically multiple relative equilibria for both small and large N. Linear stability is also studied, and situations are found where there are no stable relative equilibria. We then attempt to extend this work to the weakly viscous setting. (Received September 19, 2011)

1077-VK-1683 **Yang Zou*** (yangzou@rams.colostate.edu), Department of Mathematics, Colorado State University, Fort Collins, CO 80526, **Gerhard Dangelmayr** (gerhard@math.colostate.edu), Department of Mathematics, Colorado State University, Fort Collins, CO 80523, and **Iuliana Oprea** (juliana@math.colostate.edu), Department of Mathematics, Colorado State University, Fort Collins, CO 80523. *Intermittency and chaos near Hopf bifurcation with broken $O(2) \times O(2)$ symmetry.*

Spatiotemporal complex dynamics, including chaos and intermittency, created at the onset of electroconvection in nematic liquid crystals can be modeled by Ginzburg Landau amplitude equations governing the dynamics of the envelopes of four oblique traveling waves. Simulations from this model indicate rapid switchings between a pair of symmetry-conjugated chaotic saddles. In this paper a low dimensional dynamical system, corresponding to a Hopf bifurcation normal form with broken translational symmetries, is introduced to capture this kind of switching dynamics. Symmetries, invariant subspaces, and a symmetry related transformation are analyzed theoretically in detail, and a variety of dynamical features, including symmetry increasings and decreasings, chaos, and in-out intermittency, are demonstrated in the dynamics of the perturbed normal form. (Received September 20, 2011)

1077-VK-1803 **Yuriy Shlapak*** (yuriy.shlapak@uwc.edu), 2000 West 5th Street, Marshfield, WI 54449. *Comparative analysis of a few fast numerical schemes for finding positive and some sign-changing solutions to time-independent Gross-Pitaevskii type equations with general potentials.*

In our talk we discuss and compare a few fast numerical schemes for finding positive and some sign-changing solutions to time-independent Gross-Pitaevskii type equations. We present both theoretical results on convergence of these schemes to certain types of solutions and the results of numerical experiments based on these schemes where we find certain types of solutions to Gross-Pitaevskii type equations with various types of potentials in two dimensions. The schemes that we discuss are based on the fixed point iteration and on the Newton method. In our numerical experiments we use a highly effective spectral method of discretizing our equations by collocation at zeros of Legendre polynomials. (Received September 21, 2011)

1077-VK-2095 **Abhinandan Chowdhury*** (achowdhury@desu.edu), Dept. of Mathematical Sciences, Delaware State University, 1200 N Dupont Hwy., ETV Building Room No. 223, Dover, DE 19901. *Memory Effects for the Heat Conductivity of Random Suspensions of Spheres.*

The presence of a particulate phase defines the effective response of a suspension to changes of the average heat flux. Using the Random-Point Approximation (RPA) we show that within the first order in the concentration, one needs to solve the problem for the temperature field created by a single inclusion in a matrix subject to an unsteady temperature gradient at infinity. We solve this problem by means of Laplace transform and use the solution as the first-order kernel in the functional expansion. From this kernel we find the statistical average for the heat flux, which turns out to be a memory integral of the spatially averaged time dependent temperature gradient. Thus, we discover that the constructive relationship between the average flux and averaged temperature gradient is not local in time, but rather involves a convolution integral that represents the memory due to the heterogeneity of the system. This is a novel result, which *inter alia* gives a rigorous justification to the usage of generalizations of the heat conduction law involving fractional time derivatives. The decay of the kernel is very close to $t^{-1/2}$ for dimensionless times lesser than one and abruptly changes to $t^{-3/2}$ for larger times. (Received September 21, 2011)

1077-VK-2209 **Yajun Yang*** (yajun.yang@farmingdale.edu), Farmingdale State College of SUNY, 2350 Broadhollow Road, Farmingdale, NY 11735, and **Sheldon P. Gordon**, Farmingdale State College of SUNY, 2350 Broadhollow Road, Farmingdale, NY 11735. *Searching for the Best Quadratic Approximation of a Function.*

This talk examines the question of finding the best quadratic function to approximate a given function on an interval. The prototypical function considered is $f(x) = e^x$. Two approaches are considered, one based on Taylor polynomial approximations at various points in the interval under consideration, the other based on the fact that three non-collinear points determine a unique quadratic function. Three different techniques for measuring the error in the approximations are considered. (Received September 21, 2011)

1077-VK-2290 **Jesus A. Pascal*** (pascal_jesus@yahoo.com) and **Betsi J. Tirado** (betsi_tirado@yahoo.com). *The Dynamic Programming Equation for a Deterministic Optimal Control Problem.*

The dynamic programming method for solving deterministic optimal control problems replaces the original minimization problem over control functions (infinite dimensional)by a first order nonlinear pde equation called the Hamilton Jacobi Bellman (HJB) equation involving pointwise minimization over the set of control values, usually a subset of a finite dimensional normed vector space. The interest here is to determine the dynamic programming equation for a deterministic optimal control problem with a one dimensional state space. It turns out that the value function of this control problem is a viscosity solution of the dynamic programming (HJB) equation. (Received September 22, 2011)

1077-VK-2383 **Roseanne M Wolf*** (roseanne-wolf@uiowa.edu), 25 Lincoln Ave., Apt. 13, Iowa City, IA 52246, **Colleen C Mitchell**, Department of Mathematics, 14 MacLean Hall, Iowa City, IA 52242, **Peter Mohler**, 110 Davis Heart&Lung Research Inst, 473 W 12th Ave, Columbus, OH 43210, and **Thomas Hund**, Bevis Hall, 1080 Carmack Road, Columbus, OH 43210. *Molecular mechanism for cardiac electrical instability in human heart disease: a predictive and multiscale computational model of "ankyrin-B syndrome.".*

Heart disease claims over 400,000 lives each year in the U.S. with most deaths occurring suddenly due to cardiac electrical disturbances (arrhythmias). Ion channel dysfunction due to congenital or acquired defects has been linked to human arrhythmia. Ankyrin-B is a multifunctional adapter protein responsible for targeting select ion channels, transporters, and signaling molecules in cardiac cells. Ankyrin-B dysfunction has been linked to arrhythmia in human patients (ankyrin-B syndrome). Despite knowledge gathered from transgenic mice and human patients, molecular mechanisms responsible for arrhythmias in ankyrin-B dysfunction remains unclear. Here, we develop detailed mathematical models of ankyrin-deficient murine and human myocytes based on experimental data and perform computer simulations to determine cellular pathways responsible for abnormal electrical activity in ankyrin-B-deficient cells. Results from our simulations demonstrate that defective membrane localization of a key ion transporter, the sodium-calcium exchanger, produces severe electrical instability in ankyrin-B-deficient cells. These findings help solve the molecular mechanism underlying a human disease and highlight the importance of proper ion channel/transporter localization for excitable cell function. (Received September 22, 2011)

1077-VK-2395 **Marianne Dubinsky*** (mdubinsk@mail.umw.edu), 805 Charlotte Street, Fredericksburg, VA 22401. *Revisiting the Basel problem.*

Several methods have been considered in establishing the value of zeta(2). In this talk, we will explore some of the approaches to the Basel problem, highlighting the unique arguments in each. Our focus then shifts to a probabilistic solution which hinges on the distribution of certain random variables. The beauty of this method, is that it provides a very nice connection between several branches of mathematics. (Received September 22, 2011)

1077-VK-2408 **Keaton P. Quinn***, S 5000 Hagadorn Road, Apartment 19, East Lansing, MI 48825. *Inverse Modeling by Cumulative-Power-Penalized Least Squares.*

For a time-varying function $Y(t|\theta)$ with single covariate t and parameter vector θ conditioning likelihoods are typically simpler to model than full joint distributions which may be difficult or impossible to find analytically. Conditioning can potentially improve the identifiability of the estimation of parameters θ. Parameter estimates $(\hat{\theta})$ are often obtained as minimizers of a loss function which measures departure between the model prediction and the data. Here penalized least squares (PLS) is the loss function to be minimized and is defined as

$$\mathcal{L} = \sum_{i=1}^{n} \Big(Y(t_i|\theta) - Y(t_i|\hat{\theta}) \Big)^2 + \lambda \cdot \text{PEN} \quad \text{with } \lambda \text{ a scalar weighting factor.}$$

Estimators for θ with improved prediction bias are obtained by finding an optimal choice for λ and PEN. We introduce cumulative power

$$P(t) = \int_0^t \big(m''(s)\big)^2\, ds,$$

and define the penalty as

$$\text{PEN} = \sum_{i=1}^{n} \Big(P(t_i|\theta) - P(t_i|\hat{\theta}) \Big)^2$$

We demonstrate how the single covariate cumulative power penalty results in reduced bias. Our work show cumulative power can be used in combination with PLS to estimate unknown parameters in highly nonlinear single- and bi-variate regression problems. (Received September 22, 2011)

1077-VK-2637 **Christopher Robert Frye*** (christopher.frye@knights.ucf.edu), 576 Lake Bingham Road, Lake Mary, FL 32746, and **Costas Efthimiou**. *Effective Acceleration of Gravity due to the Expanding Universe.*

We explore the possibility that the expansion of the universe can explain two open questions in modern mathematical physics. Firstly, in studying the laws of nature, theorists have classified all phenomena into the consequences of four fundamental forces: gravitational, electromagnetic, weak, and strong. What puzzles scientists is the fact that the gravitational force is many orders of magnitude weaker than the other three forces. Secondly, by estimating the amount of matter contained in certain galaxies, astronomers can predict the orbits of stars that revolve around them. However, in many cases the predictions are very far off from the observations. This has led physicists to postulate the existence of large amounts of dark matter inhabiting our universe. In an attempt to understand these two problems better, we look into the equations of general relativity for the effective acceleration of gravity we should see after the expansion of the universe is taken into account. This might explain the weakness of gravity as measured in experiments as well as the deviation in stellar orbits from predicted trajectories. (Received September 22, 2011)

1077-VK-2700 **Calistus Ngeh Ngonghala*** (cnngonghala@nimbios.org), NIMBioS, 1534 White Ave., Suite 400, University of Tennessee, Knoxville, TN 37996-1527. *Extreme multi-stability in a chemical model system.*

Coupled systems can exhibit an unusual kind of multi-stability, namely, the coexistence of infinitely many attractors for a given set of parameters. This extreme multi-stability is demonstrated to occur in coupled chemical model systems with various types of coupling. We show that the appearance of extreme multi-stability is associated with the emergence of a conserved quantity in the long-term limit. This conserved quantity leads to a "slicing" of the state space into manifolds corresponding to the value of the conserved quantity. The state space "slices" develop as $t \to \infty$ and there exists at least one attractor in each of them. We discuss the dependence of extreme multi-stability on the coupling and on the mismatch of parameters of the coupled systems. (Received September 22, 2011)

1077-VK-2752 **Alexander J Gutierrez*** (ajg@asu.edu). *Recovery of Fourier Transforms Using Edge Information.*

The reconstruction of piecewise smooth functions from non-uniform Fourier data is an important problem in applications such as sensing (e.g. Magnetic Resonance Imaging). In this talk I present a new method of approximating the Fourier transform $\hat{f}(\omega)$ of an underlying piecewise smooth function f as an asymptotic expansion of mapped Chebyshev polynomials. This research leverages the accurate edge detection from non-uniform Fourier data (Stefan et al, 2011) in the recovery of the Fourier coefficients. The method is shown to converge exponentially in the (finite) Fourier transform domain given the exact edge locations, and in particular can be approximated on uniform modes. When the exact jump locations are not known, an optimization procedure is used to improve edge estimates and accuracy of the representation. (Received September 22, 2011)

1077-VK-2811 **Csilla Szabo*** (csilla.szabo@usma.edu), West Point, NY. *A Markov Model for Actin Polymer Dynamics and Cell Membrane Protrusion.*

Actin is a helical polymerizing protein, which is vital to the cell. This protein forms the cytoskeleton of the cell and plays a key role in cell motility. Without the ability to move cells would not be able to perform critical cell processes such as wound healing, immune system response and embryonic development. This work focuses on the role of actin in membrane protrusion, which is the first in a series of steps leading to cell motility. I present a Markov model for actin polymerization and depolymerization, where the polymer ends and membrane position are tracked. The membrane-polymer interaction is modeled as a Brownian Ratchet where the thermal fluctuations of the membrane create space for the actin filament to polymerize. The concentration and diffusion of both active ATP-bound and inactive ADP-bound monomers in the cytoplasm, conditional on the membrane position, is also included in the model. The main goals of this work are as follows: 1. Find the polymer length distribution and determine if treadmilling or steady-state behavior is observed. 2. Examine the polymer-membrane interaction and determine the protrusion velocity. 3. Determine if diffusion is a sufficient mechanism for delivering monomers to the leading edge of polymer growth. (Received September 22, 2011)

1077-VK-2924 **Stephen H. Harnish*** (harnishs@bluffton.edu). *Modeling wave velocity and frequency spectra in low-temperature, compressed LJ lattices: HPC simulations, mathematical theory and applications to acoustic metrics.* Preliminary report.

Analysis of wave velocities and vibrational spectra of solids often start with simplifying assumptions of isotropic homogeneous media with harmonic interatomic potentials. In these models the velocity of a longitudinal wave is proportional to the square root of the ratio of Young's elastic modulus and the density of the medium, while the natural angular frequency of a harmonic oscillator is the square root of Hooke's constant divided by the mass. These introductory models can explain many wave phenomena of solids. Yet a careful analysis of real material systems often requires more subtlety. For instance, in anharmonic oscillators the resonant frequency shifts are proportional to the square of the oscillation amplitude. We'll report our computational and theoretical research on an intermediate level model of the temperature dependence of wave velocity and frequency spectra in compressed LJ lattices. The high performance simulations were performed on the Glenn cluster of the Ohio Supercomputer Center and with the assistance of an undergraduate Petascale intern, sponsored by the National

Computational Science Institute. We'll end with a preliminary report on applications to acoustic metrics in analogue models of relativity. (Received September 23, 2011)

General Session on Assorted Topics

1077-VL-22 **Donald Leigh Hitzl*** (domarltd@comcast.net), 7 Candlestick Road, Orinda, CA 94563-3701, and **Frank Zele** (fzele@juno.com), 910 Sharon Park Drive, Menlo Park, CA 94025. *Investigations of the Riemann Hypothesis - Three Independent Confirmations.*

With the discovery that Xi(s), the companion function to the Riemann Zeta Function,is a spiral into the origin, never reaching there until infinite time, the Riemann Hypothesis (RH) is confirmed. Here s = sigma + it and Xi(s) = -G(s)Zeta(s) where the Riemann Transfer Function G(s) is 1/2 Gamma(s/2)s(1-s)pi to the power -s/2. G is again a CCW spiral into the origin.

Next, using the "Skeleton Key Equation" given by Edwards on page 17, a perturbation development shows that there are no zeroes in the neighborhood of ANY known zero at tn and sigma = 1/2. Setting sigma = 1/2 + delta and t = tn + eps, where the perturbations are to be small and real, a standard development through third order confirms the RH.

Last, an analytical and numerical study was conducted to determine Partial(Abs(Zeta)) wrt sigma. A set of 12 values of sigma in the critical strip of 0 < sigma < 1 were examined at the first 30 minima for each of these sigma values. In each case, the minima time tm was computed to a minimum accuracy of 10 to the -7. In all 360 cases, the partial derivative was positive to the right of sigma = 1/2 and negative to the left. (Received June 7, 2011)

1077-VL-340 **Walter S. Sizer*** (sizer@mnstate.edu), Department of Mathematics, Minnesota State University Moorhead, Moorhead, MN 56563. *An Overview of Numeral Systems.* Preliminary report.

In the past and present there have been close to 100 different symbolic numeral systems used in the world. Most of these systems are based on one or more of four principles, which can be termed repetitive, alphabetic, multiplicative, and positional. We will indicate how systems based on each of these principles work and give some less well known examples of each type of system, including Inupiaq and Glagolitic numerals. Examples of some numeral systems in current use will be illustrated with exhibits. (Received August 24, 2011)

1077-VL-346 **Martha Byrne*** (mbyrne@math.unm.edu). *Status, Interaction, and Undergraduate Mathematics in Nigeria: A VLP Experience.*

Through the Visiting Lecturer Program, Dr. Michael Nakamaye and I traveled to Ile-Ife, Nigeria and taught at Obafemi Awolowo University in October, 2010. I will discuss my experience in Nigeria and my observations about how the status structure of the academic environment affects classroom dynamics, student/faculty interaction, and student learning. Additionally, I will address the program itself and the great value it presents to the visiting lecturers and the visited institutions. (Received August 24, 2011)

1077-VL-347 **Patricia Baggett*** (baggett@math.nmsu.edu), Dept of Math Sci, MSC 3MB PO Box 30001, New Mexico State University, Las Cruces, NM 88003-8001, and **Andrzej Ehrenfeucht** (andrzej.ehrenfeucht@colorado.edu), Computer Science Department, University of Colorado, PO Box 430, Boulder, CO 80301-430. *Contradictions in the Common Core State Standards: Problems and a possible solution.*

One of the goals of the Common Core State Standards is to present a coherent view of mathematics through all grades. But the Standards still retain existing contradictions in the same material that is presented in different grades under different headings. The talk will contain: (1) examples of contradictions; (2) problems they create for students; (3) problems they create for teachers; and (4) one way (among several) that the material can be presented in a consistent manner at all grade levels. (Received August 24, 2011)

1077-VL-392 **Anita Mareno*** (aum24@psu.edu), Olmsted Building, 777 West Harrisburg Pike, Middletown, PA 17057. *Apriori bounds and maximum principles for some higher order nonlinear pdes.*

In this talk we illustrate how the 'P-function' technique can be used to obtain maximum principle results for some nonlinear pdes of order greater than or equal to four. We include results for some interesting nonlinear equations from thin plate theory. We also deduce apriori bounds on certain quantities of interest. (Received August 29, 2011)

1077-VL-492 **Heather A Bullen**, **Kristi L Haik** and **Gail Mackin*** (macking@nku.edu). *Project SOAR: Providing Low-Income, First-Generation, Underrepresented STEM Students Comprehensive Support for Success.*

Northern Kentucky University is the recipient of a National Science Foundation (NSF) S-STEM funded program entitled Project SOAR: Scholarships, Opportunities, Achievements and Results. The goal of Project SOAR is to recruit, retain, and graduate a cohort of at-risk students in STEM disciplines through community building, intensive mentoring and specially designed course-loads. Results in the first three years include: 43% of newly recruited SOAR students are underrepresented in STEM disciplines; elevated rates in retention and GPA of SOAR students; nearly 50% of rising SOAR sophomores participate in summer research. The structure and success of Project SOAR will be discussed. (Received September 04, 2011)

1077-VL-500 **Elizabeth K. Mauch*** (emauch@bloomu.edu), Bloomsburg University of Pennsylvania, 400 E. 2nd St., 3106 McCormick Center for Human Services, Bloomsburg, PA 17815. *Recruitment and Retention of First Generation Mathematics Majors.*

Typically, the recruitment and retention of first-generation college students is measured in their general success in obtaining any college degree. The author will present the findings of an NSF S-STEM recruitment and retention grant which targeted first generation college students and studied the success of retaining the students in mathematics. Findings include activities which were beneficial in retaining students not only in the freshman year, but also in the sophomore year. Many of the students who received the grant easily were retained in the freshman year. However, many students faced increasing difficulty as they entered their sophomore year. Retention activities not only focused on academics but also on social issues that the students faced. (Received September 05, 2011)

1077-VL-531 **Wasin So*** (wasin.so@sjsu.edu). *Matrices with Equal Power Property.* Preliminary report.

In linear algebra, there are two types of matrix-matrix multiplication: the ordinary multiplication and the Hadamard (entry-wise) multiplication. Accordingly, given a square matrix, there are two types of power: ordinary and Hadamard. We are interested in characterizing those matrices having these two types of powers equal. Diagonal matrices are the obvious, but there are many more! (Received September 06, 2011)

1077-VL-610 **Mohammad K Azarian*** (azarian@evansville.edu), Department of Mathematics, University of Evansville, 1800 Lincoln Avenue, Evansville, IN 47722. *Jensen's Inequality Versus Algebra in Finding the Exact Maximum.*

In this paper we find the exact maximum value of a function without the conventional method of using critical numbers. In fact, we find the exact maximum without even finding the derivative of the function. First we apply Jensen's Inequality, and then we use simple algebra to find the exact maximum. We conclude our presentation by posing two questions. (Received September 08, 2011)

1077-VL-639 **Zhanbo Yang*** (yang@uiwtx.edu), Dept. Mathematical Sciences, University of the Incarnate Word, CPO #311, 4301 Broadway, San Antonio, TX 78209, and **F G Wukovits**, **A. Daniel** and **J. Beltrami**. *"Leading Disadvantaged Students to Success in Mathematics" —- A midterm report of our S-STEM funded project.* Preliminary report.

In 2008, UIW received funding from NSF under the S-STEM program to provide scholarship and other support to students who are majoring in mathematics. The project has a number of objectives that covers from recruitment to retention to career development. The first class of students under this program came in the fall of 2009 and most of them are now at least juniors. We will report the lesions learned during the first three years of this five-year project: what works, what does not? What are the things we wish we had done from the start? The most important things we learned through this endeavor are that close monitoring and early intervention are the keys to retention and persistence. (Received September 09, 2011)

1077-VL-842 **John T. Jacobson*** (jjacob26@students.kennesaw.edu). *Combinatorial Proofs of Fibonacci Identities by Means of the Path Graph.* Preliminary report.

In 1982, Prodinger and Tichy define the Fibonacci number of a graph G, $i(G)$, to be the number of independent sets (including the empty set) of the graph. They do so because the Fibonacci number of the path graph, P_n, is the Fibonacci number F_{n+2}. Nelson's *Proof without Words* series provides numerous visual arguments for several mathematical identities, some of which feature the Fibonacci sequence. In *Proofs that Really Count*, Benjamin and Quinn provide purely combinatorial proofs of several mathematical identities, some of which feature the Fibonacci sequence. This talk marries these visual and combinatorial features to prove Fibonacci identities by means of the path graph. (Received September 13, 2011)

1077-VL-846 **Hong Lien T. Tran*** (htran14@students.kennesaw.). *Domination and Independence on the Triangular Honeycomb Chessboard.* Preliminary report.

Puzzles on the chessboard have long been studied by mathematicians. *Across the Board: The Mathematics of Chessboard Problems* by John Watkins is an indispensable collection of mathematically themed chessboard problems. We do not restrict ourselves to the standard 8×8 chessboard. Generalizations are quickly made to the square board of sides other than $n = 8$, $m \times n$ rectangular boards and other variant surfaces. Chessboard problems are most frequently set in the context of Graph Theory. Two classic problems in Graph Theory that appear again and again are those of dominating sets of minimum cardinality and independent sets of maximum cardinality. For chessboards the question of a minimum dominating set transforms into how to threaten or occupy every square on the board with the fewest pieces. Maximum independent sets become the problem of how to place the maximum number of non-attacking pieces. Our project explores these two combinatorial problems on the variant triangular honeycomb chessboard for the rook, bishop, knight and king. (Received September 13, 2011)

1077-VL-942 **Pat Kiihne***, pkiihne@mail.ic.edu. *Using Screen Capture Video to Aid Instruction.*

Despite our students' comfort level with technologies such as Facebook and Twitter, they remain uneasy with mathematical software packages such as Maple. Screen capture videos can ease students' transition to these software packages. A screen capture video shows what occurs on the computer screen as the narrator operates a program. The narrator provides a description of the keystrokes as part of the voiceover. I made screen capture videos for a multivariable calculus class. In this talk I will describe how to make such a video, how to use them as a study aid for students learning Maple, and the advantages and disadvantages of making and using such videos. I will also talk about other courses where screen capture videos may be used. (Received September 14, 2011)

1077-VL-982 **Jenna P Carpenter*** (jenna@latech.edu), Po Box 10348, Ruston, LA 71272. *Mentoring Junior Faculty: A Formula for Success.*

New faculty struggle with the often competing demands of teaching, research and service, on top of trying to figure out processes and procedures for a myriad of required activities. Equally important to faculty success and retention is navigating, and finding a home within, the department and campus culture. Research clearly shows the value of implementing a formal mentoring program for new faculty to assist and support them in this transition. Given that the only real resource required to implement such a program is some time and attention from a willing leader, this is a particularly timely strategy for improving faculty satisfaction, success, and retention in economically challenging times. This talk will review such a faculty mentoring program, highlighting the availability of great resources on the web, sharing successful research-based strategies and best practices for starting and running a mentoring program, feedback from participants, as well as practical information on how to maintain a program over time. (Received September 15, 2011)

1077-VL-1348 **Steven Schlicker*** (schlicks@gvsu.edu). *What can a right triangle look like?*

We all know what a right triangle looks like – or do we? The picture we have in our minds is likely based in Euclidean geometry in the plane, but that is not the only possibility. In this presentation we discuss the concept of orthogonality in the space of nonempty compact subsets of n-dimensional real space and describe how Euclidean orthogonality of compact sets is similar to and different from our standard view of orthogonality. The presentation will include pictures of several seemingly odd right triangles. (Received September 19, 2011)

1077-VL-1377 **Homer W. Austin*** (hwaustin@salisbury.edu), Department of Mathematics and Computer Scienc, 1101 Camden Avenue, Salisbury University, Salisbury, MD 21801, and **Jathan W. Austin** (jwaustin@udel.edu), Department of Education, University of Delaware, 130 Willard Hall Education Building, Newark, DE 19716. *Red, White, and Blue: Pythagorean Triples in Undergraduate Mathematics Teaching.* Preliminary report.

The presenters in this talk will share ideas on Pythagorean triples that have been insightful and useful in teaching topics in courses ranging from mathematics content courses for elementary teachers to courses in mathematics for liberal arts for non-mathematics majors; for mathematics majors, some of these ideas have been employed in discrete mathematics, linear algebra, and number theory. Many of these ideas have also been used as topics in courses for in-service public-school mathematics teachers. (Received September 19, 2011)

1077-VL-1668 **Ricardo Enrique Rojas*** (ricardo.rojas@northern.edu), 1200 South Jay Street (#714), Aberdeen, SD 57401. *How I Taught A Course About The History Of Mathematics For The First Time.*

I taught a course about the history of mathematics for the first time in my life during the Spring 2011 semester. I will present the pedagogy that I used to teach this class. I will also present some of the factors that motivated me to adopt the aforementioned pedagogy. (Received September 20, 2011)

1077-VL-1724 **Bill Linderman*** (wclinder@king.edu), Department of Mathematics, King College, Bristol, TN 37620. *Deciphering a Message Using the Vigenère Square.* Preliminary report.

Vigenère described a method for enciphering a message using a keyword. The method is similar to a Caesar shift but involves a polyalphabetic substitution. We will show how analyzing letter frequencies can be used to decipher the message when the length of the keyword is known. Demonstrations will be in *Mathematica*. (Received September 20, 2011)

1077-VL-1892 **Perry Y.C. Lee*** (plee@kutztown.edu), 267 Lytle Hall, Department of Mathematics, Kutztown University of Pennsylvania, Kutztown, PA 19530. *"Resistance" is Futile: Understanding the Effect of Resistance in Physical Systems.*

Resistance occurs in many physical systems, and its effect on a system can be measured by, for example, a force, temperature, or time. For example, a highly reliable micro-electronic circuit is one that can not only exceed design specifications in computing performance, but also one that can effectively remove generated heat before electronic components overheat and subsequently fail. Designing such a circuit requires knowledge of an important design concept known as 'thermal resistance.'

In this paper, to demonstrate the concept and the effect of resistance, the total time taken to mow a flat 2-D rectangular grass region is presented in detail using basic algebra. It was found that the total time taken to cover the entire area is primarily dependent on the speed of the lawn mower, and the paths taken called *sweeps* to cover the entire area.

'Natural' resistance is quantified where its effect is the minimum time taken to sweep across the area. Additional time taken due to directional changes from one sweep to the next is calculated. This time taken can be construed as a result of the effect of increased resistance, and can become a significant portion of the total time taken. Recommendations for minimizing the total time taken are proposed. (Received September 21, 2011)

1077-VL-1930 **Kayla Bradley Dwelle***, dwellek@obu.edu, and **Ruth A. Enoch**, renoch@atu.edu. *Into the deep end of the mathematical pool: some preliminary experiences teaching with IBL.*

Recently, at each of our institutions, we have tried out teaching with an IBL method for the first time. Like our students, we found much of the experience similar to being thrown into the deep end of the pool, needing to learn how to "swim". In this talk, we will discuss how we implemented IBL in the classroom, what worked, what didn't and what we would choose to change the next time we teach with IBL. Additionally, we will make recommendations for others who have not yet tried this method in the classroom. (Received September 21, 2011)

1077-VL-1947 **Bernard Beecher*** (Beecherb@msn.com), Bernard Beecher, Bmcc/CUNY-The City University of New York, 199 Chambers Street Room N518, Manhattan, NY 10007. *Modeling Examination scores with the Wakeby Distribution.*

It is usually assumed that test scores are normally distributed; however, in this paper I will show that test scores are not normally distributed; and that test scores can be modeled using the Wakeby distribution. Examination schemes may be classified as either norm-referenced or criterion-referenced. Norm-referenced refers to examinations such as SAT (Scholastic Aptitude Test), where the students are usually inadequately prepared for such examinations. Large number of such students received very low scores and a few receiving high scores. In this case the test scores are positively skewed; In the case of, criterion-referenced the teacher sets the scoring scheme, usually the student have some prior knowledge as to the content and rigor of the examination; thus the passing rate for this scheme tends to be very high, and as a result the test scores tends to be negatively skewed. (Received September 21, 2011)

1077-VL-1997 **Daniel J. Ghezzi*** (danielghezzi@kings.edu), 144 White Birch Lane, Dallas, PA 18612. *What Does the Normality Test Indicate About the Coverage Probability of the One Sample t-based Confidence Interval?* Preliminary report.

When conducting a study to estimate the mean of a population variable, the researcher desires a sufficiently large sample size so as to estimate the mean with a sufficiently narrow confidence interval. Further, for large sample sizes, the Central Limit Theorem allows the researcher to assume, with high confidence, that the sampling distribution of the sample mean is approximately normal. When large sample sizes are not possible, the Central Limit Theorem does not apply, and the researcher performs a hypothesis test to determine whether it is safe to assume that the data was selected from a normally distributed variable. In this talk, I will analyze the relationship between the p-value of the Anderson-Darling Normality Test and the confidence interval's probability of covering the population mean. (Received September 21, 2011)

1077-VL-2001 **Steve Rhine** and **Colin Starr*** (cstarr@willamette.edu). *The Algebraic Thinking Project and the Encyclopedia of Algebraic Thinking.* Preliminary report.

There are hundreds of research articles in math education on the teaching and learning of algebra, but it is not always clear how to bring the results of this research into practice. Neither pre-service nor in-service teachers have the time or inclination to wade through thousands of pages of text to find what they need. The Algebraic Thinking Project has distilled the results of several hundred such articles into the Encyclopedia of Algebraic Thinking, a searchable online wiki-based encyclopedia that is intended to be easily accessible to pre- and in-service teachers. I will discuss the project and describe the encyclopedia. (Received September 21, 2011)

1077-VL-2185 **Salvatore Giunta*** (salvatoregiunta@mail.adelphi.edu), Adelphi University, 1 South Ave., Garden City, NY 11530. *The Braikenridge-Maclaurin Construction.* Preliminary report.

We present an applet that demonstrates the Braikenridge-Maclaurin theorem, using the Pascal line to show that we do not need six points to determine a conic section (only five are required). The applet will construct any conic section from five points in general position. We also discuss the history of the construction, including the correspondence between Braikenridge and Maclaurin, and the priority dispute that later arose. (Received September 21, 2011)

1077-VL-2278 **Becky E Hall*** (hallb@wcsu.edu), 181 White Street, Danbury, CT 06810. *Creating a Meaningful Mock Classroom Experience for Pre-Service Secondary Teachers.* Preliminary report.

It is difficult to imitate a real teaching experience for pre-service teachers prior to student teaching. If pre-service teachers present lessons to their peers on fundamental topics such as solving linear equations, their peers are bored by the content. This leads to an artificial classroom environment. This experience does not prepare the pre-service teacher for the actual classroom, and it is not informative for the rest of the class. In this talk, I will discuss concrete solutions to this problem that I have implemented in my *Teaching Mathematics in the Secondary Schools* course. (Received September 22, 2011)

1077-VL-2389 **Hong Yuan*** (hyuan@bmcc.cuny.edu) and **Xinsheng Lu** (xslu@shnu.edu.cn). *Mathematics Teacher Preparation in Shanghai for Grades 1-9.*

Fundamental understanding of mathematics is essential for preparing mathematics teachers for the common core curriculum. 2009 PISA results showed that students from Shanghai, China, scored 600 on the mathematics scale, leading the world, while students in the United States scored 487, lower than the OECD average score of 496. Much of Shanghai's success arises from the quality of its mathematics teachers. This presentation will introduce the mathematics teacher preparation program for Grades 1-9 at Shanghai Normal University (SHNU). SHNU is responsible for training 100 percent of pre-service elementary math teachers and 70 percent of pre-service middle school math teachers, as well as leading in-service math teachers in Shanghai. The content of mathematics courses for pre-service and in-service teachers will be reviewed. (Received September 22, 2011)

1077-VL-2396 **Kristina J Woodside*** (woodsidekj@jay.washjeff.edu), 50 S. Lincoln Street, Washington, PA 15301. *Tiling Deficient Chessboards with n-Polyominoes.*

An $m \times m$ board is called *deficient* if a 1×1 square is missing from anywhere on the board. An n-polyomino is a geometric shape formed by placing n equal squares edge to edge. With a fixed n, we prove that all deficient $m \times m$ boards can be tiled using n-polyominoes such that $m^2 - 1$ is divisible by n. We offer results for $n = 3$, $n = 4$, and $n = 5$, and we discuss our progress toward a generalization for all n. (Received September 22, 2011)

1077-VL-2402 **Oscar Levin*** (oscar.levin@unco.edu), School of Mathematical Sciences, University of Northern Colorado, Greeley, CO 80639. *Counting Liars and Truth-tellers: Binomial Identities through Logic Puzzles.*

We consider liar and truth-teller logic puzzles in which each speaker makes a claim regarding the number of liars or truth-tellers in the group. Our goal is to count the number of such puzzles, distinguishing between puzzles with no, multiple, or unique solutions. By counting these quantities in multiple ways, we uncover new combinatorial proofs of some well known (and lesser known) binomial identities. (Received September 22, 2011)

1077-VL-2411 **Timothy B. Flowers*** (flowers@iup.edu). *Asymptotic Behavior of some Strodt Polynomials.*

A recent paper by Borwein, Calkin, and Manna uses an idea of Strodt to generalize Bernoulli and Euler polynomials and view them as members of a polynomial family. We use these ideas to demonstrate the asymptotics of several families of non-uniform Strodt polynomials. We will also present some polynomials for which the asymptotics are not currently known. (Received September 22, 2011)

1077-VL-2526 **Tewodros Amdeberhan** (tamdeber@tulane.edu), **Valerio De Angelis*** (vdeangel@xula.edu) and **Victor Moll** (vhm@tulane.edu). *Wilf's conjecture.*

The complementary Bell numbers $\widetilde{B}(n)$ with exponential generating function $f(x) = \sum_{n=0}^{\infty} \frac{\widetilde{B}(n)}{n!} x^n = \exp(1-e^x)$ count the difference between the number of partitions of $\{1, 2, \ldots, n\}$ with an even number of blocks, and those with an odd number of blocks. H.Wilf conjectured that $\widetilde{B}(n) \neq 0$ for all $n > 2$. In this talk we discuss Wilf's conjecture, and we present an extension of the same conjecture to the family of super-exponential functions obtained by composing the function $x \mapsto 1 - e^x$ with itself. (Received September 22, 2011)

1077-VL-2545 **Malgorzata M Czerwinska*** (mmczerwi@olemiss.edu), Department of Mathematics, University of Mississippi, University, MS 38677-1848. *Exposed and strongly exposed points in symmetric spaces of measurable operators.*

Let $\mathcal{M}$ be a semifinite von Neumann algebra with a faithful, normal, semifinite trace τ, and E be a symmetric Banach function space on $[0, \tau(\mathbf{1}))$. The symmetric spaces $E(\mathcal{M}, \tau)$ of τ-measurable operators consists of all τ-measurable operators x for which the singular value function $\mu(x)$ belongs to E and is equipped with the norm $\|x\|_{E(\mathcal{M},\tau)} = \|\mu(x)\|_E$.

Let $(X, \|\cdot\|)$ be a Banach space, with the unit sphere and the unit ball denoted by S_X and B_X, respectively. An element $x \in S_X$ is an *exposed point* of B_X if there exists a normalized functional $F \in X^*$ which supports B_X exactly at x, i.e. $F(x) = 1$ and $F(y) \neq 1$ for every $y \in B_X \setminus \{x\}$. If, moreover, $F(x_n) \to 1$ implies $\|x - x_n\| \to 0$ for all sequences $\{x_n\} \subset B_X$, then x is a *strongly exposed point* of B_X and F *strongly exposes* B_X at x.

We will discuss the relationships between exposed and strongly exposed points of the unit ball of an order continuous symmetric function space E, and of the unit ball of the space of τ-measurable operators $E(\mathcal{M}, \tau)$. It is a joint work with Anna Kamińska and Damian Kubiak from the University of Memphis. (Received September 22, 2011)

1077-VL-2557 **Jean W. Richard*** (jrichard@bmcc.cuny.edu), BMCC CUNY The City University of New York, 199 Chambers Street, N524, New York, NY 10007, and **Hong Yuan**, BMCC CUNY The City University of New York, 199 Chambers Street, N523, New York, NY 10007. *Hua Loo-keng's Movement of Popularizing Mathematics and Quantitative Literacy (1958 to 1985).*

There is a close resemblance between Hua Loo-keng's movement of popularizing mathematics in China (1958 to 1985) and the current approach to quantitative literacy in the United States (or numeracy in Europe). Hua Loo-keng who was self-taught and one of the most brilliant mathematicians of the 20th century started in 1958 the movement of popularizing mathematics in Shandong provice, in China. This movement would spread to all the Chinese provinces and had the objectives to teach advanced mathematical concepts and their applications using innovative teaching methods to Chinese workers. The workers in various industries found applications for these mathematical concepts in their workplaces. Currently, in the United States quantitative literacy has the objectives to broaden individuals' capacities in applying mathematics in their daily lives and in their workplaces. This presentation will emphasize the similarities between Hua Loo-keng's movement and the current approach to quantitative literacy and how it can benefit from the experiences of the movement of popularizing mathematics. (Received September 22, 2011)

1077-VL-2695 **Elyn Rykken*** (elrykken@muhlenberg.edu). *A Student Inspired Capstone Experience.* Preliminary report.

Based on student feedback, our department has recently added a capstone requirement. Wanting to offer students flexibility, we allow our mathematics majors to select one of two options. They may choose between specially designated coursework and a research experience (which may include extending work done in an REU). We are in the initial phases of implementing this experience. Our new problem-solving course for the capstone will run for the first time this spring. This talk will focus on the development, organization and implementation of this senior-year experience. (Received September 22, 2011)

1077-VL-2826 **Charles Peter Funkhouser*** (cfunkhouser@fullerton.edu), Mathematics Department, California State University, P.O. Box 6850, Fullerton, CA 92834, and **Scott A. Annin** and **Miles Pfahl**. *Native American-based Mathematics Materials for Undergraduate Courses.* Preliminary report.

This project develops and researches undergraduate mathematics materials based in the culture and mathematics of Native American Peoples from the Western and Plains states. Mathematics topics include probability, number theory, transformational geometry, and pre-service elementary and secondary education-related content. These materials–both paper and electronic–are classroom ready, and are developed and piloted in consultation with tribes in the Pacific Northwest, the Rocky Mountains, and the Plains. This work is an NSF TUES Type 2 funded project. (Received September 22, 2011)

1077-VL-2859 **S Nihan Er*** (se102305@ohio.edu), 3571 Mt. Zion Rd., Apt. B, Jackson, OH 45640. *Perceptions of Turkish High School Mathematics Teachers Regarding the 2005 Curricular Changes and Their Effects on Mathematical Proficiency and University Entrance Exam Preparation.* Preliminary report.

The nationwide university entrance examination, known as the Student Selection and Placement Examination (ÖSYS), has an important place in the Turkish education system. Many students begin to study for this exam in the early years of their education. Student preparation accelerates during the high school years, especially the last year of the high school. Since 1985, the system of the ÖSYS and Turkish secondary school mathematics education program have been changed a few times. The purpose of this study is to investigate the perceptions of Turkish high school mathematics teachers regarding the 2005 curricular changes and their impact on students' mathematical proficiency and on students' success on the ÖSYS. Another aim is to explore possible differences among the perceptions of teachers who work in different types of schools (Anatolian, general, and science high schools) and have varying levels of teaching experience. The study involves surveying a large number of high school mathematics teachers and interviewing 21 teachers who have at least 10 years teaching experience. I will present some preliminary findings of the study. (Received September 22, 2011)

1077-VL-2879 **Rebecca Garcia***, Department of Mathematics and Statistics, Box 2206, Huntsville, TX 77341-2206. *Benjamin Franklin's Magic.* Preliminary report.

In several letters written in the mid-1700s, Benjamin Franklin produced his version of magic squares and what he called his "magical circle of circles." A magic circle is an arrangement of numbers in a circular grid with annuli and radii adding to a common number. In this talk, we will revisit Benjamin Franklin's magic circle of order 8 and answer various questions on their construction and enumeration using modern techniques in algebra. Then, we will discuss a method to construct the only known Franklin magic circle of order 16. (Received September 22, 2011)

1077-VL-2895 **Frederick A. Adkins*** (fadkins@iup.edu), Mathematics Department, Indiana University of Pennsylvania, Indiana, PA 15705, and **Yu-Ju Kuo** (yjkuo@iup.edu), Mathematics Department, Indiana University of Pennsylvania, Indiana, PA 15705. *Mentoring and Networking Mathematics and Science Majors in Applying Mathematics.* Preliminary report.

Activities, experiences, and results from creating a blended math and science cohort of upper-level undergraduates and graduate students in the M.S. in Applied Mathematics program are summarized. With funding support from the National Science Foundation's Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) program, we seek to expand recruitment, improve retention, and further develop student skills in applied mathematics. Each year, need-based scholarships support six new graduate students and ten new junior or senior undergraduates in addition to those already in the program. Scholarship program activities establish a supportive connection of master's students with undergraduates. Science majors take coursework towards a minor or double major in a mathematical area. Through networking of science and mathematics majors, cohort students participate in interdisciplinary activities, investigate careers or graduate schools, communicate with external mentors, and attend workshops on use of mathematical software and technology. Many sponsored events are open to the community and positively impact the local academic culture. On assessments, students report improved satisfaction with the academic environment, their selected major, and their career plans. (Received September 22, 2011)

1077-VL-2921 **Edward D. Smith*** (edward.smith@pima.edu), 2216 West Silverbell Tree Drive, Tucson, AZ 85745. *Communication: The Success to Online Courses.* Preliminary report.

With the expansion of online courses and degrees, instruction struggles for patterns of success. The instruction of online courses can be very limited in dimensional connections. Math courses often focus to the assignments and students rarely discuss the lessons. The design of this talk is to opinion of a strategy to engage more students with applications that require more than practice. (Received September 23, 2011)

2010 MATHEMATICS SUBJECT CLASSIFICATION

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ABSTRACTS

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