ABSTRACTS • Volume 36 • Number 3 • Summer 2015 • AMS

ABSTRACTS

of Papers Presented to the American Mathematical Society

Volume 36, Number 3, Issue 181 Summer 2015

Abstracts for

ISSN 0192-5857 Pages 869–1048

AMS

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* Indicates who will present the paper at the meeting.

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Abstracts of Papers Presented to the American Mathematical Society (ISSN 0192-5857) is published four times a year by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2294. The subscription price for Volume 36 (2015) is US$174.00 list, US$139.20 institutional member, US$104.40 individual member. Please add US$5 for delivery within the United States; US$11 for delilvery outside the United States. Subscription renewals are subject to late fees. See `www.ams.org/customers/macs-faq.html#journal` for more information. Periodicals postage paid at Providence, RI. POSTMASTER: Send address change notices to Abstracts of Papers Presented to the American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294 USA.

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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
1114	October 24–25, 2015	Fullerton, CA	EXPIRED	Vol 36, No. 4
1115	November 14–15, 2015	New Brunswick, NJ	EXPIRED	Vol 36, No. 4
1116	January 6–9, 2016	Seattle, WA	EXPIRED	Vol 37, No. 1
1117	March 5–6, 2016	Athens, GA	January 19	Vol 37, No. 2
1118	March 19–20, 2016	Stony Brook, NY	February 2	Vol 37, No. 2
1119	April 9–10, 2016	Salt Lake City, UT	February 16	Vol 37, No. 2
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1121	September 24–25, 2016	Brunswick, ME	July 19	Vol 37, No. 3
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1123	October 28–30, 2016	Minneapolis, MN	August 30	Vol 37, No. 4
1124	November 12–13, 2016	Raleigh, NC	September 13	Vol 37, No. 4
1125	January 4–7, 2017	Atlanta, GA	TBA	Vol 38, No. 1
1126	March 10–12, 2017	Charleston, SC	TBA	TBA
1127	April 1–2, 2017	Bloomington, IN	TBA	TBA
1128	April 22–23, 2017	Pullman, WA	TBA	TBA
1129	May 6–7, 2017	New York, NY	March 21	TBA
1130	July 24–28, 2017	Montréal, Canada	TBA	TBA

CHICAGO, IL, October 2–4, 2015

Abstracts of the 1112th Meeting.

00 ► General

1112-00-34 **Eyad Massarwi*** (eyadmassarwi@gmail.com), 6214 S Narragansett Ave Unit 1N, Chicago, IL 60638, and **Paul Musial** (pmusial@csu.edu). *A Stieltjes Type Extension of the L^r-Perron Integral.*

We explore properties of L^r-derivates with respect to a monotone increasing Lipschitz function. We then define L^r-ex-major and L^r-ex-minor functions with respect to a monotone increasing Lipschitz function and use these to define a Perron-Stieltjes type integral which extends the integral of L.Gordon. (Received June 14, 2015)

1112-00-86 **Stewart E. Brekke*** (stewabruk@aol.com), 2900 Maple ave, Downers Grove, IL 60515. *Constants of Convergences and Divergences both Mathematical and Physical.* Preliminary report.

Lines which approach each other, sometimes ending in a point are convergent lines. Lines which move away from each other, sometimes starting in a point, are called divergent lines. These lines when convergent approach each other measured by an angle called an angle of convergence. Lines which move away from each other measured by an angle of divergence. These angles do not change and therefore are constants. For example two straight lines $y = x + 1$ and $y = 2x$ converge at P(1,2) as x approaches 1. The angle of convergence at P(1,2) as 26.57 degrees.Again, this angle does change. In the physical world the plot of proton versus neutron numbers of light and heavy nuclei diverges with a divergence angle of appox. 11.4 degrees. This number is a constant and does not change. Physical science graphs are many which have these constant angles of convergence and divergence all of which do not change over time. Therefore, a new manner of looking at mathematical convergences and divergences should be initiated. (Received July 20, 2015)

1112-00-245 **Tefjol Pllaha*** (tefjol.pllaha@gmail), 385 Bob-O-Link Dr, Lexington, KY 40503.
Extension Theorems for Sublinear Codes.

The MacWilliams extension theorem classifies Hamming isometries of linear codes over finite fields. The result was extended to linear codes over finite Frobenius rings and for linear codes over finite Frobenius modules. Recently it has been shown that for sublinear codes up to a certain length a similar extension property holds true with respect to the Hamming weight. We investigate the extension property for additive codes over rings and for additive codes over fields with respect to Rosenbloom-Tsfasman weight. (Received August 05, 2015)

1112-00-250 **Edray H Goins**, **Luis A Melara** and **Alejandra Alvarado*** (aalvarado2@eiu.edu), Eastern Illinois University, Department of Mathematics and Computer Scienc, 600 Lincoln Ave., Charleston, IL 61920. *Approximating Coefficients of Shabat Polynomials.*

Preliminary report.

In 1984, Alexander Grothendieck, inspired by a result of Gennadii Belyĭ from 1979, constructed a finite, connected planar bipartite graph via rational functions $\mathbb{P}^1(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$ with critical values $\{0, 1, \infty\}$ by looking at the inverse image of the triangle formed by these three points. He called such graphs Dessins d'Enfants. Conversely, Riemann's Existence Theorem implies that every finite, connected planar graph arises in this way. We are interested in constructing Shabat Polynomials (generalized Chebyshev polynomials), the Belyĭ functions corresponding to trees. This construction comes down to finding the roots of a system of nonlinear equations. (Received August 05, 2015)

1112-00-277 **Amrita Acharyya**, **Jon M Corson** and **Bikash C Das*** (bikash.das@ung.edu).
Cofinite Graphs and Groupoids and their Profinite Completions.

We define cofinite graphs and cofinite groupoids in a unified way that extends the notion of cofinite groups introduced by B. Hartley. The common underlying structure of all these objects is that they are directed graphs endowed with a certain type of uniform structure, that we call a cofinite uniformity. We begin by exploring the fundamental theory of cofinite directed graphs in full generality. The general theory turns out to be almost completely analogous to that of cofinite groups. For instance, every cofinite directed graph has a unique completion which is a compact cofinite direct graph. Moreover, compact cofinite directed graphs are precisely the profinite directed graphs, i.e., projective limits of finite discrete topological directed graphs. We then apply the general theory to directed graphs with additional structure such as graphs (in the sense of Serre) and groupoids, thus leading to the notions of cofinite graphs and cofinite groupoids. Cofinite groupoids with only finitely many identities behave much the same as cofinite groups, which are the same thing as cofinite groupoids with a single identity. However the situation for cofinite groupoids with infinitely many identities is more complicated. (Received August 06, 2015)

1112-00-280 **Amrita Acharyya*** (amrita.acharyya@utoledo.edu), **Jon M Corson** and **Bikash C Das**. *Coverings of Profinite Graphs.*

We define a covering of a profinite graph to be a projective limit of a system of covering maps of finite graphs (Our finite graphs are graphs in the sense of Serre). With this notion of covering, we develop a covering theory for profinite graphs which is in many ways analogous to the classical theory of coverings of abstract graphs. For example, it makes sense to talk about the lifting criterion of a map of profinite graphs. Also we show that universal cover of a connected profinite graph always exists and is unique. We define the profinite fundamental group of a profinite graph and show that a connected cover of a connected profinite graph is the universal cover if and only if its profinite fundamental group is trivial. (Received August 06, 2015)

1112-00-369 **Avery Beau Wolinsky*** (bwolinsky@kccapitalmanagement.com), 212 Bluffwood Drive, Danville, KY 40422. *World Record Largest Mersene Prime Exponent Discoverer.*

The Largest World Record Setting Mersene Prime $2^P - 1$ Conjecture Leads to the Primality of a $3/2^2x$ Primality for all Numbers Included in the Enclosed Series (Received August 09, 2015)

1112-00-386 **Francisco-Javier Cirre** (jcirre@mat.uned.es) and **Peter Turbek*** (turbek@purduecal.edu). *The number of real ovals of a cyclic cover of the sphere.*

A compact Riemann surface X which is a cyclic cover of degree n of the Riemann sphere has a defining equation of the form $y^n = f(x)$ where f is a complex polynomial. If f has real coefficients then complex conjugation σ leaves X invariant. The fixed point set of σ in X consists of a disjoint union of simple closed curves, called *ovals*. In this paper we determine a procedure to count the exact number of ovals of σ in terms of the multiplicities of the real roots of f. (Received August 09, 2015)

1112-00-500 **Nitesh V Chawla*** (nchawla@nd.edu). *Coupled: Link Prediction in Coupled Networks.*
We study the problem of link prediction in *coupled networks*, where we have the structure information of one (source) network and the interactions between this network and another (target) network. The goal is to predict the missing links in the target network. The problem is extremely challenging as we do not have any information of the target network.

We propose a unified framework, CoupledLP, to solve the problem. Given two coupled networks, we first leverage atomic propagation rules to automatically construct implicit links in the target network for addressing the challenge of target network incompleteness, and then propose a Coupled Factor Graph to incorporate the meta-paths extracted from the coupled part of the two networks for transferring heterogeneous knowledge. We evaluate the proposed framework on two different genres of datasets: disease-gene (DG) and mobile social networks. The proposed problem of coupled link prediction and the corresponding framework demonstrate both the scientific and business applications in biology and social networks. (Received August 10, 2015)

1112-00-524 **Alexander Lichtman*** (lichtman@uwp.edu), Alexander Lichtman, 5 Ashwood Ct, Madison, WI 53719. *Embedding of some classes of group rings in division rings.*
Preliminary report.
We prove that the group rings of some classes of groups contain no zero divisors and can be imbedded into division rings. We study the properties of these division rings. (Received August 10, 2015)

1112-00-571 **Zoltan Toroczkai*** (toro@nd.edu), University of Notre Dame, Department of Physics, 225 NSH, Notre Dame, IN 46556. *Constrained Graph Construction Problems for Network Modeling.*
Here I will discuss some of the fundamental questions related to graph ensemble based modeling of empirical networks. In particular I will focus on degree based and joint-degree based graph existence, construction, sampling and counting problems and to a lesser extent, on soft-constraints based modeling using exponential random graph ensembles. (Received August 11, 2015)

1112-00-680 **Risi Kondor*** (risi@cs.uchicago.edu). *Multiresolution Matrix Factorization.*
The common thread in Multiresolution Analysis, Fast Multipole Methods, Multigrid, and Structured Matrices is that they all exploit structure (specifically, hierarchical structure) in the underlying domain to speed up computations. In Statistical and Machine Learning problems these methods have had less influence, because the underlying structure is less apparent.

In this talk we describe Multiresolution Matrix Factorization (MMF), which reinterprets Orthogonal Multiresolution Analysis as a matrix operation, and hence generalizes it to almost any finite space whose metric structure can be described by a symmetric matrix. We show that MMF can be successfully applied in a range of practical tasks from matrix compression to preconditioning large linear systems. The work presented in this talk is joint with Nedelina Teneva and Pramod K Mudrakarta. (Received August 18, 2015)

1112-00-681 **Sara Jamshidi*** (jamshidi@math.psu.edu), The Pennsylvania State University, Department of Mathematics, 109 McAllister Bldg, State College, PA 16802-6401. *Object classification based on the representativeness heuristic.*
Automated object classification generally fails when the collection of sensed features are sufficiently distinct from the known collections within a given dictionary. We present an uncertainty model arising from a (locally distributive) lattice algebra generated from a given object poset whose order structure is based on generality, known as hyponymy in semantic field theory. Probabilistic decisions are based on principle filters and a weaker notion of complementation within the object poset. This method gives rise to a particular kind of formal concept analysis inspired by the representativeness heuristic. From the perspective of the user, this can allow for good approximations of classifications when the correct answer is absent in the dictionary.

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1112-00-682 **David T. Anderson*** (dtanders@facstaff.wisc.edu), University of Wisconsin-Madison. *Similarities and differences between stochastic and deterministic mod= els of reaction networks.*
If the abundances of the constituent molecules of a biochemical re= action system are sufficiently high then their concentrations are typically= modeled by a coupled set of ordinary differential equations (ODEs). If, h=

owever, the abundances are low then the standard deterministic models do no= t provide a good representation of the behavior of the system and stochasti= c models are used. It is important to understand the similarities and diff= erences in the solutions that come from each modeling choice. I will prese= nt two results. The first gives conditions on the network that guarantee b= oth models produce quite stable behavior. The second set of conditions gua= rantees a special form of stability for the ODE model, but a form of instab= ility for the stochastic model. (Received August 18, 2015)

1112-00-683 **Jonathan Weare*** (weare@uchicago.edu), University of Chicago. *Understanding stratification approaches to Monte Carlo simulation.*

I will discuss an ensemble sampling scheme based on a decomposition of the target average of interest into subproblems that are individually easier to solve and can be solved in parallel. The most basic version of the scheme computes averages with respect to a given density and is a generalization of the Umbrella Sampling method for the calculation of free energies. We have developed a careful understanding of the accuracy of the scheme that is sufficiently detailed to explain the success of umbrella sampling in practice and to suggest improvements including adaptivity. For equilibrium versions of the scheme we have developed error bounds that reveal the existing understanding of umbrella sampling is incomplete and leads to a number of erroneous conclusions about the scheme. Our bounds are motivated by new perturbation bounds for Markov Chains that we recently established and that are substantially more detailed than existing perturbation bounds for Markov chains. They demonstrate that equilibrium umbrella sampling is robust in the sense that in limits in which the straightforward approach to sampling from a density becomes exponentially expensive, the cost to achieve a fixed accuracy with umbrella sampling can increase only polynomially. (Received August 26, 2015)

1112-00-684 **Kate Juschenko*** (kate.juschenko@gmail.com), Northwestern University. *Subgroups of the interval exchange transformation group.*

I will discuss several classes of subgroups of interval exchange transformation group (IET). These subgroups come from topological full groups of corresponding rotations. Amenability and absence of free subgroups are the main questions we are going to discuss with relation to the subgroups of IET. (Received August 26, 2015)

01 ► History and biography

1112-01-5 **Donald A. Sokol*** (vsokol@sbcglobal.net), 11S.047 Palisades Rd., Burr Ridge, IL 60527. *The Uncertainty Principle of the Pythagorean Theorem.*

It's not widely recognized that circa 1800 B.C., the Babylonian algorithm for the integer triple, $a^2 + b^2 = c^2$, was constructed as $a = 2(x + y)y$; $c = a + x^2$ and $b = \sqrt{c^2 - a^2}$ and later updated to $b = c - 2y^2$ (where $x = 1$, $y = 1$ then $a = 4$, $c = 5$ and $b = 3$). Euclid later, circa 300 B.C., modified this algorithm to $a = 2xy$, $c = x^2 + y^2$ and $b = x^2 - y^2$ with appropriate caveats. (Where $x = 2$, $y = 1$ then $a = 4$, $c = 5$, and $b = 3$). Still later, circa 2000 A.D., it was shown that $a = 2(x - y)y$, $c = -a + x^2$ and $b = c - 2y^2$. (Where $x = 3$, $y = 1$ then $a = 4$, $c = 5$ and $b = 3$). At least six other algorithms using various combinations of $+/-x$, and $+/-y$ in "a" are possible without redundancy. Other better known algorithms for integer triples in x and y include reciprocal pairs Ala Robson and Sierpinski's modified Euclidian based algorithm. The result is that one cannot easily determine which algorithm was used to produce a specific integer triple. (Received August 04, 2015)

1112-01-12 **Yousuf Kerai*** (ykerai@gmail.com), 180-B Shabbirabad, Syedna Tayyeb Road, Karachi, Sindh 75350, Pakistan, and **Glen Van Brummelen** and **Taro Mimura**. *Al-Samaw'al's Curious Approach to Trigonometry.*

The 12th-century mathematician, Ibn Yahya al-Samaw'al al-Maghribi, now better known for his algebra, wrote the extensive treatise, Exposure of the Errors of the Astronomers. This fascinating under-studied work, containing criticisms of a number of astronomers, provides an interesting study of debates over the proper practice of medieval astronomy. In particular, al-Samaw'al stresses consistency and purity of method. One of his objections is to the methods that had been used to determine the geometrically unattainable sine of one degree in Ptolemy's Almagest as well as in later Muslim works. To avoid this seemingly unavoidable problem, al-Samaw'al presents an alternate trigonometric table. (Received April 29, 2015)

1112-01-18 **Glen R Van Brummelen*** (gvb@questu.ca), Quest University, 3200, Squamish, BC V8B 0N8, Canada. *Al-Kashi's Two Methods for Finding* $\sin 1^\circ$. Preliminary report.

Jamshīd al-Kāshī, an early 15th century astronomer and mathematical prodigy, solved the problem of finding $\sin 1^\circ$ twice: once early in his career in the *Khāqānī Zīj*, and once late in life. The first solution followed

traditional geometric methods, although reaching a level of precision unbeaten in pre-modern cultures; the second was algebraic and featured the use of an ingenious method related to fixed point iteration. We shall explore the changing disciplinary boundaries highlighted by these methods, note its impact in 18th-century India, and make parallels to similar developments in late 16th-century Europe. (Received May 25, 2015)

1112-01-50 **Stanisław Domoradzki** (domoradz@ur.edu.pl) and **Margaret Stawiska-Friedland*** (stawiska@umich.edu), 416 Fourth St., Ann Arbor, MI 48103. *The road to the Retract Principle: Tadeusz Ważewski (1896-1972) and his early work in topology.* Preliminary report.

In 1947, Tadeusz Ważewski, a Polish mathematician, proved his Retract Principle, a profound application of topology to ordinary differential equations. It was subsequently generalized by many authors and gave rise to the theory of Conley index. In this talk we will discuss Ważewski's Retract Principle and his earlier works which set a course for this important result. We will present some unpublished documents. (Received July 06, 2015)

1112-01-51 **Eli Maor*** (elimaor@earthlink.net), 9407 Natchez Avenue, Morton Grove, IL 60053. *Infinities where you Least Expect them.*

A trip to Antarctica leads to some unexpected transfinite discoveries that would have made Cantor happy. (Received July 06, 2015)

1112-01-52 **Stephen M. Stigler*** (stigler@uchicago.edu), Statistics Department, 5734 University Ave, Chicago, IL 60637. *The Seven Pillars of Statistical Wisdom.*

What is statistics – how does it differ from mathematics and computer science as a discipline? Taking a historical perspective I will specify seven great ideas that have evolved to form the support, the pillars of our discipline. The presentation of these seven will be in historical context, but this is not intended to be exclusively a historical talk. They are intended to show the relevance of history for the understanding of a mathematical science. They will illuminate the ways the use of mathematics can lead to unsuspected paradoxes; for example, how wrong an elementary result of Euclid's can be for the modern age, the surprising roles symmetry and additivity can play in agricultural experimentation, and the counter-intuitive behavior of accumulating statistical information. (Received July 07, 2015)

1112-01-53 **Amanda Marie Steckly*** (asteckly@luc.edu), 7622 W. Arcadia St., Morton Grove, IL 60053, and **Marie Turano** (mturano@luc.edu) and **Kathryn Pantell** (kpantell@luc.edu). *The Continuing Influence of Sophie Germain.* Preliminary report.

Sophie Germain's life and her mathematics have served as a continuing inspiration for research and for motivation especially for women mathematicians. Her significant contribution to the study of Fermat's Last Theorem incorporated "Germain primes", where p and 2p+1 are both prime. Her influence continues to this day with attempts to prove that there are infinitely many Germain primes, and related topics including Cunningham chains, twin primes, Mersenne primes, and diverse applications of Germain primes. (Received July 07, 2015)

1112-01-54 **Anne Leggett McDonald*** (amcdona@luc.edu), 2032 Seward St, Evanston, IL 60202. *1600 Women with U.S. Doctorates in the Mathematical Sciences, 1960-1979. Preliminary report.*

For a number of years I have been building a database of the women who earned doctorates (in almost all cases, PhDs) in the mathematical sciences from U.S. educational institutions over the two decades from 1960 through 1979. My collaborator Bettye Anne Case and I were interested in analyzing this cohort for a variety of reasons. Women up to 1959 had been well studied in the books written by Green & LaDuke and by Murray, and we wanted to see what the career paths had been for women with more recent degrees who had had adequate time to become established in their chosen arenas. Those two decades were also interesting times to be in graduate school, due to the rise of feminism and other social and cultural factors.

I will present some statistical information about this cohort and give a rough accounting of the careers pursued by these women, most of whom not too surprisingly had (and still have) academic careers. I will discuss some of the difficulties I've run into while building the database. But happily, given the wonders of the Internet, I have been able to find at least some information past the earned doctorate on a large percentage of the women in the database. (Received July 09, 2015)

1112-01-288 **Steven Hurder*** (hurder@uic.edu), Department of Math (m/c 249), University of Illinois at Chicago, 322 SEO, 851 S. Morgan Street, Chicago, IL 60607-7045. *The Semicentennial Anniversary of University of Illinois at Chicago.* Preliminary report.

Fifty years ago, the "Chicago Circle Campus of the University of Illinois" was established, by converting the Navy Pier college for returning veterans into a research university located in downtown Chicago. This panel will trace some of the history and development of what is now the Department of Mathematics, Statistics, and Computer Science at University of Illinois at Chicago. (Received August 06, 2015)

1112-01-380 **Henry P Towsner*** (htowsner@math.upenn.edu), Department of Mathematics, David Rittenhouse Lab., 209 South 33rd Street, Philadelphia, PA 19104. *Computable Information in Ultraproducts.* Preliminary report.

Proofs involving ultraproducts are often described as non-constructive. In fact, almost all applications of ultraproducts to other areas of mathematics prove theorems which could have computable bounds, and, viewed correctly, the ultraproduct proof gives computable bounds.

These proofs often use highly non-computable statements as intermediate steps in the proof. However we can interpret these non-computable statements about the ultraproduct as more complicated but computable statements about the original structures. (Received August 09, 2015)

1112-01-381 **Drew Armstrong*** (armstrong@math.miami.edu), Department of Mathematics, University of Miami, Coral Gables, FL 33146. *What is a field?* Preliminary report.

I will discuss the history of the abstract field concept from Galois to Steinitz. (Received August 09, 2015)

03 ► Mathematical logic and foundations

1112-03-26 **Timothy McNicholl*** (mcnichol@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011. *Computable copies of lp spacces.*

Suppose p is a computable real so that $p \geq 1$. It is shown that the halting set computes a surjective linear isometry between any two computable copies of ℓ^p. It is also shown that this result is optimal in that when $p \neq 2$ there are two computable copies of ℓ^p with the property that any oracle that computes a linear isometry of one onto the other must also compute the halting set. These results hold in both the real and complex case. (Received June 02, 2015)

1112-03-31 **Bernard Anderson**, **Barbara Csima** and **Karen Lange*** (karen.lange@wellesley.edu). *Bounded low and high sets.*

Anderson and Csima defined a jump operator, the *bounded jump*, with respect to bounded Turing (or weak truth table) reducibility. They previously showed that the bounded jump is closely related to the Ershov hierarchy and that it satisfies an analogue of Shoenfield jump inversion. We now explore bounded low and high sets. We also consider whether the analogue of the Jump Theorem holds for the bounded jump; do we have $A \leq_{bT} B$ if and only if $A^b \leq_1 B^b$? We show the forward direction holds but not the reverse. (Received June 10, 2015)

1112-03-37 **Jeffry L. Hirst*** (hirstjl@appstate.edu), Department of Mathematical Sciences, ASU Box 32092, Appalachian State University, Boone, NC 28608. *Uniform reduction and reverse mathematics.* Preliminary report.

This talk will describe preliminary efforts to clarify the relationship between reverse mathematics and uniform reductions. A report on the recent Dagstuhl Seminar 15392 on Weihrauch reducibility and reverse analysis will be included. (Received June 22, 2015)

1112-03-80 **Peter A Cholak*** (cholak@nd.edu) and **Charlie McCoy** (mccoy@up.edu). *Effective Prime Uniqueness.*

Assuming the obvious definitions we show that a decidable model that is effectively prime is also effectively atomic. This implies that two effectively prime (decidable) models are computably isomorphic. This is in contrast to the theorem that there are two atomic decidable models which are not computably isomorphic. One corollary of the proof is that the prime uniqueness theorem holds in RCA_0. (Received July 17, 2015)

1112-03-144 **Nathanael L. Ackerman**, **Cameron E. Freer*** (freer@mit.edu) and **Robert S. Lubarsky**. *Feedback Turing Computability, and Turing Computability as Feedback.*

The notion of a feedback query is a natural generalization of choosing for an oracle the set of indices of halting computations. Notice that, in that setting, the computations being run are different from the computations in the oracle: the former can query an oracle, whereas the latter cannot. A feedback computation is one that can

query an oracle, which itself contains the halting information about all feedback computations. Although this is self-referential, sense can be made of at least some such computations.

In this paper, we study feedback around Turing computability. In one direction, we examine feedback Turing machines, and show that they provide exactly hyperarithmetic computability. In the other direction, Turing computability is itself feedback primitive recursion (at least, one version thereof). (Received July 29, 2015)

1112-03-170 **Valentina Harizanov*** (harizanv@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *Computable categoricity and Scott families.* Preliminary report.

A computable structure A is called computably categorical if for every computable isomorphic structure B there is a computable isomorphism from A to B. More generally, A is relatively computably categorical if for every isomorphic structure B there is an isomorphism from A to B, which is computable relative to the atomic diagram of B. Relative computable categoricity of A is equivalent to the existence of computably enumerable Scott family of existential formulas. Goncharov was the first to show that computable categoricity does not imply relative computable categoricity. His example was a graph. More examples of such structures in natural classes followed, even when the structures are 1-decidable. Here, we present a new example of such a structure that is a Fraïssé limit. This is joint work with E. Fokina and D. Turetsky. (Received August 01, 2015)

1112-03-225 **Denis R. Hirschfeldt** and **Carl G. Jockusch***, jockusch@math.uiuc.edu, and **Rutger Kuyper** and **Paul E. Schupp**. *Coarse reducibility and algorithmic randomness.*

A set $D \subseteq \omega$ is a *coarse description* of a set $A \subseteq \omega$ if the symmetric difference of A and D has asymptotic density 0. We say that B is *nonuniformly coarsely reducible to* A (written $B \leq_{nc} A$) if every coarse description of A computes a coarse description of B. We say that B is *uniformly coarsely reducible to* A (written $B \leq_{uc} A$) if there is a fixed Turing functional Φ which witnesses that $B \leq_{nc} A$. We show that the Turing degrees are embeddable in the uniform coarse degrees and also in the nonuniform coarse degrees. We prove that if $X \leq_T 0'$ is 1-random and A is computable from every coarse description of X, then A is K-trivial. Therefore every set computable from every coarse description of a weakly 2-random set is computable. In the other direction, we show that for every 1-random set $X \leq_T 0'$, there is a promptly simple set computable from every coarse description of X, and also not every K-trivial set is computable from every coarse description of some 1-random set. We show that if $X \oplus Y$ is weakly 3-random, then the nonuniform coarse degrees of X and Y form a minimal pair. (Received August 04, 2015)

1112-03-229 **Caroline Terry*** (cterry3@uic.edu). *Zero-one laws for edge weighted graphs.*

Fix integers $k \geq 3$ and $q \geq 2$, and define $\mathcal{L}_q = \{R_1, \ldots, R_q\}$ to be the language consisting of q binary relation symbols. For each $n \in \mathbb{N}$, define $F_{k,q}(n)$ to be the set of $\mathcal{L}_q$-structures with universe $[n] = \{1, \ldots, n\}$ such that each R_i is symmetric and irreflexive, and such that for any set of k points $X \subseteq [n]$, $\sum_{x \neq y \in X} |\{i : R_i(x, y)\}| \leq q$. We present results on the approximate asymptotic structure of $F_{k,q}(n)$ for various values of k and q. In special cases of k and q we refine these results to yield a logical 0-1 law. These results generalize existing 0-1 laws for the families of finite K_n-free graphs for $n \geq 3$. This is joint work with Dhruv Mubayi. (Received August 05, 2015)

1112-03-242 **Wesley Calvert**, **Andrey N. Frolov**, **Valentina Harizanov** and **Julia F. Knight*** (knight.1@nd.edu), 255 Hurley Hall, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556, and **Charles McCoy**, **Alexandra Soskova** and **Stefan Vatev**. *Strong jump inversion.* Preliminary report.

A structure $\mathcal{A}$ admits *strong jump inversion* if for any set X, if $\mathcal{A}$ has a copy that is low over X, then it has an X-computable copy. In particular, if there is a low copy, then there is a computable copy. Downey and Jockusch [**1**] showed that every Boolean algebra admits strong jump inversion. The second author [**2**] showed that certain linear orderings do, in particular, those in which every element lies on a discrete set, and either the discrete sets are all finite, with a bound on the sizes, or else, any infinite interval properly contains maximal discrete sets of size at least n for all n. There are other examples: special kinds of trees, groups, and equivalence structures. We look for general conditions sufficient to account for many of these examples.

References

[1] R. Downey and C. G. Jockusch, "Every low Boolean algebra is isomorphic to a recursive one", *PAMS*, vol. 122(1994), pp. 871-880.

[2] A. N. Frolov, "Low linear orderings", *Journal of Logic and Computation*, vol. 22(2012), pp. 745-754.

(Received August 05, 2015)

1112-03-260 **David Marker*** (marker@uic.edu), Dept Mathematics (MC 249), University of Illinois at Chicago, 851 S. Morgan St., Chicago, IL 60607. *Remarks on uncountable recursively saturated real closed fields.*

We will discuss the following two results.

1) There is a family of $2^{\aleph_1}$ recursively saturated elementarily equivalent ω_1-like models of PA with isomorphic real closures.

2) For any Scott set S there is a recursively saturated real closed field where the types realized are exactly the types coded in S.

The first result is joint with James Schmerl and Charles Steinhorn. The second is joint with Alf Dolich, Julia Knight and Karen Lange. (Received August 06, 2015)

1112-03-295 **Meng-Che Ho*** (ho@math.wisc.edu), 480 Lincoln Drive, Madison, WI 53706. *Describing Groups.*

Recall that the index set of a computable structure is the set of indices for its computable copies. The calculation of the complexity of index set usually involves finding an optimal Scott sentence (a sentence in $L_{\omega_1,\omega}$ that describes the stucture up to isomorphism.) J. Knight and et al. determined the complexity of index sets of various structures.

In this talk, we focus on finding the complexity of index sets of various groups, generalizing methods that was previously used by J. Knight and et al. We found computable Scott sentences for various different groups or class of groups, including nilpotent groups, polycyclic groups, and the lamplighter group. In some of these cases, we also showed that the sentence we had are optimal. (Received August 07, 2015)

1112-03-340 **Russell G Miller*** (russell.miller@qc.cuny.edu), Mathematics Dept., Queens College - CUNY, 65-30 Kissena Blvd., Queens, NY 11367. *Hilbert's Tenth Problem for subrings of the rationals.*

For a ring R, Hilbert's Tenth Problem is the set $HTP(R)$ of polynomials $p \in R[X_1, X_2, \ldots]$ for which $p = 0$ has a solution in R. In 1970, Matiyasevich completed work of Davis, Putnam, and Robinson, giving a 1-reduction from the Halting Problem to $HTP(\mathbb{Z})$. We show that this method can succeed only on a measure-0 subclass of the class of all subrings of $\mathbb{Q}$, because the class of those R_W for which $W' \not\leq_1 HTP(R_W)$ has measure 1. (Here R_W is the subring in which just the primes in W have inverses. The usual measure on Cantor space is transferred to the class of all subrings of $\mathbb{Q}$ using this correspondence.) The proof uses a theorem from the Ph.D. thesis of Stuart Kurtz. (Received August 08, 2015)

1112-03-359 **Jason M Rute*** (jmr71@math.psu.edu), University Park, PA 16802. *Application of computable continuous model theory to a question in proof theory.*

There are many ways to express that a sequence converges. They range from the most explicit but least uniform—a rate of convergence; to the moderately explicit and moderately uniform—a bound on the number of jumps by epsilon; to the least explicit but most uniform—a bound of metastable convergence (which I will define in this talk).

Using proof theory, Kolhenbach showed that uniform metastable bounds can be computability extracted from the proof of a convergence theorem. Using model theory, Avigad and Iovino showed that metastable bounds of a convergence theorem are always uniform—but their methods do not provide a way to compute the bounds. Using computable analysis and computable model theory, I show that not only are the bounds always uniform, but they can computed from the statement of the theorem alone (without regards to the proof). (Received August 08, 2015)

1112-03-374 **James Freitag*** (freitagj@gmail.com), UCLA Mathematics Department, Box 951555, Los Angeles, CA 90095-1555, and **Rahim Moosa**. *Around Jouanolou-type Theorems.*

Around 20 years ago, Hrushovski built on a theorem of Jouanolou concerning hypersurface solutions to Pfaffian equations in order to prove that any differential variety with constant coefficients has either finitely many co-order one subvarieties or admits a nontrivial differential rational map to the constant field. Hrushovski's generaliation of Jouanolou's theorem allowed for a strong characterization of the possible algebraic relations between solutions of any order one ODE. In model theoretic terms, Hrushovski showed that any strongly minimal order one ODE is either nonorthogonal to the constants or has a trivial countably categorical forking geometry.

In this talk, I will explain several generalizations of Hrushovski's theorem. The first direction removes the assumption of constant coefficients, while the second generalizes the work to the case of several derivations. (Received August 09, 2015)

1112-03-424 **Barbara F Csima*** (csima@uwaterloo.ca) and **Matthew Harrison-Trainor**. *Degrees of Categoricity on a Cone.*

A degree of categoricity is, roughly speaking, the Turing degree of difficulty of computing isomorphisms between all computable copies of a given computable structure. Not all computable structures have a degree of categoricity, and we do not have a characterization of which Turing degrees are degrees of categoricity. In this talk, we discuss the notion of a structure having a degree of categoricity on a cone, that is, having a cone in the Turing degrees where the structure has a degree of categoricity relative to every degree in the cone. When we look at degrees of categoricity on a cone, the strange behavior disappears. (Received August 10, 2015)

1112-03-438 **Anand Pillay*** (apillay@nd.edu). *Bounded invariant equivalence relations and Borel cardinality (joint with K. Krupinski and T. Rzepecki).*

If E is an automorphism invariant equivalence relation on a sort in a saturated model of a countable theory, we call E bounded if it has at most continuum many classes. Such an equivalence relation E can be considered as an equivalence relation on the (Polish) space of complete types over a countable model and as such we can ask about its Borel cardinality. We prove that E is either type-definable (i.e. closed, so essentially trivial) or non smooth; and other related results. We use the topological dynamics of the automorphism group of a saturated model. (Received August 10, 2015)

1112-03-443 **Mariya I Soskova***, Sofia University, 5 James Bourchier Blvd, 112 Sofia, Bulgaria. *Defining the jump classes in the local structure of the enumeration degrees.*

Recent work by Slaman and Soskova has established that the local structure of the enumeration degrees, the degrees bounded by the first jump of the least degree, is an automorphism base for the global structure of the enumeration degrees. This motivates our interest in the question, which classes of degrees are first order definable in the local structure of the enumeration degrees. In previous work with Ganchev, we had established that the low enumeration degrees and the total enumeration degrees are locally definable. I will describe some recent work with Ganchev, in which the previous two results are applied to show the definability of all jump classes in the local structure of the enumeration degrees. (Received August 10, 2015)

1112-03-465 **Allen Gehret***, Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green Street, Urbana, IL 61801. *Towards a Model Theory for Logarithmic Transseries.*

The ordered valued differential field $\mathbb{T}$ of *logarithmic-exponential transseries* has recently been shown (by the authors of [1]) to have a good model theory, completing much of the program described in [1]. There it was also conjectured that the subfield $\mathbb{T}_{\log}$ of $\mathbb{T}$ of *purely logarithmic transseries* would also have a good model theory (model-completeness, NIP, etc.). In this talk I will report on my work on the model theory of $\mathbb{T}_{\log}$.

References

[1] Matthias Aschenbrenner, Lou van den Dries, and Joris van der Hoeven, *Towards a model theory for transseries*, ***Notre Dame Journal of Formal Logic***, vol. 54 (2013), no. 3-4, pp. 279–310.

(Received August 10, 2015)

1112-03-466 **Damir Dzhafarov** (damir.dzhafarov@uconn.edu), **Ludovic Patey** (ludovic.patey@gmail.com), **Reed Solomon*** (david.solomon@uconn.edu) and **Linda Brown Westrick** (linda.westrick@gmail.com). *RT^1_k, SRT^2_ℓ and sc-reducibility.* Preliminary report.

We review the notion of sc-reducibility and discuss recent work showing that if $k > \ell \geq 2$, then RT^1_k is not sc-reducible to SRT^2_ℓ. (Received August 10, 2015)

1112-03-474 **Sylvia Carlisle*** (carlisle@rose-hulman.edu). *Types in the theory of $\mathbb{R}$-trees.* Preliminary report.

An $\mathbb{R}$-tree is metric space such that between any two points there is a unique geodesic segment. An $\mathbb{R}$-tree is *richly branching* if the set of points with at least 3 branches of a given length is dense. We study $\mathbb{R}$-trees as metric structures using an appropriate continuous signature. The theory rb$\mathbb{R}$T of richly branching $\mathbb{R}$-trees is the model companion to the theory of $\mathbb{R}$-trees; it is complete, has quantifier elimination, and is stable but not superstable. Here, we discuss types and type spaces for rb$\mathbb{R}$T. We describe the independence relation, canonical bases and principal types of finite tuples. We consider the d-metric on types and show that the space of 2-types over the empty set is nonseparable. (Received August 10, 2015)

1112-03-476 **Cameron Donnay Hill*** (cdhill@wesleyan.edu), Dept. of Mathematics and Comp. Science, Wesleyan University, 265 Church Street, Middletown, CT 06459. *Sufficient conditions for tight control of the asymptotics of definable sets.*

In 1-dimensional and N-dimensional asymptotic classes, Elwes, Macpherson, and Steinhorn have formulated a context in which the sizes of definable sets in finite structures are under control as tightly as one might reasonably hope in light of the Lang-Weil estimates for varieties over finite fields. In this talk, I will discuss sufficient conditions for "1-dimensional asymptotic-ness," and broadly similar conditions (related to Hrushovski's pseudo-finite dimensions), that arise from structural Ramsey theory and the study of 0,1-laws for first-order logic. (Received August 10, 2015)

1112-03-490 **Gabriel Conant*** (gconan2@uic.edu). *Unstable theories without the strict order property.*

We consider several classes of unstable theories without the strict order property, each of which is motivated by important examples of homogeneous structures. Our main focus will be on theories equipped with an abstract notion of free amalgamation, which reflects the behavior of free amalgamation of relational structures. We give characterizations of simplicity for these theories, and present partial results and questions on the role of forking and thorn-forking in the non-simple case. (Received August 10, 2015)

1112-03-553 **Damir D Dzhafarov*** (damir@math.uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269, and **Stephen Flood**, **Reed Solomon** and **Linda Brown Westrick**. *Effectiveness of the dual Ramsey's theorem.*

The dual Ramsey's theorem (DRT) states that given a nice finite coloring of all partitions of ω into k parts, there is a partition of ω into infinitely many parts, every coarsening of which into k parts has the same color. The niceness condition on the coloring here is a topological one, usually having the property of Baire or being Borel. However, most work on DRT in computability theory has focused on the case where the colorings are topologically open. We show that, in the case of colorings with the property of Baire, the latter is actually not a restriction as far as logical strength is concerned, as the two versions are equivalent over RCA_0. By contrast, we show that the Borel formulation is only equivalent to the open one over ATR_0. While the Borel DRT implies ATR_0, it is unknown whether the Baire DRT does as well, so by the preceding result this question is equivalent to whether or not the Borel and Baire versions of DRT are equivalent. We also identify several combinatorial variants and fragments of the Borel DRT, and study their relationships to the Carlson-Simpson lemma, and to the stable Ramsey's theorem for pairs. This is joint work with Stephen Flood, Reed Solomon, and Linda Brown Westrick. (Received August 11, 2015)

1112-03-563 **Rutger Kuyper*** (mail@rutgerkuyper.com), Department of Mathematics, University of Wisconsin, 480 Lincoln Dr., Madison, WI 53706-1388. *A measure of uniformity.*

There are two well-known ways to compare the difficulty of two *mass problems*, i.e. of sets $\mathcal{A}, \mathcal{B} \subseteq \omega^\omega$. The first of these, *Medvedev reducibility*, says that $\mathcal{A}$ reduces to $\mathcal{B}$ if there is a single Turing functional Φ such that $\Phi(\mathcal{B}) \subseteq \mathcal{A}$. On the other hand, we say that $\mathcal{A}$ *Muchnik reduces* to $\mathcal{B}$ if every element of $\mathcal{B}$ computes an element of $\mathcal{A}$.

These two reducibilities can be seen as two opposite extremes: Medvedev reducibility is as uniform as possible, while Muchnik reducibility is as non-uniform as possible. Therefore, if some reduction is not completely uniform, one can only conclude that it is a Muchnik reduction, even though intuitively it might feel like there is some uniformity contained in the reduction.

We propose a hierarchy of reducibilities between Medvedev and Muchnik reducibility, which capture different levels of uniformity. We say that $\mathcal{A}$ *n-uniformly reduces* to $\mathcal{B}$ if there is a Π^0_n-cover $\mathcal{V}_0, \mathcal{V}_1, \dots$ of $\mathcal{B}$ such that the elements from $\mathcal{B} \cap \mathcal{V}_i$ uniformly compute elements from $\mathcal{A}$. We use this concept to measure the uniformity of some well-known Muchnik reductions. (Received August 11, 2015)

1112-03-600 **Wesley C Calvert*** (wcalvert@siu.edu), Department of Mathematics, Mail Code 4408, 1245 Lincoln Drive, Southern Illinois University, Carbondale, IL 62901, and **Vina Castelli**. *What could we be, if not rational?* Preliminary report.

Mathematicians determine truth by finding deductive proofs from some appropriate axiomatic system — perhaps ZFC, or PA. This is emphatically not how people think. The fact that people are rational does not prevent logicians from modeling their thought.

Indeed, the study of "mental models" seems to invite logical analysis. People empirically seem to start with axioms, construct models of those axioms, and reason by checking truth in these models. Many parts of this are beyond the logical, but it is altogether consistent with logical practice to explore how an incomplete theory controls its family of models.

The recent master's thesis of Vina Castelli suggests how this might be done. Castelli demonstrated an essential increment in cognitive load for elementary students to learn division with remainder by showing that it is not provably possible in a weak fragment of first-order arithmetic that does appear to prove most things that students learn earlier. The present, largely speculative talk, will suggest how work like Castelli's might allow logicians to explain well-known empirical observations in cognition. (Received August 11, 2015)

1112-03-621 **Gregory Igusa*** (gigusa@nd.edu), **Julia Knight** and **Noah Schweber**. *Computing with the reals as a structure.*

In recent work, Noah Schweber defines a reducibility notion for structures A and B, potentially uncountable. The idea of the reducibility is that $A \leq_w^* B$ if, after a forcing collapse that causes A and B to become countable, every copy of B computes a copy of A. The reducibility is natural in that it does not depend on the specific forcing that is used, and that it coincides with Muchnik reducibility on countable structures.

One advantage of using this reducibility is that it allows us to specify the exact structures and signatures that we wish to work with. This talk will be primarily focused on structures that are referred to as "the reals." We will consider the computability theorist's reals, Cantor space and Baire space, and also consider the traditional reals, $R = (\mathbb{R}, +, \cdot, <)$, as well as several expansions and reducts of R. Somewhat surprisingly, in this reducibility, Cantor space is an outlier. It is strictly weaker than the other structures that we mention, all of which are equivalent.

Of additional interest is the fact that the study of this reducibility is not "isolated": it uses and produces new results in classical computability theory and effective structure theory that make no mention of $\leq_w^*$. (Received August 11, 2015)

1112-03-644 **Joseph S. Miller*** (jmiller@math.wisc.edu), University of Wisconsin—Madison, Department of Mathematics, 480 Lincoln Drive, Madison, WI 53706-1388. *Subclasses of the K-trivial degrees.* Preliminary report.

I will talk about joint work with Greenberg and Nies on the fine structure of the class of K-trivial sets. The motivating example is the class of sets that are computable from both halves of a random sequence, which was already known to be a proper subclass of the K-trivial sets. We give several characterizations of this class and prove that it is an ideal generated by its c.e. elements. This work generalizes to the class of sets that are computable from the join of every k out of n parts of a random sequence. We call such a set a *k/n-base*. Ranging over rationals k/n, we get a natural dense family of subideals of the K-trivial sets. The union of these ideals is the ideal of sets that are robustly computable from some random sequence.

I will finish by describing a further generalization of k/n-bases. For example, consider a random sequence $Z = Z_1 \oplus Z_2 \oplus Z_3 \oplus Z_4 \oplus Z_5 \oplus Z_6$. Say that a set A is computable from every join of 3 out of 6 parts of Z, but also from $Z_1 \oplus Z_2$. Then we can conclude that A is actually a 3/7-base (as witnessed by a different random sequence), and this is the best possible conclusion. In general, arbitrary families of projections do not give us new subideals of the K-trivial sets. (Received August 11, 2015)

1112-03-659 **Alex Kruckman*** (kruckman@gmail.com), Department of Mathematics, UC Berkeley, Berkeley, CA 94709. *Ergodic invariant Keisler measures.*

Invariant types and Keisler measures have played an important role in many recent model-theoretic developments, especially in the realm of NIP theories. When studying invariant measures, the ergodic decomposition theorem suggests that we focus on the ergodic invariant measures. In the model-theoretic setting, these are the Keisler measures which are "type-like" in the sense that every almost invariant (invariant up to measure 0) definable set has measure 0 or 1. In an NIP theory, every ergodic measure is a type, but the space of ergodic measures is much richer in theories with the independence property. In this talk, I will suggest ergodic invariant Keisler measures as a tool for studying the dichotomy between "randomness" and forking, especially in simple and NTP2 theories, and present some results in this direction. (Received August 11, 2015)

1112-03-661 **Johanna N.Y. Franklin*** (johanna.n.franklin@hofstra.edu), Department of Mathematics, Room 306, Roosevelt Hall, Hofstra University, Hempstead, NY 11549-0114, and **Dan Turetsky** (dan.turetsky@vuw.ac.nz). *Levels of genericity and lowness for isomorphism.*

A Turing degree $\mathbf{d}$ is said to be low for isomorphism if, whenever it can compute an isomorphism between two computable structures, a computable isomorphism already exists between them; that is, if whenever $\mathcal{A} \cong_{\mathbf{d}} \mathcal{B}$, then $\mathcal{A} \cong_{\mathbf{0}} \mathcal{B}$. Franklin and Solomon proved that every 2-generic degree was low for isomorphism and conjectured that the degrees that were properly 1-generic were neither low for isomorphism nor degrees of categoricity. We

provide a counterexample to this conjecture by constructing a real that is 1-generic and low for isomorphism but not computable from a 2-generic. (Received August 11, 2015)

1112-03-665 **Titus H. Klinge**, **James I. Lathrop** and **Jack H. Lutz*** (lutz@cs.iastate.edu), Department of Computer Science, Iowa State University, Ames, IA 50011. *Robust Biomolecular Finite Automata.*

In this paper we present a uniform method for translating an arbitrary nondeterministic finite automaton (NFA) into a deterministic mass action chemical reaction network (CRN) that simulates it. The CRN receives its input as a continuous time signal consisting of concentrations of chemical species that vary to represent the NFA's input string in a natural way. The CRN exploits the inherent parallelism of chemical kinetics to simulate the NFA in *real time* with a number of chemical species that is *linear* in the number of states of the NFA. We prove that the simulation is correct and that it is robust with respect to perturbations of the input signal, the initial concentrations of species, the output (decision), and the rate constants of the reactions of the CRN. (Received August 11, 2015)

1112-03-674 **Alice Medvedev*** (amedvedev@ccny.cuny.edu). *Unions of chains of signatures.*

We meditate on a particularly naive notion of a limit of a sequence of theories: a union of conservative expansions. That is, we consider a sequence of nested signatures $L_1 \subset L_2 \subset \ldots$, each one a subsignature of the next, and a sequence of L_i-theories T_i where each T_i is precisely the set of L_i-consequences of T_{i+1} (and hence is a subset of T_{i+1}). It turns out that many model-theoretic properties then pass from all T_i to their union T; these include consistency, completeness, quantifier elimination, partial quantifier elimination such a model-completeness, elimination of imaginaries, stable embeddedness of some definable set, characterization of algebraic closure; stability, simplicity, rosiness, dependence. Our motivating example is the theory T of fields with an action by $(\mathbb{Q}, +)$, seen as a limit of (theories of) fields with $(\mathbb{Z}, +)$-actions. (Received August 11, 2015)

05 ► Combinatorics

1112-05-8 **Liam Solus**, **Caroline Uhler** and **Ruriko Yoshida***, 725 Rose Street, Lexington, KY 40536. *The facets of the cut polytope and the extreme rays of cone of concentration matrices of certain graphs.* Preliminary report.

For a graph G with p vertices the cone of concentration matrices consists of all real positive semidefinite $p \times p$ matrices with zeros in entries corresponding to nonedges of G. The extremal rays of this cone and their associated ranks are well-studied with applications in matrix completion problems, maximum likelihood estimation, and Gauss elimination of sparse matrices. It is well-known that the extremal rays of this cone in the case of the cycle are either rank 1 or rank $p-2$. Similarly, the cut polytope of the cycle has facets of two distinct shapes. With hyperplane translations and general duality theory of spectrahedra, we demonstrate that a facet of a fixed shape corresponds to an extremal ray of a fixed rank.This shows that, in the case of the cycle, the different facet shapes in the cut polytope identify the ranks of extremal rays in the cone of concentration matrices, and this correspondence arises from the cutsets defining the facets. More generally, we show that if a graph G has this property, then taking the clique sum of G with either a cycle or a tree produces another graph with the same property. (Received March 29, 2015)

1112-05-27 **Tobias Windisch*** (windisch@ovgu.de), OvGU Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany. *Rapid mixing and Markov bases.*

In the past, research in algebraic statistics has mostly focused on determination of Markov bases whereas mixing times of the resulting Markov chains have not received significant attention. In this talk, we discuss the behavior of Markov chains on lattice points of polytopes using Markov bases. We show that, in fixed dimension, those Markov chains cannot mix rapidly. We also present a way to adapt Markov bases so that the fastest mixing behavior can be obtained. (Received June 03, 2015)

1112-05-32 **Fatemeh Mohammadi*** (fatemeh.mohammadi@ist.ac.at), 10623 Berlin, Germany, **Maria Kateri** (maria.kateri@rwth-aachen.de), 52056 Aachen, Germany, and **Bernd Sturmfels** (bernd@berkeley.edu), Berkeley, CA 94720. *A Family of Quasisymmetry Models.*

Abstract: We present a one-parameter family of statistical models for square contingency tables that interpolates between the classical quasisymmetry model and its Pearsonian analogue. Thus there more options available for data analysis of square contingency table. The more interesting practical application lies in analysing and

comparing independent square tables of the same set-up, when they cannot be modeled adequately all by the same (classical or Pearsonian) QS model.

Algebraically, this corresponds to deformations of toric ideals associated with graphs. We show that these models belong to a broader class of ϕ-divergence QS models. Measures of divergence quantify the distance between two probability distribution. Our discussion of the statistical issues centers around maximum likelihood estimation. (Received August 10, 2015)

1112-05-42 **Tri Lai*** (tmlai@ima.umn.edu), 207 Church Street SE, 306 Lind Hall, Minneapolis, MN 55455. *Proof of a conjecture of Kenyon and Wilson on semicontiguous minors.*

In their paper on circular planar electrical networks (arXiv:1411.7425), Kenyon and Wilson showed how to test if a network is well-connected by checking that $\binom{n}{2}$ minors of the response matrix are positive. In particular, they proved that any contiguous minor of a response matrix can be expressed as a Laurent polynomial in the central minors. Interestingly, the Laurent polynomial is the generating function of domino tilings of a weighted Aztec diamond. They conjectured that any semicontiguous minor can also be written in terms of domino tilings of a region on the square lattice. In this paper we present a proof of the conjecture. (Received July 02, 2015)

1112-05-64 **Mikhail Muzychuk** (muzy@netanya.ac.il), Netanya, Israel, and **Bangteng Xu*** (bangteng.xu@eku.edu), 521 Lancaster Ave., Richmond, KY 40475. *Terwilliger Algebras of Wreath Products of Association Schemes.*

Terwilliger algebras of wreath products of special association schemes are studied in several papers. In this talk we present the Terwilliger algebra of the wreath product of two arbitrary association schemes $\mathcal{S}$ and $\mathcal{T}$. We will express the Terwilliger algebra of the wreath product of $\mathcal{S}$ and $\mathcal{T}$ and its primitive central idempotents in terms of the Terwilliger algebras of $\mathcal{S}$ and $\mathcal{T}$ and their primitive central idempotents. The known results of Hanaki, Kim, etc. are special cases of our results. (Received July 14, 2015)

1112-05-68 **Patricia Hersh** (plhersh@ncsu.edu) and **Victor Reiner*** (reiner@math.umn.edu). *Representation stability for cohomology of configuration spaces in* $\mathbf{R}^d$.

Church, Farb and others have shown that the representations of the symmetric group S_n on the cohomology of the configuration space of n ordered points in $\mathbf{R}^d$ stabilize in a certain fashion as n gets large. They also provide some bounds on how large n must be for this to occur.

We give the sharp onset for this stability, by analyzing the S_n-representations which are known to control the cohomology: the Whitney homology of set partition lattices for d even, and the higher Lie representations for d odd. (Received July 15, 2015)

1112-05-70 **Mohammad Hosein Khalife** and **Bruce E Sagan*** (sagan@math.msu.edu), Department of Mathematics, Wells Hall, 619 Red Cedar Road, East Lansing, MI 48824, and **Emad Zahedi**. *Distance preserving graphs.*

Let $G = (V, E)$ be a graph and let $d_G(\cdot, \cdot)$ be the distance function of G. Call a subgraph H of G *isometric* if $d_H(v, w) = d_G(v, w)$ for all vertices v, w of H. A connected graph G is said to be *distance preserving*, abbreviated to dp, if it has an isometric subgraph with k vertices for all k from 1 to $|V|$. Dp graphs have appeared in research on network clustering, but their study is relatively new. We will discuss various properties of dp graphs, including when certain graph operations such as taking products or adding a simplicial vertex preserve being dp. We will also present some conjectures about these graphs. (Received July 15, 2015)

1112-05-72 **Miklós Bóna**, **Marie-Louise Bruner** and **Bruce E Sagan*** (sagan@math.msu.edu), Department of Mathematics, Wells Hall, 619 Red Cedar Road, East Lansing, MI 48824. *Longest increasing subsequences and log concavity.* Preliminary report.

Let $\mathfrak{S}_n$ be the nth symmetric group and view the elements of $\mathfrak{S}_n$ as sequences. Let $l_{n,k}$ be the number of $\pi \in \mathfrak{S}_n$ having k as the length of a longest increasing subsequence. William Chen conjectured that the sequence $l_{1,n}, l_{2,n}, \ldots, l_{n,n}$ is log concave. We also conjecture that if $i_{n,k}$ is the number of involutions in $\mathfrak{S}_n$ with longest increasing subsequence length k then $i_{1,n}, i_{2,n}, \ldots, i_{n,n}$ is log concave. We show that these two conjectures are strongly related. We also present evidence to support the truth of both. Our main tool is the Robinson-Schensted correspondence. Many other associated conjectures will be discussed. (Received July 15, 2015)

1112-05-73 **Zachary Hamaker**, **Joel Lewis**, **Brendan Pawlowski** and **Bruce E Sagan*** (sagan@math.msu.edu), Department of Mathematics, Wells Hall, 619 Red Cedar Road, East Lansing, MI 48824. *Pattern avoidance and quasisymmetric functions - an update.* Preliminary report.

Let $\mathfrak{S}_n$ denote the nth symmetric group. Given a set Π of permutations we let $\mathfrak{S}_n(\Pi)$ be all permutations in $\mathfrak{S}_n$ which avoid all elements of Π. Following a suggestion of Woo, we consider the associated generating function defined by $Q_n(\Pi) = \sum_{\sigma \in \mathfrak{S}_n(\Pi)} F_{\mathrm{Des}\ \sigma}$ where Des σ is the descent set of σ and F is the associated fundamental quasisymmetric function. Some preliminary work on the subject was presented at the Eau Claire AMS meeting last year. In the present talk we will discuss new research on the subject, including a connection due to Adin and Roichman with representation theory. (Received July 15, 2015)

1112-05-75 **Jia Huang**, **Joel Brewster Lewis*** (jblewis@math.umn.edu), **Alejandro H. Morales** and **Victor Reiner**. *Absolute order in general linear groups.*

We study a partial order on the general linear group $GL(V)$ called the *absolute order*, derived from viewing $GL(V)$ as a group generated by reflections, i.e., elements whose fixed space has codimension one. The absolute order can be characterized in two equivalent ways, one via additivity of length for factorizations into reflections, the other via additivity of fixed space codimensions. We discuss some general properties of this order, including self-duality of its intervals.

Working over a finite field $\mathbb{F}_q$, we show via a complex character computation that the poset interval from the identity to a Singer cycle (or any regular elliptic element) in $GL_n(\mathbb{F}_q)$ has a strikingly simple formula for the number of chains passing through a prescribed set of ranks. More generally, we discuss generating function formulas counting arbitrary factorizations of regular elliptic elements in $GL_n(\mathbb{F}_q)$, keeping track of the fixed space codimensions of the factors. (Received July 15, 2015)

1112-05-79 **Po-Shen Loh*** (ploh@cmu.edu), Dept of Math Sciences, Wean 6113, Carnegie Mellon University, Pittsburgh, PA 15213. *Directed paths: from Ramsey to Ruzsa and Szemeredi.*

Starting from an innocent Ramsey-theoretic question regarding directed paths in tournaments, we discover a series of rich and surprising connections that lead into the theory around a fundamental problem in Combinatorics: the Ruzsa-Szemerédi induced matching problem. Using these relationships, we prove that every coloring of the edges of the transitive n-vertex tournament using three colors contains a directed path of length at least $\sqrt{n} \cdot e^{\log^* n}$ which entirely avoids some color. We also completely resolve the analogous question for ordinary monochromatic directed paths in general tournaments, as well as natural generalizations of the Ruzsa-Szemerédi problem which we encounter through our investigation. (Received July 17, 2015)

1112-05-88 **Eva Czabarka**, **Laszlo A. Szekely*** (szekely@math.sc.edu) and **Todd J. Vision**. *Number of gene duplication episodes and Gallai's min-max theorem on intervals.*

In 1996, Guigo et al. [Mol. Phylogenet. Evol., 6 (1996), 189–203] posed the following problem: for a given species tree and a number of gene trees, what is the minimum number of duplication episodes, where several genes could have undergone duplication together to generate the observed situation. (Gene order is neglected, but duplication of genes could have happened only on certain segments that duplicated). We study two versions of this problem, one of which was algorithmically solved not long ago by Bansal and Eulenstein. We provide min-max theorems for both versions that generalize Gallai's archetypal min-max theorem on intervals, allowing simplified proofs to the correctness of the algorithms (as it always happens with duality) and deeper understanding. An interesting feature of our approach is that its recursive nature requires a generality that bioinformaticians attempting to solve a particular problem usually avoid. (Received July 21, 2015)

1112-05-115 **Esther Banaian**, **Steve Butler*** (butler@iastate.edu), **Christopher Cox**, **Jeffrey Davis**, **Jacob Landgraf** and **Scarlitte Ponce**. *Enumerating two-ball prime juggling patterns.*

Juggling patterns can be described by a closed walk in a (directed) state graph, where each vertex (or state) is a landing pattern for the balls and directed edges connect states which can occur consecutively. The number of such patterns of length n is well known, but a long standing problem is to count the number of prime juggling patterns (those juggling patterns corresponding to cycles in the state graph). For the case of two balls we give an expression for the number of prime juggling patterns of length n by establishing a connection with partitions of n into distinct parts. From this we show the number of two-ball prime juggling patterns of length n is $\big(\gamma - o(1)\big)2^n$ where $\gamma = 1.32963879259\ldots$. (Received July 25, 2015)

1112-05-129 **Yang Yang*** (yyang@math.wisc.edu), Department of Mathematics, University of Wisconsin, 480 Lincoln Drive, Madison, WI 53706. *Upper Triangular Matrices and Billiard Arrays.*

Fix a nonnegative integer d, a field $\mathbb{F}$, and a vector space V over $\mathbb{F}$ with dimension $d+1$. Let T denote an invertible upper triangular matrix in $\mathrm{Mat}_{d+1}(\mathbb{F})$. Using T we construct three flags on V. We find a necessary and sufficient condition on T for these three flags to be totally opposite. In this case, we use these three totally opposite flags to construct a Billiard Array B on V. It is known that B is determined up to isomorphism by a certain triangular array of scalar parameters called the B-values. We compute these B-values in terms of the entries of T. We describe the set of isomorphism classes of Billiard Arrays in terms of upper triangular matrices. (Received July 27, 2015)

1112-05-131 **Eric S Egge*** (eegge@carleton.edu), Department of Mathematics and Statistics, Carleton College, Northfield, MN 55057. *A New Notion of Noncontiguous Containment for Ordered, Rooted Trees.* Preliminary report.

Inspired, perhaps, by the vast and growing literature on patterns in permutations, over the last decade several authors have proposed and studied definitions of containment and avoidance for various classes of trees, most often full binary trees. In this talk I will give yet another definition of containment for trees, describe how this definition connects containment in (not necessarily full) binary trees with classical pattern containment in permutations, and discuss some new enumerative results. Some of these results will involve ternary trees avoiding various sets of patterns, while others will concern the number of occurrences of various binary trees in other binary trees. (Received July 28, 2015)

1112-05-132 **Jonathan Cutler*** (jonathan.cutler@montclair.edu) and **Luke Pebody**. *A proof of the Roller Coaster Conjecture.*

For a graph G, we let $i_t(G)$ be the number of independent sets in G of size t and we call $(i_t(G))_{t=0}^{\alpha(G)}$ the independence sequence of G. For a collection of graphs with independence number is α, we say that the independence sequence for the collection is any-ordered on the index set $S = \{s_1, s_2, \ldots, s_q\} \subseteq [\alpha]$ if, for any permutation π of S, there is a graph G in the collection such that

$$i_{\pi(s_1)}(G) < i_{\pi(s_2)}(G) < \cdots < i_{\pi(s_q)}(G).$$

Alavi, Erdős, Malde, and Schwenk proved that the collection of all graphs with independence number α is any-ordered on $[\alpha]$. A graph is well-covered if every maximal independent set has the same size. Michael and Traves proved that the independence sequence of any well-covered graph is increasing on its first half. They also conjectured that for the collection of well-covered graphs with independence number α, the independence sequence is any-ordered on $\{\lceil \alpha/2 \rceil, \lceil \alpha/2 \rceil + 1, \ldots, \alpha\}$. This conjecture become known as the Roller Coaster Conjecture. In this talk, we will outline a proof of this conjecture, including a graph construction that is related to well-known designs. (Received July 28, 2015)

1112-05-136 **Dominique Guillot**, **Apoorva Khare*** (khare@stanford.edu) and **Bala Rajaratnam**. *Critical exponents of graphs.*

We study the set of powers that preserve positive semidefiniteness, when applied entrywise to matrices with structure of zeros prescribed by a graph. This is part of a broad program to study entrywise functions preserving positivity on distinguished submanifolds of the cone. In our main result, we completely classify the powers preserving positivity with respect to all chordal/decomposable graphs. Additionally, we introduce a new graph invariant which we call the "critical exponent". Our results provide natural connections between combinatorics and analysis by relating the discrete sparsity structures of matrices to their spectral properties. (Received July 28, 2015)

1112-05-138 **Liam Solus*** (liam.solus@uky.edu), **Caroline Uhler** and **Ruriko Yoshida**. *A Polyhedral Description of Extremal PSD Matrices for Certain Graphs.*

Given a graph G on p vertices we consider the closure of the cone of concentration matrices associated to G, i.e. the cone of all $p \times p$ positive semidefinite matrices with zeros in entries corresponding to the nonedges of G. Due to its applications in PD-completion problems and maximum-likelihood estimation, the geometry of this cone is of general interest. A natural pursuit in this geometric investigation is to characterize the possible ranks of the extremal rays of this cone. Two other well-studied convex bodies associated to G are the cut polytope and its positive semidefinite relaxation, the elliptope of G. Via an application of standard spectrahedral duality we will see that the dual to the elliptope of G is the trace two affine section of the cone of concentration matrices. Using the geometric relationship between these four convex bodies we will see that, in the case of graphs with no K_5 minors, extremal matrices of rank b in the cone of concentration matrices are given by the constants b

where $v^T x = b$ is a facet-supporting hyperplane of the cut polytope of G. In the special case of series-parallel graphs we see that all extremal ranks are given in this fashion. Time permitting, we will discuss the more general implications. (Received July 28, 2015)

1112-05-143 **Zdeněk Dvořák** (rakdver@iuuk.mff.cuni.cz) and **Bernard Lidický*** (lidicky@iastate.edu). *Precoloring extension for planar graphs.*

Aksenov proved that in a planar graph G with at most one triangle, every precoloring of a 4-cycle can be extended to a 3-coloring of G. We give an exact characterization of planar graphs with two triangles in that some precoloring of a 4-cycle does not extend. We apply this characterization to solve the precoloring extension problem from two 4-cycles in a triangle-free planar graph in the case that the precolored 4-cycles are separated by many disjoint 4-cycles.

As a corollary, we prove that there exists a constant $D > 0$ such that if H is a planar triangle-free graph and $S \subseteq V(H)$ consists of vertices at pairwise distances at least D, then every precoloring of S extends to a 3-coloring of H. This gives a positive answer to a conjecture of Dvořák, Král' and Thomas, and implies an exponential lower bound on the number of 3-colorings of triangle-free planar graphs of bounded maximum degree. (Received July 29, 2015)

1112-05-147 **Chassidy Bozeman**, **Joshua Carlson**, **Michael Dairyko**, **Derek Young** and **Michael Young*** (myoung@iastate.edu). *Lower Bounds for the Exponential Domination Number of $C_m \times C_n$.*

A vertex v in an exponential dominating set assigns weight $2^{1-dist(v,u)}$ to vertex u. An exponential dominating set of a graph G is a subset of $V(G)$ such that every vertex in $V(G)$ has been assigned a sum weight of at least 1.

In this talk the exponential dominating number, denoted by $\gamma_e(G)$, for the graph $G = C_m \times C_n$ is discussed. Anderson et. al. proved that $\frac{mn}{15.875} \leq \gamma_e(C_m \times C_n) \leq \frac{mn}{13}$ and conjectured that $\frac{mn}{13}$ is also the asymptotic lower bound. We use a linear programing approach to sharpen the lower bound to $\frac{mn}{13.7619+\epsilon(m,n)}$. (Received July 29, 2015)

1112-05-148 **Thomas Lam**, **Seung Jin Lee** and **Mark Shimozono*** (mshimo@math.vt.edu), Department of Mathematics, MC 0123, 460 McBryde Hall, Virginia Tech, 225 Stanger Street, Blacksburg, VA 24061. *Schubert polynomials for affine flags.* Preliminary report.

We exhibit a natural ring isomorphism from the cohomology of the affine flag variety to the tensor product of those of the affine Grassmannian and the finite flag variety, the latter having componentwise product. We give a general expression for the image of an affine flags Schubert class. In type A it is a sum of products of affine Stanley functions and ordinary Schubert polynomials. This construction works equivariantly as well. The above isomorphism is also equivariant for the action of the extended affine nilHecke algebra. (Received July 30, 2015)

1112-05-154 **Jiangxu Kong**, **Hong-Jian Lai** and **Murong Xu*** (xumurong@math.wvu.edu), West Virginia University, Dept. of Math 320 Armstrong, P.O. Box 6310, Morgantown, WV 26506-6310. *On linear r-hued colorings of sparse graphs.*

For positive integers k and r, a (k, r)-coloring is a proper k-coloring c of G such that $|c(N(v))| \geq \min\{d(v), r\}$ for any $v \in V(G)$; and such a coloring is linear if for every pair of distinct colors, the color classes induce a linear forest of G, (that is a subgraph with maximum degree at most 2). The liner r-hued chromatic number of G, denoted by $\chi_r^\ell(G)$, is the smallest integer k such that G has a linear (k, r)-coloring. We will present some of the recently achieved results on linear r-hued colorings of graphs. (Received July 30, 2015)

1112-05-178 **Laura Escobar** and **Karola Meszaros*** (karola@math.cornell.edu). *Realizing subword complexes via triangulations of root polytopes.*

Subword complexes are simplicial complexes introduced by Knutson and Miller to illustrate the combinatorics of Schubert polynomials and determinantal ideals. They proved that any subword complex is homeomorphic to a ball or a sphere and asked about their geometric realizations. We show that a family of subword complexes can be realized geometrically via triangulations of root polytopes. This implies that a family of $beta$-Grothendieck polynomials are special cases of reduced forms in the subdivision algebra of root polytopes. Based on joint work with Laura Escobar. (Received August 02, 2015)

1112-05-181 **Akalu Tefera*** (teferaa@gvsu.edu). *On Proofs of Certain Combinatorial Identities.*

In this talk, we present proofs of new combinatorial identities discovered by Otto G. Ruehr in his solution to Problem E2765 of the American Mathematical Monthly. (Received August 02, 2015)

1112-05-184 **Joshua Hallam*** (hallamjw@wfu.edu). *Some applications of quotient posets.*
Given a poset and an equivalence relation on the poset, the quotient poset is obtained by ordering the equivalence classes in a way related to the ordering of the original poset. We will discuss how quotient posets can be used to study the Möbius function, the characteristic polynomial, the rank polynomial, and increasing forests of graphs. (Received August 02, 2015)

1112-05-196 **Sung Y. Song*** (sysong@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011-2061, and **Grant Bowling**, **Kavi Duvvoori** and **Robert Lazar**. *A family of q-analog partially balanced t-designs over $GF(q)$.* Preliminary report.
A q-analog partially balanced t-design over the finite field $GF(q)$, denoted a PB t-$(v, k, \{\lambda_1, \lambda_2, \ldots, \lambda_m\}; q)$-design, is a collection of k-dimensional subspaces of a v-dimensional vector space over $GF(q)$, such that each t-dimensional subspace is contained in λ_i k-subspaces in the collection for some $i \in \{1, 2, \ldots, m\}$. By using the field reduction maps, we give a construction of a family of non-trivial PB t-$(v, k, \{\lambda_1, \lambda_2, \ldots, \lambda_m\}; q)$-designs with v composite for small t and m. (Received August 03, 2015)

1112-05-199 **Jonathan Cutler** and **A. Jamie Radcliffe*** (jamie.radcliffe@unl.edu). *The Friendship Paradox and its friends.*
The Friendship Paradox, first noted by the sociologist Scott Feld in 1991, is the statement that your friends, on average, have more friends than you do, and that it's not because you're a mathematician.

I will discuss joint work with Jon Cutler in which we consider the two original versions of the paradox (sometimes not clearly distinguished from one another), and a number of natural extensions. Of these extensions, some are motivated by graph theory and some by the original context of friendship networks. (Received August 03, 2015)

1112-05-201 **Z. Füredi**, **A. Kostochka*** (kostochk@math.uiuc.edu) and **J. Verstraëte**. *Stability in the Erdős–Gallai Theorem on cycles and paths.* Preliminary report.
The Erdős-Gallai Theorem states that for $k \geq 2$, every graph of average degree more than $k-2$ contains a k-vertex path. This result is a consequence of a stronger result of Kopylov: if $t \geq 2$, $k \in \{2t+1, 2t+2\}$, $n \geq \frac{5t-3}{2}$, and G is an n-vertex 2-connected graph with at least $h(n,k,t) = \binom{k-t}{2} + t(n-k+t)$ edges, then G contains a cycle of length at least k unless $G = H_{n,k,t} := K_n - E(K_{n-t})$. We prove a stability version of the Erdős-Gallai Theorem: For all $n \geq 3t > 3$, and $k \in \{2t+1, 2t+2\}$, every n-vertex 2-connected graph G with $e(G) > h(n,k,t-1)$ either contains a cycle of length at least k or contains a set of t vertices whose removal gives a star forest. In particular, if $k = 2t+1 \neq 7$, then $G \subseteq H_{n,k,t}$. The lower bound $e(G) > h(n,k,t-1)$ in these results is tight. (Received August 03, 2015)

1112-05-205 **Megan Owen*** (megan.owen@lehman.cuny.edu). *Polyhedral subdivisions and a partial CLT for tree space.*
The space of metric phylogenetic trees introduced by Billera, Holmes, and Vogtmann (2001) is a polyhedral cone complex. It is also non-positively curved, so there is is a unique shortest path (geodesic) between any two trees. I will show how the combinatorics of geodesics with a specified fixed endpoint give rise to a finer polyhedral subdivision, and how this subdivision can be used to prove a partial Central Limit Theorem on the tree space. This talk is a combination of joint work with Ezra Miller and Scott Provan, and Huiling Le and Dennis Barden. (Received August 04, 2015)

1112-05-214 **Rafael S. González D'León*** (rafaeldleon@uky.edu). *A family of symmetric functions associated with Stirling permutations.*
We present exponential generating function analogues to two classical identities involving the ordinary generating function of the complete homogeneous symmetric function. After a suitable specialization the new identities reduce to identities involving the first and second order Eulerian polynomials. These results led us to consider a family of symmetric functions associated with the *Stirling permutations* introduced by Gessel and Stanley. (Received August 04, 2015)

1112-05-217 **Nantel Bergeron*** (bergeron@yorku.ca), Dept. Math and Stat., York University, 4700 Keele St, Toronto, Ontario M3J 1P3, Canada, and **Cesar Ceballos**. *Hopf algebra on c-clusters.*
The Hopf algebra of subword complexes induces a natural sub-Hopf algebra on c-clusters of finite type. Cluster complexes for Weyl groups were introduced by Fomin and Zelevinsky. These complexes encode the combinatorial structure behind the associated cluster algebra of finite type, and were further extended to arbitrary Coxeter groups by Reading. The resulting c-cluster complexes use a Coxeter element c as a parameter and have

been extensibly used to produce geometric constructions of generalized associahedra. The basis elements of our Hopf algebra of c-clusters are given by disjoint unions of pairs of clusters (A,T) of finite type, where A is any acyclic cluster seed and T is any cluster obtained from it by mutations. The multiplication and comultiplication operations are natural from the cluster algebra perspective on T. However, subword complexes allow to nontrivially extend these operations to remarkable operations on the acyclic seed part A. (Received August 04, 2015)

1112-05-219 **Abdollah Khodkar*** (akhodkar@westga.edu), University of West Georgia, 1601 Maple Street, Carrollton, GA 30118. *Pancyclic, Bipancyclic and Oddly Bipancyclic Graphs.*

A graph with n vertices is **pancyclic** if, for every k in the range $3 \leq k \leq n$, it contains a cycle of length k. Pancyclic graphs, which were first introduced by Bondy in 1971, are a generalization of Hamiltonian graphs, which have a cycle of the maximum possible length.

A bipartite graph with n vertices, n even, is said to be **bipancyclic** if it contains cycles of all even lengths from 4 to n. Similarly, a bipartite graph with n vertices, n odd, is said to be **oddly bipancyclic** if it contains cycles of all even lengths from 4 to $n-1$.

A pancyclic graph is called **uniquely pancyclic** if it contains precisely one cycle of each length. Uniquely bipancyclic graphs and uniquely oddly bipancyclic graphs are defined similarly. In this talk we will learn more about this topic.

(Received August 04, 2015)

1112-05-220 **Hong-Jian Lai*** (hjlai@math.wvu.edu), Department of mathematics, West Virginia University, Morgantown, WV 26506-6310, and **Murong Xu** (xumurong@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26506-6310. *On r-hued colorings of graphs.*

For positive integers k and r, a (k,r)-coloring is a proper k-coloring c of G such that $|c(N(v))| \geq \min\{d(v), r\}$ for any $v \in V(G)$. The r-hued chromatic number of G, denoted by $\chi_r(G)$, is the smallest integer k such that G has a (k,r)-coloring. When $r = 2$, $\chi_2(G)$ is also called the dynamic chromatic number of G. We will present some of the recent developments of r-hued colorings of graphs. (Received August 11, 2015)

1112-05-221 **Miaomiao Han*** (mmhan@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26506-6310, and **Hong-Jian Lai** (hjlai@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26506-6310. *On dense strongly $\mathbb{Z}_{2s+1}$-connected graphs.*

Let G be a graph and $s > 0$ be an integer. If, for any function $b : V(G) \to \mathbb{Z}_{2s+1}$ with $\sum_{v \in V(G)} b(v) \equiv 0 \mod 2s+1$, G always has an orientation D such that the net outdegree at each v is congruent to $b(v) \mod 2s+1$, then G is strongly $\mathbb{Z}_{2s+1}$-connected. Contract all nontrivial strongly $\mathbb{Z}_{2s+1}$-connected subgraphs of G to get the $\mathbb{Z}_{2s+1}$-reduction G', In this paper, we prove that for any integers $s, t > 0$ and real numbers a, b with $0 < a < 1$, there exist an integer N and a finite family $\mathcal{Y}$ of non-strongly $\mathbb{Z}_{2s+1}$-connected graphs such that for any connected simple graph G with order $n \geq N$ and independence number $\alpha(G)$, if G satisfies one of the following conditions:

(i) $\alpha(G) \leq t$ and for any edge $uv \in E(G)$, $\max\{d_G(u), d_G(v)\} \geq an + b$, or

(ii) $\alpha(G) \leq t$ and for any $u, v \in V(G)$ with $dist_G(u,v) = 2$, $\max\{d_G(u), d_G(v)\} \geq an + b$, or

(iii) for any $uv \notin E(G)$, $\max\{d_G(u), d_G(v)\} \geq an + b$,

then G is strongly $\mathbb{Z}_{2s+1}$-connected if and only if the $\mathbb{Z}_{2s+1}$-reduction of G is not in the finite family $\mathcal{Y}$. (Received August 11, 2015)

1112-05-222 **Murong Xu*** (xumurong@math.wvu.edu), Department of Mathematics, Morgantown, WV 26506-6310, **Jiangxu Kong** (kongjiangxu@163.com), School of Mathematical Science, Xiamen University, Xiamen, 361005, Peoples Rep of China, and **Hong-Jian Lai** (hjlai@math.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26506-6310. *On linear r-hued colorings of sparse graphs.*

For positive integers k and r, a (k,r)-coloring is a proper k-coloring c of G such that $|c(N(v))| \geq \min\{d(v), r\}$ for any $v \in V(G)$; and such a coloring is linear if for every pair of distinct colors, the color classes induce a linear forest of G, (that is a subgraph with maximum degree at most 2). The liner r-hued chromatic number of G, denoted by $\chi_r^{\ell}(G)$, is the smallest integer k such that G has a linear (k,r)-coloring. We will present some of the recently achieved results on linear r-hued colorings of graphs. (Received August 11, 2015)

1112-05-231 **Jiaao Li*** (joli@mix.wvu.edu), Department of Mathematics, West Virginia University, Morgantown, WV 26506-6310. *Group connectivity, graph strength and degree sequence realization.*

The concept of group connectivity was introduced by Jaeger as a generalization of nowhere-zero flows. Let G be a graph and Π be the set of all partitions of $V(G)$. The strength of G, $\eta(G)$, is defined as $\eta(G) = \min_{\pi\in\Pi} \frac{|\partial\pi|}{|\pi|-1}$, where $\partial\pi$ denotes the set of edges crossing over the sets of partition $\pi \in \Pi$. Both of group connectivity and graph strength problems can be well studied by contraction and reduction method. In this talk, we discuss the relationship between group connectivity and graph strength. We prove that if G is Z_k-connected, then $\eta(G) \geq \frac{k-1}{k-2}$. This solves a conjecture of Luo et al. for Z_k-connected graphs while it was unknown for even integer $k \geq 6$ previously. As an application, we solve the corresponding graphic and multigraphic sequence Z_k-connected realization problems. (Received August 07, 2015)

1112-05-235 **Kimberly D'souza*** (ksevin2@lsu.edu) and **Guoli Ding** (ding@math.lsu.edu). *A Decomposition Theorem for Weakly 4-Connected Graphs.* Preliminary report.

A graph G is called H-free if G does not contain a graph isomorphic to H as a minor. In this talk, we consider finding H-free graphs, where H is a weakly 4-connected graph. If we have a 3-connected graph G, we discuss a decomposition theorem for splitting G into weakly 4-connected components. We prove that G is H-free if and only if each of the weakly 4-connected components is H-free. We are able to apply this decomposition to the problem of finding all H-free graphs for a chosen weakly 4-connected graph H. First, we generate all of the weakly 4-connected H-free graphs. Then, we are able to reverse the decomposition to generate all 3-connected H-free graphs. Finally, we use a well known theorem to describe the entire set of H-free graphs. In this talk, we will first discuss the decomposition theorem. Then, we will show the application of the theorem to the Pyramid, a weakly 4-connected graph. (Received August 05, 2015)

1112-05-240 **Art Duval**, **Bennet Goeckner**, **Caroline Klivans*** (klivans@brown.edu) and **Jeremy Martin**. *A non-partitionable Cohen-Macaulay simplicial complex.*

A long-standing conjecture of Stanley states that every Cohen- Macaulay simplicial complex is partitionable. We disprove the conjecture by constructing an explicit counterexample. Due to a result of Herzog, Jahan and Yassemi, our construction also disproves the conjecture that the Stanley depth of a monomial ideal is always at least its depth. (Received August 05, 2015)

1112-05-243 **Daniel Irving Bernstein*** (dibernst@ncsu.edu) and **Seth Sullivant** (smsulli2@ncsu.edu). *Hierarchical models: normality and related properties.*

Associated to a simplicial complex $\mathcal{C}$ with ground set $\{1, 2, \ldots, m\}$ and an integer vector $\mathbf{d} \in \mathbb{N}^m$ is the design matrix $\mathcal{A}_{\mathcal{C},\mathbf{d}}$ for a hierarchical model. We are interested in developing techniques for determining when $\mathcal{A}_{\mathcal{C},\mathbf{d}}$ satisfies various "niceness" properties. The case where $\mathbf{d} = \mathbf{2}$, the vector of all 2s, is of particular interest. New results include a complete classification of the simplicial complexes that give rise to unimodular $\mathcal{A}_{\mathcal{C},\mathbf{2}}$, and progress towards the classification problem for compressed and normal $\mathcal{A}_{\mathcal{C},\mathbf{2}}$. (Received August 05, 2015)

1112-05-244 **Jonathan E Beagley*** (jon.beagley@valpo.edu), 1900 Chapel Drive, Valparaiso, IN 46383, and **Paul Drube** (paul.drube@valpo.edu), 1900 Chapel Drive, Valparaiso, IN 46383. *The Raney generalization of Catalan numbers.*

The Raney numbers $R_{p,r}(k)$ are a two-parameter generalization of the Catalan numbers. We will give a new combinatorial interpretation for the Raney numbers in terms of planar embeddings of a collection of trees. This interpretation generalizes the usual interpretation of the p-Catalan numbers. These results are applied to specific Raney numbers, and we show how these relate to counting certain types of non-elliptic A_2 webs with specific boundary words. (Received August 05, 2015)

1112-05-248 **Alexander R Miller*** (arm@illinois.edu). *Smith normal forms of some combinatorial matrices.*

I will present some results and conjectures about Smith normal forms of certain combinatorial matrices over integer polynomials. (Received August 05, 2015)

1112-05-249 **Carolina Benedetti**, **Joshua Hallam*** (hallamjw@wfu.edu) and **John Machacek**. *A combinatorial Hopf algebra of simplicial complexes.* Preliminary report.

In this talk, a combinatorial Hopf algebra for simplicial complexes will be discussed. In particular, we will give a cancellation-free formula for its antipode. Then we will define a family of characters. These characters will

be used to generate symmetric functions which encode information about colorings of the simplicial complex as well as its f-vector. (Received August 05, 2015)

1112-05-257 **Darij Grinberg*** (darijgrinberg@gmail.com), 70 Pacific Street, Apt 334, Cambridge, MA 02139, and **Pavel Galashin** and **Gaku Liu**. *A generalization of dual stable Grothendieck polynomials.*

Given a skew partition λ/μ, the dual stable Grothendieck polynomial corresponding to it is a formal power series in infinitely many commuting variables $x_1, x_2, x_3, \ldots$; it is defined as the sum of $\mathbf{x}^{\operatorname{ircont} T}$ over all reverse plane partitions T of shape λ/μ. Here, $\operatorname{ircont} T$ denotes the integer sequence whose i-th term is the number of columns of T which contain the entry i, and $\mathbf{x}^\alpha$ denotes the monomial $x_1^{\alpha_1} x_2^{\alpha_2} x_3^{\alpha_3} \cdots$ (in commuting variables) for any sequence $\alpha = (\alpha_1, \alpha_2, \alpha_3, \ldots)$ of nonnegative integers. Lam and Pylyavskyy have shown that this dual stable Grothendieck polynomial is a symmetric function, whose highest homogeneous component is the Schur function $s_{\lambda/\mu}$.

In a paper that is to appear on the arXiv soon, Pavel Galashin, Gaku Liu and I have obtained a multiparameter generalization of this construction, which also generalizes the Schur functions. We have proven that our generalized functions are still symmetric, and obey a version of the Littlewood-Richardson rule. We furthermore conjecture a generalized version of the Jacobi-Trudi identity exhibiting a surprising symmetry. (Received August 06, 2015)

1112-05-270 **Rebecca Patrias***, patri080@umn.edu, and **Pavlo Pylyavskyy**. *Dual filtered graphs and K-theoretic combinatorial Hopf algebras.*

Using the Hecke insertion algorithm of Buch-Kresh-Shimozono-Tamvakis-Yong, we define a K-theoretic analogue of Fomin's dual graded graphs called dual filtered graphs. The key formula in the definition is $DU - UD = D + I$. We discuss two main constructions of dual filtered graphs: the Mobius construction, which corresponds to natural insertion algorithms, and the Pieri construction, which is an algebraic construction. The main examples in this talk stem from the K-theoretic combinatorial Hopf algebras of Lam and Pylyavskyy. (Received August 06, 2015)

1112-05-271 **Henry Kvinge*** (hkvinge@math.ucdavis.edu) and **Monica Vazirani**. *The influence of the Kirillov-Reshetikhin crystal $B^{1,1}$ on the structure of simple cyclotomic KLR modules.*

Khovanov-Lauda-Rouquier (KLR) algebras were invented to categorify the negative half of the quantum Kac-Moody algebra associated to a symmetrizable Cartan data. It was later shown by Lauda-Vazirani that the simple modules of the cyclotomic KLR algebra, R^Λ, carry the structure of the highest weight crystal $B(\Lambda)$. It follows from this that any properties of $B(\Lambda)$ should be the shadow of some module-theoretic property of simple R^Λ-modules.

In classical affine type, highest weight crystals (which are infinite) have the remarkable property that they can be constructed from the tensor product of the much more tractable perfect crystals (which are finite). In this talk I will describe the algebraic analogue of this phenomenon in terms of simple R^Λ-modules in the case where the perfect crystal is the Kirillov-Reshetikhin crystal $B^{1,1}$ and Λ is the fundamental weight Λ_i.

This is joint work with Monica Vazirani. (Received August 06, 2015)

1112-05-282 **Karim Adiprasito**, **Eran Nevo** and **Jose Alejandro Samper*** (samper@math.washington.edu). *The geometric lower bound theorem.*

We study the relationship between the g-theorem and polytopes that approximate convex bodies with smooth boundary. In 1994 Kalai posited a visionary conjecture stating that if K is a convex body whose boundary is C^1 and P is a simplicial polytope that gives a good approximation of K, then the face numbers of P must be far from extremal in the sense of the g-theorem. We will explain this conjecture, sketch a proof of the lower bound part of the conjecture for general C^1-convex bodies, give a tight (up to a constant) lower bound on the g-numbers of P in terms of the quality of the approximation (when K is C^2), and use this lower bound to resolve the conjecture in general for polytopes that arise from randomly sampling points from K. (Received August 06, 2015)

1112-05-285 **Victor Reiner**, **Bridget Tenner*** (bridget@math.depaul.edu) and **Alexander Yong**. *0-Hecke factorizations: a class of non-reduced words.*

Given a permutation $w \in S_n$, let $R(w)$ be the set of reduced words for w. The 0-Hecke monoid is generated by adjacent transpositions with the usual relations, with the exception that these generators are now idempotents instead of involutions. Thus a length-L' 0-Hecke word for w, with $L' > L$, is a non-reduced word for w.

We will show that for a class of permutations $\{w(k,a,b)\}$, the ratio of the number of length-$(L+1)$ 0-Hecke words for w to the number of reduced words for w is $(L+1)(k-1)ab/(a+b)$. (Received August 06, 2015)

1112-05-286 **Bridget Tenner*** (bridget@math.depaul.edu). *Reduced words via enumerations and graphs.*

The reduced words of a Coxeter group element are fundamental to understanding the group's architecture and that of its related objects. These words, and the Coxeter relations connecting them, define several natural graph structures and lead to a range of enumerative problems. (Received August 06, 2015)

1112-05-292 **Satoshi Murai**, Department of Pure and Applied Mathematics, School of Information Science and Technology, Osaka University, Toyonaka, Osaka 560-0043, Japan, and **Isabella Novik*** (novik@math.washington.edu), Department of Mathematics, University of Washington, Seattle, WA 98195-4350. *Face numbers of manifolds with boundary.*

We discuss several very recent results on face numbers of simplicial complexes that triangulate manifolds (or even normal pseudomanifolds) with boundary. One of our results provides a sharp lower bound on the number of interior edges of a simplicial normal pseudomanifold with boundary in terms of the number of interior vertices and relative Betti numbers. Another result is an extension of the first one to sharp lower bounds on the number of higher-dimensional interior faces of a simplicial manifold with boundary under an additional restriction that all vertex links of this manifold have the weak Lefschetz property. These results are natural analogs of known results and conjectures for closed manifolds. (Received August 07, 2015)

1112-05-293 **Caroline Terry*** (cterry3@uic.edu). *Zero-one laws for edge weighted graphs.*

Define a weighted graph G to be a pair (V,w) where V is a set of vertices and $w:\binom{V}{2}\to\mathbb{N}$ is a weight function. Given integers $k\geq 3$ and $r\geq 2$, define a (k,r)-graph to be a weighted graph (V,w) with the property that for any set of k points $X\subseteq[n]$, $\sum_{x\neq y\in X} w(x,y)\leq r$. For each $n\in\mathbb{N}$, define $F_{k,r}(n)$ to be the set of (k,r)-graphs with vertex set $[n]=\{1,\ldots,n\}$. We present results on the approximate asymptotic structure of $F_{k,r}(n)$ for various values of k and r. In special cases of k and r we refine these results to yield a logical 0-1 law. These results generalize existing 0-1 laws for the families of finite K_n-free graphs for $n\geq 3$. This is joint work with Dhruv Mubayi. (Received August 11, 2015)

1112-05-294 **Andrew R Francis*** (a.francis@uws.edu.au), Centre for Research in Mathematics, Western Sydney University, Penrith, NSW 2751, Australia. *Tree-based phylogenetic networks.*

A binary phylogenetic network may or may not be obtainable from a tree by the addition of directed edges (arcs) between tree arcs. In this talk I will present a precise and easily tested criterion that efficiently determines whether or not any given network can be realized in this way. The proof provides a polynomial-time algorithm for finding one or more trees (when they exist) on which the network can be based. I will also talk about a number of interesting consequences, and some further relevant questions and observations.

Joint work with Mike Steel. (Received August 07, 2015)

1112-05-303 **Paul Drube***, 1900 Chapel Drive, Valparaiso, IN 46383. *Combinatorics of Tableau Inversions.*

A tableau inversion is a pair of entries in row-standard tableau T that lie in the same column of T yet lack the appropriate relative ordering to make T column-standard. An i-inverted Young tableau is a row-standard tableau along with a precisely i inversion pairs. Tableau inversions were originally introduced by Fresse to calculate the Betti numbers of Springer fibers in Type A; in this talk we approach the topic of tableau inversions from a completely combinatorial perspective. We present formulas enumerating the number of i-inverted Young tableaux for a variety of tableau shapes, and share the results of a computer program developed to calculate tableau inversions. We close by discussing generalizations of tableau inversions to semistandard tableaux. (Received August 07, 2015)

1112-05-312 **Tyler Lewis Mitchell*** (tmitchell2@niu.edu). *Fusion Rings with Degrees 1 and 4.*

Fusion rings are a class of table algebras that generalize group rings with basis the group and character rings of a finite group with basis the irreducible characters. Examples are the Grothendieck rings of fusion categories, algebraic structures that are related to conformal field theory. When considering the character ring of a group as a fusion ring, the usual degree of a character coincides with the value assigned by the degree map. Hence classifying fusion rings based on the degree set is a generalization of classifying groups based on the degrees of the irreducible characters. The main theorem classifies real fusion rings with degrees 1 and 4 such that all stabilizers have the same order (so-called *stabilizer-regular* fusion rings). (Received August 07, 2015)

1112-05-313 **Jan Reimann***, Department of Mathematics, Pennsylvania State University, University Park, PA 16802. *Random graphs, finite extension constructions, and complexity.*

The study of (infinite) random graphs has recently been greatly advanced by the development of the theory of graphons. These continuous structures yield countable random graphs "from above", via sampling, as opposed to the approach "from below", such as via Fraissé limits.

Petrov and Vershik showed how to obtain countable universal random graphs by sampling them from graphons. Their approach was extended recently to other structures by Ackerman, Freer, and Patel.

We investigate the complexity of such universal graphons. Our main result is that if a 0-1-valued graphon is constructed in a "tame" way (via a kind of finite extension method), then the induced fiber topology (also known as the r_W-topology) is not compact.

This is joint work with Cameron Freer (MIT). (Received August 07, 2015)

1112-05-314 **Lisa Berry** and **Devadoss Satyan** (laforcey@gmail.com), Akron, OH 44313, and **Stefan Forcey*** (sforcey@uakron.edu), **Stephen Reisdorff** and **Patrick Showers**. *Poset polytopes and some conjectured tree polytopes.*

I'll define and give examples of how a new simple polytope can be associated to every poset. The facets of this polytope are certain connected lower sets (order ideals). Special cases give many famous polytopes and new ways to construct them: associahedra, cyclohedra, and all the other graph-associahedra arise from new truncations on product polytopes. Nestohedra and hypergraph-associahedra are also generated, as well as new polytopes not in any of those categories. Recently we proved that three sequences of painted-tree polytopes were actually equivalent to graph-associahedra for fans and stars, yielding new ways of illustrating products in the painted-tree algebras. That leaves open the conjecture that another four such sequences are also polytopal. (Received August 07, 2015)

1112-05-325 **Jozsef Balogh**, **Theodore Molla** and **Maryam Sharifzadeh*** (sharifz2@illinois.edu), Apt# 43, 612 West Church Street, Champaign, IL 61820. *On the Ramsey-Corradi-Hajnal theory.*

The classical Corrádi-Hajnal theorem states that every n-vertex graph G with $\delta(G) \geq 2n/3$ contains a triangle factor, where $3|n$. In this paper we determine the minimum degree condition for graphs with sublinear independence number. In particular we show that if an n-vertex graph has sub-linear independence number then the constant $2/3$ can be improved to $1/2 + \epsilon$ for arbitrary small constant $\epsilon > 0$. Additionally, we also consider a fractional variant of Corrádi-Hajnal Theorem, settling a conjecture of Balogh-Kemkes-Lee-Young. Let $t \in (0, 1)$ and $w : E(K_n) \to [0, 1]$. We call a triangle in K_n heavy if the sum of the weights of its edges is at least $3t$. We prove that if $G(V, E) = K_n$ with $n = 3k$ and $w : E \to [0, 1]$ such that for every v the sum of $w(e)$ for all edges e incident to v is at least $\left(\frac{1+2t}{3} + o(1)\right) n$, then there are k vertex disjoint heavy triangles in G.

This is joint work with Jozsef Balogh and Theodore Molla (Received August 07, 2015)

1112-05-326 **Jozsef Balogh*** (jozsebal@gmail.com), Urbana, IL 61821, and **Hong Liu**, **Maryam Sharifzadeh** and **Andrew Treglown**. *On problems of Cameron and Erdos.*

In 1990 and 1999, Cameron and Erdos proposed several problems in additive combinatorics. They asked about the number of sum-free sets, number of maximal sum-free sets, number of Sidon sets in [n]. Additionally they asked the number of sets in [n] without k-term arithmetic progression. In the talk we survey the recent progress on these questions. (Received August 07, 2015)

1112-05-327 **Steven Klee***, Seattle University Department of Mathematics, 901 12th Avenue, Seattle, WA 98122, and **Matthew Stamps**. *Graded Betti numbers of cycle graphs and standard Young tableaux.*

We consider the cycle graph on n vertices, viewed as a 1-dimensional simplicial complex. Minimal free resolutions of the Stanley-Reisner ideals of these graphs have been widely studied from the perspectives of combinatorics, algebra, and topology. In this talk, we will discuss a bijective proof showing that the Betti numbers of the resolution are given by the number of standard Young tableaux of a certain shape. (Received August 07, 2015)

1112-05-329 **Lauren Keough***, lakeough@davidson.edu, and **Jamie Radcliffe**. *Maximizing 2-independent sets in 3-uniform hypergraphs.* Preliminary report.

There has been recent interest in extremal problems in which one maximizes the number of a certain substructure among graphs with some fixed parameters. For example, the Kahn-Zhao theorem gives an upper bound on the number of independent sets in d-regular graphs. It is an easy corollary of the Kruskal-Katona Theorem that, for any n and m, the lex graph maximizes the number of independent sets of each size among graphs with n vertices and m edges. We will extend extremal results about the number of independent sets to 3-uniform hypergraphs

of fixed size and order. In hypergraphs we say a set of vertices, I, is j-independent if $|I \cap E| < j$ for any edge E. We answer the maximization question for 2-independent sets in 3-uniform hypergraphs with n vertices and m edges for particular values of n and m. (Received August 07, 2015)

1112-05-330 **Christine Bessenrodt**, **Vasu Tewari*** (tewari.vasu@gmail.com) and **Steph van Willigenburg**. *Littlewood-Richardson rules for symmetric skew quasisymmetric Schur functions.*

Skew quasisymmetric Schur functions are a generalization of a natural refinement of Schur functions called quasisymmetric Schur functions, and contain an extremely important class of symmetric functions called skew Schur functions. One way of expanding skew Schur functions in terms of Schur functions is to use the famed version of the classical Littlewood-Richardson rule involving Yamanouchi words. This given, a natural question to consider is whether there exists an analogous rule for skew quasisymmetric Schur functions.

In this talk we will give two Littlewood-Richardson rules for symmetric skew quasisymmetric Schur functions that are analogous to the aforementioned version of the classical Littlewood-Richardson rule. Furthermore, both our rules have the nice property that they contain this version as a special case. We will then apply our rules to combinatorially classify symmetric skew quasisymmetric Schur functions, thereby answering a conjecture of Bessenrodt, Luoto and van Willigenburg affirmatively. This talk is based on joint work with Christine Bessenrodt and Steph van Willigenburg. (Received August 07, 2015)

1112-05-341 **Jian Cheng**, **You Lu**, **Rong Luo*** (rluo@math.wvu.edu) and **Cun-Quan Zhang**. *Signed circuit covers of signed graphs.* Preliminary report.

It is known that a signed graph G has a signed circuit cover if and only if it is s-bridgeless where a signed circuit cover of G is a family $\mathcal{F}$ of signed circuits such that each edge of G belongs to at least one member of $\mathcal{F}$. Recently, Máčajová et al. proved that every s-bridgeless signed graph G has a signed circuit cover with length at most $11|E(G)|$ [JGT2015]. Recently we improve the result of Máčajová et al. and prove that every s-bridgeless signed graph G has a signed circuit cover with length at most $\frac{14}{3}|E(G)| - \frac{5}{3}\epsilon_N(G) - 2$, where $\epsilon_N(G)$ is the negativeness of G. In particular, if G is a g-bridgeless signed graph (and thus 2-edge-connected signed graph) with even negativeness, the coefficient $\frac{14}{3}$ can be reduced to $\frac{11}{3}$. (Received August 08, 2015)

1112-05-349 **Wen Liu*** (lwen@math.wisc.edu), 202 Eagle Heights, Apt. K, Madison, WI 53705. *The Incidence Algebra of the Attenuated Space Poset.*

In this talk, we consider the incidence algebra T of the poset P based on the attenuated space $\mathcal{A}_{q^2}(N, M)$. We display some relations among the raising matrix R, the lowering matrix L, and a certain diagonal matrix K. Using these relations we obtain a $U_q(sl_2)$-module structure on $\mathbb{C}P$. We find two central elements of T, and show that these elements generate the center $Z(T)$. We discuss the combinatorial meaning of these central elements.

This is a joint work with Professor Paul Terwilliger. (Received August 08, 2015)

1112-05-351 **Oliver Pechenik*** (pecheni2@illinois.edu), Department of Mathematics, 1409 W. Green Street, Urbana, IL 61801, and **Alexander Yong**. *Knutson-Vakil puzzles compute equivariant K-theory of Grassmannians.*

Puzzles are combinatorial objects introduced by A. Knutson and T. Tao in their solution of the Horn problem on eigenvalues of Hermitian matrices. By work of A. Knutson and R. Vakil, puzzles are known to encode certain geometric degenerations relevant to the Schubert calculus of Grassmannians. In 2005, A. Knutson and R. Vakil used puzzles to conjecture the first combinatorial rule for the Schubert structure coefficients in the torus-equivariant K-theory of Grassmannians. We resolve this conjecture by relating it to our recent tableau rule for the same coefficients. (Received August 08, 2015)

1112-05-352 **Oliver Pechenik** (pecheni2@illinois.edu), Math Dept., UIUC, 1409 W Green Street, Urbana, IL 61801, and **Alexander Yong*** (ayong@uiuc.edu), Math Dept., UIUC, 1409 W. Green Steet, Urbana, IL 61801. *Genomic tableaux and Equivariant K-theory of Grassmannians.*

I will discuss a tableau rule for equivariant K-theory of Grassmannians. The proof is based on a generalization of Schützenberger's jeu de taquin. This rule is used to resolve the puzzle conjecture of A. Knutson–R. Vakil and a different tableau conjecture of H. Thomas–A. Yong. While this is a continuation of Oliver Pechenik's talk, it will be largely self-contained. (Received August 08, 2015)

1112-05-356 **Michael Ferrara*** (michael.ferrara@ucdenver.edu), **Catherine Erbes**, **Ryan M. Martin** and **Paul Wenger**. *Stability of the Potential Function.* Preliminary report.

A graphic sequence π is potentially H-graphic if there is some realization of π that contains H as a subgraph. The Erdős-Jacobson-Lehel problem asks to determine $\sigma(H,n)$, the minimum even integer such that any graphic sequence π with sum at least $\sigma(H,n)$ is potentially H-graphic.

Recently, Ferrara, LeSaulnier, Moffatt and Wenger determined $\sigma(H,n)$ asymptotically for all H. In short, their result states that for a graph H, there is a family $\mathcal{P}(H)$ of graphic sequences such that $\sigma(H,n) = \sigma(\pi)n+o(n)$ for every $\pi \in \mathcal{P}(H)$.

In this paper, we prove several stability results for the Erdős-Jacobson-Lehel problem, similar to the stability results of Erdős and Simonovits for the Turán problem. We say that a graph H is σ-stable if every graphic sequence with sum close to $\sigma(H,n)$ that is not potentially H-graphic can be transformed into a sequence in $\mathcal{P}(H)$ with $o(n)$ additions and subtractions. We show that there is a large family of graphs that are σ-stable. However, we also show that, in contrast to the Turán problem, not all graphs are σ-stable. (Received August 08, 2015)

1112-05-357 **Michael Ferrara'*** (michael.ferrara@ucdenver.edu), **Christopher Cox**, **Ryan Martin** and **Benjamin Reiniger**. *Chvátal-type results for degree sequence Ramsey numbers.*

A sequence of nonnegative integers $\pi = (d_1, d_2, ..., d_n)$ is *graphic* if there is a (simple) graph G of order n having degree sequence π. In this case, G is said to *realize* or be a *realization of* π. Given a graph H, a graphic sequence π is *potentially H-graphic* if there is some realization of π that contains H as a subgraph.

In this paper, we consider a degree sequence analogue to classical graph Ramsey numbers. For graphs H_1 and H_2, the *potential-Ramsey number* $r_{pot}(H_1, H_2)$ is the minimum integer N such that for any N-term graphic sequence π, either π is potentially H_1-graphic or the complementary sequence $\overline{\pi} = (N-1-d_N, \ldots, N-1-d_1)$ is potentially H_2-graphic.

We prove that if $s \geq 2$ is an integer and T_t is a tree of order $t \geq 9(s-2)$, then

$$r_{pot}(K_s, T_t) = t + s - 2.$$

This result, which is best possible up to the coefficient on the bound on t, is a degree sequence analogue to a classical 1977 result of Chvátal on the graph Ramsey number of trees vs. cliques. To obtain this theorem, we prove a sharp condition that ensures an arbitrary graph packs with a forest, which may be of independent interest. (Received August 08, 2015)

1112-05-385 **Julia Chuzhoy*** (cjulia@ttic.edu), 6045 S. Kenwood Ave, Chicago, IL 60637. *Excluded Grid Theorem: Improved and Simplified.*

One of the key results in Robertson and Seymour's seminal work on graph minors is the Excluded Grid Theorem. The theorem states that for every fixed-size grid H, every graph whose treewidth is large enough, contains H as a minor. This theorem has found many applications in graph theory and algorithms. Let f(k) denote the largest value, such that every graph of treewidth k contains a grid minor of size f(k). Until recently, the best known bound on f(k) was sub-logarithmic in k. In this talk we will survey new results and techniques that establish polynomial bounds on f(k). (Received August 09, 2015)

1112-05-395 **Martin Merker** and **Luke Postle*** (lpostle@uwaterloo.ca), 200 University Ave West, Waterloo, ON N2L 3G1, Canada. *Bounded Diameter Arboricity.*

We discuss the notion of bounded diameter arboricity, wherein the edges of a graph are partitioned into forests of bounded diameter. We prove that a graph of arboricity $k \in \{2,3\}$ has bounded diameter arboricity at most $k+1$. We conjecture that this holds for all larger k. (Received August 09, 2015)

1112-05-397 **Emily Leven**, **Brendon Rhoades** and **Andy Wilson*** (atwilson0328@gmail.com). *Bijections for the Shi and Ish arrangements.*

The Shi hyperplane arrangement was introduced by Shi to study the Kazhdan-Lusztig cellular structure of the affine symmetric group. More recently, the Ish hyperplane arrangement was introduced by Armstrong in the study of diagonal harmonics. Armstrong and Rhoades discovered a deep combinatorial similarity between the Shi and Ish arrangements. We solve a collection of problems posed by Armstrong and Armstrong-Rhoades by giving bijections between regions of Shi(n) and Ish(n) which preserve certain statistics. The key tools in our bijections are the introduction of an Ish analog of parking functions, which we call rook words, and a new instance of the cycle lemma. (Received August 09, 2015)

1112-05-398 **C. Y. Amy Pang*** (amypang@lacim.ca). *A Hopf-Algebraic Lift of the Down-up Markov Chain on Partitions to Permutations.*

Abstract. In "Card shuffling and the decomposition of tensor products", Jason Fulman explores a Markov chain on partition diagrams, where each step removes a box then adds a new box. The stationary distribution of this chain is the Plancherel measure, which suggests that it is the image under the RSK-shape map of a chain on permutations with uniform stationary distribution. Fulman proves that one possible lift, starting from the identity permutation, is the "top-to-random shuffle": remove the top card of a deck, and reinsert it at a uniformly chosen position. We construct a different lift, valid from more initial distributions, using a new and very general result regarding Markov chains from non-negative linear maps. This abstract result essentially reduces the lift construction to a well-known fact: the algebra of symmetric functions is a subquotient of the Malvenuto-Reutenauer Hopf algebra of permutations. This talk is based on the preprint of the same title (arXiv:1508.01570). (Received August 09, 2015)

1112-05-399 **Deepak Bal*** (bald@mail.montclair.edu). *Rainbow Structures in Random Graphs.*

Consider a graph whose edges have been assigned colors. A set of edges is called rainbow if all the edges in the set receive different colors. In this talk I will discuss some recent results concerning rainbow structures (matchings, Hamilton cycles, spanning trees) when the underlying graph is a random graph and the edges have been assigned colors randomly. (Received August 09, 2015)

1112-05-400 **Anna Weigandt*** (weigndt2@illinois.edu), 1409 W. Green St, Urbana, IL 61801, and **Alexander Yong** (ayong@uiuc.edu), 1409 W. Green St, Urbana, IL 61801. *The prism tableau model for Schubert polynomials.*

The Schubert polynomials lift the Schur basis of symmetric polynomials into a basis for all polynomials. However, their original definition does not make their monomial non-negativity manifest. Instead, various combinatorial models for the terms have been discovered over the past two decades. We propose the *prism tableau model* – this separates the data of each monomial into colors. In the special case, a prism tableau straightforwardly reduces to a semistandard Young tableau. (Received August 10, 2015)

1112-05-401 **Jay Pantone*** (jp@dartmouth.edu). *Asymptotics of Permutation Classes and the Method of Differential Approximants.*

When you're unable to find the generating function for a combinatorial sequence, the next best thing is to compute many initial terms. Recently, we've found thousands of initial terms of four permutation classes for which we cannot derive (or even guess) the generating functions.

The Method of Differential Approximants allows one to predict the asymptotic behavior of a combinatorial sequence using only known initial terms. While this technique is well-known in the field of statistical mechanics, we have not seen it used very often in combinatorics. After explaining how the method works, we'll use it to estimate the asymptotic behavior of our four mysterious permutation classes. (Received August 09, 2015)

1112-05-404 **Prasad V Tetali*** (tetali@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30030. *Independent sets in regular graphs : spectral stability.* Preliminary report.

Let $B(d,n)$ denote the d-regular graph on n vertices which consists of the disjoint union of complete bipartite graphs. It follows from the results of Kahn and of Zhao that among all d-regular graphs on n vertices $B(d,n)$ maximizes the number of independent sets. In this talk, we show a spectral stability phenomenon of this result in the following sense. The eigenvalues of (the adjacency matrix) of $B(d,n)$ are known to be $d, -d$ and zeroes and we show that, if the smallest eigenvalue of G is bounded away from $-d$, then the number of independent sets in G is exponentially smaller than that in $B(d,n)$. This and related results obtained in joint work with Hiep Han will be covered in the talk. (Received August 09, 2015)

1112-05-406 **Dong Ye*** (dong.ye@mtsu.edu), Department of Mathematical Sciences, MTSU Box 34, Murfreesboro, TN 37130. *Inverses of Graphs.* Preliminary report.

Let (G,w) be a weighted graph with a weight-function $w : E(G) \to \mathbb{R}\backslash\{0\}$. A weighted graph (G,w) is invertible to a new weighted graph if its adjacency matrix is invertible. The inverse of a weighted graph (G,w) can be characterized based on the Sachs subgraphs of G that are spanning subgraphs with only K_2 or cycles (or loops) as components. The inverses of bipartite graphs with a unique perfect matching have strong connections with the Mobius function of posets. Besides the combinatorial interests, graph inverses can be applied to bound median eigenvalues of graphs. In this talk, some recent developments on inverses of graphs will be presented. This talk is based on joint work with D. Klein, B. Mandal and Y. Yang. (Received August 10, 2015)

1112-05-407 **Roger Tian*** (rgtian@math.ucdavis.edu). *Expansion Formulae for Top to Random Shuffling.*

Card shuffling is a much-studied topic in probability theory and combinatorics. In the top to random shuffle, the first a cards are removed from a deck of n cards $12\dots n$ and then inserted back into the deck. I will analyze top to random shuffling from a combinatorial perspective, by deriving an expansion formula for these shuffles via a bijection and further generalizing the formula to the situation where each card in the deck has multiple faces. These expansion formulae can be used for enumeration and calculating probabilities. (Received August 10, 2015)

1112-05-409 **Eric Marberg*** (eric.marberg@gmail.com). *Extending the theory of PSD algebras to Hopf monoids in species.*

A vector species is a functor from the category of finite sets with bijections to vector spaces, and a Hopf monoid (in the category of vector species) consists of a vector species with unit, counit, product, and coproduct morphisms satisfying several compatibility conditions, analogous to a graded Hopf algebra. Zelevinsky introduced the notion of a positive self-dual (PSD) Hopf algebra to characterize the algebraic structure of the ring of the symmetric functions; a PSD algebra consists of a self-dual graded Hopf algebra with a basis of "Schur functions" whose structure constants are positive integers. In this talk I will discuss the structure theory and classification of Hopf monoids exhibiting certain strong forms of self-duality, which can be viewed as species analogues of positive self-duality for Hopf algebras. Such results provide a simple way of understanding the relationships between various Hopf algebras attached to towers of unipotent groups, recently considered in the literature. (Received August 10, 2015)

1112-05-415 **Jean-Baptiste Priez***, Bâtiment 650, PCRI, Rue Noetzlin, 91190 Gif-sur-Yvette, France. *Polynomial realizations of Hopf algebras.*

We formalize the theory of polynomial realizations of Hopf algebras. This gives a framework in which many combinatorial Hopf algebras easily arise from elementary combinatorial ingredients. As an example, we construct a family of Hopf algebras with basis indexed by generalized parking functions. We will finally see how polynomial realizations may be naturally lifted within the theory of bimonoids. (Received August 10, 2015)

1112-05-427 **Csaba Biro*** (csaba.biro@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Stephen J Young** and **Mitchel T Keller**. *The cover graph of a poset and its dimension.*

In recent years, some new connections between the cover graph of a poset and its dimension have been discovered. We show some new results in the area. (Received August 10, 2015)

1112-05-432 **Karl R.B. Schmitt***, 1900 Chapel Dr, Gellersen Center, Valparaiso University, and **Linda Eroh**, **Henry Escuadro**, **Ralucca Gera** and **Samuel Prahlow**. *A Method of Approximating Cliques in Networks: k-dense.*

Motivated by the idea of community (or sub-graph) detection within a network/graph, we focused on finding characterizations of k-dense communities, introduced by Saito, Yamada and Kazama. In this research, we characterize which graphs are k-dense but not $(k+1)$-dense for some values of k and study the minimum and maximum number of edges such graphs can have. Proofs of these minimum and maximums are built using enumerative combinatorics. A better understanding of k-dense sub-graphs (or communities) helps in the study of the connectivity of large complex graphs (or networks) in the real world. (Received August 10, 2015)

1112-05-435 **Andrzej Dudek*** (andrzej.dudek@wmich.edu), Kalamazoo, MI 49008. *On Ramsey-type problems for sequences.*

Ramsey theory can loosely be described as the study of structure which is preserved under finite decomposition. A classical Ramsey theorem states that in any r-coloring of the edges of a sufficiently large complete graph, one will always find a monochromatic complete subgraph.

In this talk, we discuss analogous results for sequences and permutations. In particular, we study the behavior of the following function $f(r, X)$, which is the length of the shortest sequence Y such that any r-coloring of the entries of Y yields a monochromatic subsequence that also preserves the order of X. (Received August 10, 2015)

1112-05-441 **Michael Schroeder** and **Rebecca Smith*** (rnsmith@brockport.edu). *Sorting with two stacks in series.* Preliminary report.

Knuth showed that a permutation π can be sorted by a stack (meaning that by applying push and pop operations to the sequence of entries $\pi(1), \ldots, \pi(n)$ we can output the sequence $1, \ldots, n$) if and only if π avoids the permutation 231, i.e., if and only if there do not exist three indices $1 \leq i_1 < i_2 < i_3 \leq n$ such that $\pi(i_1), \pi(i_2), \pi(i_3)$ are in the same relative order as 231.

Atkinson, Murphy, and Ruškuc considered sorting with two increasing stacks in series, i.e., two stacks whose entries must be in increasing order when read from top to bottom. The second stack must be such that the entries are always in increasing order to successfully sort a permutation. However, this restriction places new limitations on the first stack. We consider a different limitation for the first stack; one where the entries must be in decreasing order from top to bottom. This decreasing restriction creates a sortable permutation class enumerated by the Schröder numbers. We show a bijection between these permutations and a class of lattice paths also known to be enumerated by the Schröder numbers. (Received August 10, 2015)

1112-05-442 **Benjamin Braun*** (benjamin.braun@uky.edu), **Matthias Beck**, **Matthias Koeppe**, **Carla D. Savage** and **Zafeirakis Zafeirakopoulos**. *Generating functions and triangulations for lecture hall cones.* Preliminary report.

We investigate the arithmetic-geometric structure of the lecture hall cone

$$L_n := \left\{ \lambda \in R^n : 0 \leq \frac{\lambda_1}{1} \leq \frac{\lambda_2}{2} \leq \frac{\lambda_3}{3} \leq \cdots \leq \frac{\lambda_n}{n} \right\}.$$

We show that L_n is isomorphic to the cone over the lattice pyramid of a reflexive simplex whose Ehrhart h^*-polynomial is given by the $(n-1)$st Eulerian polynomial, and prove that lecture hall cones admit regular, flag, unimodular triangulations. After explicitly describing the Hilbert basis for L_n, we conclude with observations and a conjecture regarding the structure of unimodular triangulations of L_n, including connections between enumerative and algebraic properties of L_n and cones over unit cubes. (Received August 10, 2015)

1112-05-447 **Nathan Bliss** and **Jeff Sommars*** (sommars1@uic.edu), 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60607, and **Xiangcheng Yu** and **Jan Verschelde**. *Polynomial Homotopy Continuation in the Cloud.*

Polynomial homotopy continuation methods apply symbolic-numeric algorithms to solve polynomial systems. We describe the design and implementation of our web interface to PHCpack and reflect on the application of polynomial homotopy continuation methods to solve polynomial systems in the cloud. We prove that the graph isomorphism problem is equivalent to checking if the support of two polynomial systems are isomorphic, and we describe how this is necessary for the web interface. (Received August 10, 2015)

1112-05-457 **Kevin Dilks*** (kevin.dilks@ndsu.edu). *q Gamma Nonnegativity.*

A polynomial $\sum_{i=0}^{n} a_i t^i$ with symmetric coefficients ($a_{n-i} = a_i$) has a unique expansion $\sum_{k=0}^{\lfloor n/2 \rfloor} \gamma_k t^k (1+t)^{n-2k}$, and is said to be *gamma nonnegative* if $\gamma_k \geq 0$ for all k. We either prove or conjecture a stronger q-analogue of this property for several polynomials in two variables t,q, whose $q = 1$ specializations are known to be gamma nonnegative. (Received August 10, 2015)

1112-05-460 **Guantao Chen*** (gchen@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303, **Zhiquan Hu**, Faculty of Mathematics and Statistics, Central China Normal University, Wuhan, Peoples Rep of China, and **Feifei Song**, Faculty of Mathematics and Statistics, Central China Normal, Wuhan, Peoples Rep of China. *Linkage and Hadwiger's conjecture.* Preliminary report.

Let G be a graph and S be a vertex subset of G. The pair (G, S) is called *knitted* if, for every partition of S into non-empty subsets $S_1, S_2, \ldots, S_t$, there exist disjoint connected subgraphs $C_1, C_2, \ldots, C_t$ in G so that $S_i \subseteq V(C_i)$ for each $1 \leq i \leq t$. A graph G is called *ℓ-knitted* if (G, S) is knitted for all subsets S of $V(G)$ with $|S| = \ell$. We show that every 6ℓ-connected graph is ℓ-knitted and obtain a degree sum condition for a graph G to be (G, S)-knitted, which involves only the degree sum of nonadjacent vertices of S. Hadwiger conjectured that every k-chromatic graph contains a K_k-minor. We show that if G is a vertex-minimal k-chromatic graph with no K_k minors, then G is $\lceil k/6 \rceil$-connected. (Received August 10, 2015)

1112-05-471 **Axel Brandt**, **Michael Ferrara**, **Mohit Kumbhat**, **Sarah Loeb**, **Derrick Stolee*** (dstolee@iastate.edu) and **Matthew Yancey**. *I,F-Partitions of Sparse Graphs.*

A *star k-coloring* is a proper k-coloring where the union of two color classes induces a star forest. While every planar graph is 4-colorable, not every planar graph is star 4-colorable. One method to produce a star 4-coloring is to partition the vertex set into a 2-independent set and a forest; such a partition is called an *I,F-partition*.

We use a combination of potential functions and discharging to prove that every graph with maximum average degree less than $\frac{5}{2}$ has an I,F-partition, which is sharp and answers a question of Cranston and West [A guide to the discharging method, arXiv:1306.4434]. This result implies that planar graphs of girth at least 10 are star 4-colorable, improving upon previous results of Bu, Cranston, Montassier, Raspaud, and Wang [Star coloring of sparse graphs, *J. Graph Theory* **62** (2009), 201-219]. (Received August 10, 2015)

1112-05-473 **Angele M. Hamel*** (ahamel@wlu.ca), Wilfrid Laurier University, Waterloo, Ontario , Canada, and **Ronald C. King**. *Symplectic Tokuyama's identity.* Preliminary report.

Tokuyama's identity involves the deformation and expansion of Weyl's denominator formula multiplied by a general linear group character. Deformations of Weyl's original denominator formula to other root systems have been discovered, and it is thus natural to look for versions of Tokuyama's identity for these root systems. Our previous work has considered such identities in both the orthogonal and symplectic cases. In this talk we discuss some new results for the symplectic case. (Received August 10, 2015)

1112-05-478 **Travis Scrimshaw*** (tscrim@ucdavis.edu), Department of Mathematics, One Shields Avenue, Davis, CA 95616. *KKR-type bijection in exceptional types.* Preliminary report.

We prove a conjectural bijection by bin Mohammad between tensor products of certain Kirillov–Reshetikhin crystals and rigged configurations and extend it to affine types satisfying certain conditions. Moreover, we give an extension of the bijection given by Okado and Sano to $\bigotimes_{i=1}^{N} B^{r_i,1}$ in type $E_6^{(1)}$ and for certain r_i in type $E_7^{(1)}$. (Received August 10, 2015)

1112-05-519 **Vidya Venkateswaran***, vidyav@math.mit.edu. *A p-adic interpretation of some integral identities for Hall-Littlewood polynomials.*

If one restricts an irreducible representation of GL_n to the orthogonal subgroup (respectively, the symplectic subgroup), classical branching rules tell us when the trivial representation is contained in the restricted representation. In both cases, the partition λ that indexes the original representation must satisfy a particular condition: in the orthogonal (respectively, symplectic) case, λ (resp. λ') must have all even parts. Using character theory, these results may be rephrased in terms of integrals involving the Schur functions. Since Hall-Littlewood polynomials are t-generalizations of Schur functions, one may consider t-analogs of these results. We will discuss these identities, focusing on an interpretation using p-adic representation theory that parallels the Schur case. (Received August 10, 2015)

1112-05-521 **Yannic Vargas*** (yannicmath@gmail.com). *Permutation patterns and Hopf algebra of permutations.*

We investigate several instances of permutations patterns, an analogous notion of the classical pattern of words to permutations, in some combinatorial Hopf algebras of permutations. First, using analogues of the classical shuffle and infiltration products for words, we define two new Hopf algebras of permutations related to the notion of permutation pattern. Furthermore, we present a new formula for the product of the monomial basis, introduced by Aguiar and Sottile, of the Hopf algebra of permutations studied by Malvenuto and Reutenauer, in terms of special types of permutation patterns, using the notion of planar posets introduced by Foissy. (Received August 10, 2015)

1112-05-523 **Kayla Harville**, **Talmage James Reid*** (mmreid@olemiss.edu) and **Haidong Wu**. *Regular and Binary Matroids without Certain Minors.*

We determine classes of binary and regular matroids without certain small minors. We prove a decomposition theorem for regular matroids without a fixed vertically 4-connected minor and apply this result to extend some results from graphs to regular matroids. (Received August 10, 2015)

1112-05-535 **Jay Schweig***, 401 MSCS, Stillwater, OK 74078, and **Russ Woodroofe**. *The Order Partition and Subposet Lattices.*

Given a poset P, the associated order partition lattice, O(P), is the lattice of partitions that are "compatible" with the poset P. When P is the antichain, O(P) is the standard partition lattice. When P is a chain, O(P) is the Boolean lattice. Another lattice associated to a poset P is its subposet lattice, which is the lattice of all labeled subposets of P, ordered by refinement. We investigate the topology of the order complexes of these lattices, using EL- and CL-labelings to show that they are shellable. (Received August 11, 2015)

1112-05-539 **Stephen G. Hartke*** (stephen.hartke@ucdenver.edu), Dept of Mathematical and Statistical Sciences, University of Colorado Denver, Denver, CO. *Graph realizations of a degree sequence constrained by a vertex partition.* Preliminary report.

Given a sequence $\pi = (d_1, \ldots, d_n)$, a graph G is a *realization* of π if π is the degree sequence of G. Motivated by questions about social and biological networks, we study realizations of a degree sequence that have the additional constraint that the number of edges between each pair of parts of a vertex partition is fixed. For partitions with two parts, we resolve the questions of how to test whether a given sequence has a compatible realization and whether the space of all such realizations is connected using small changes.

This is joint work with Péter Erdős, Leo van Iersel, and István Miklós. (Received August 11, 2015)

1112-05-543 **Alejandro H. Morales*** (ahmorales@math.ucla.edu), **Igor Pak** and **Greta Panova**. *q-analogues of Naruse's hook-length formula for skew shapes.*

The celebrated hook-length formula of Frame, Robinson and Thrall from 1954 gives a product formula for the number of standard Young tableaux of straight shape. No such product formula exists for skew shapes but there are determinantal and positive formulas involving Littlewood-Richardson coefficients. In 2014, Naruse announced a positive formula without these coefficients and very close to the formula for the straight shape case. We give two q-analogues of Naruse's formula involving semistandard Young tableaux and reverse plane partitions of skew shape. We show that the Hillman-Grassl correspondence is a bijection explaining these q-analogues. (Received August 11, 2015)

1112-05-545 **Baogang Xu**, Nanjing Normal University, **Gexin Yu*** (gyu@wm.edu), College of William and Mary, and **Xiaoya Zha**, Middle Tennessee State University. *A note on chromatic number and induced odd cycles.* Preliminary report.

An odd hole is an induced odd cycle of length at least 5. Scott and Seymour confirmed a conjecture of Gyárfás and proved that if a graph G has no odd holes then $\chi(G) \leq 2^{2^{\omega(G)+2}}$. Chudnovsky, Robertson, Seymour and Thomas showed that if G has neither K_4 nor odd holes then $\chi(G) \leq 4$. In this note, we show that if a graph G has neither triangles nor quadrilaterals, and has no odd holes of length at least 7, then $\chi(G) \leq 3$, and for each vertex u of G, the set of vertices of the same distance to u induces a bipartite subgraph. This also answers some questions by Plummer and Zha. (Received August 11, 2015)

1112-05-559 **Ragnar Freij*** (ragnar.freij@aalto.fi), Department of Communications and Networking, PO Box 13000, FI-00076 AALTO, 00630 Helsinki, Finland, and **Thomas Westerbäck** and **Camilla Hollanti**. *Weight enumeration of cooperative locally repairable codes.* Preliminary report.

Cooperative locally repairable codes have recently gathered wide interest, both for their applications in large scale distributed storage systems, and for their purely mathematical properties. In this talk, we will analyze locally repairable codes from the perspective of the strong connection between linear codes and matroids, and more generally between arbitrary codes and polymatroids. Well known techniques to calculate Tutte and rank polynomials of matroids are applied to the weight enumeration polynomials on locally repairable codes, which in turn give results on the possible field sizes over which given localities can be achieved. We also consider a (to our knowledge) new generalization of locally repairable codes, where the repair can be performed on several different scales, further enhancing the robustness of a storage system. (Received August 11, 2015)

1112-05-566 **Jie Han** (jasonhan2011@gmail.com), **Allan Lo** (s.a.lo@bham.ac.uk), **Andrew Treglown** (a.c.treglown@bham.ac.uk) and **Yi Zhao*** (yzhao6@gsu.edu), Department of Math & Stat, Georgia State University, Atlanta, GA 30303. *Exact minimum codegree threshold for K_4^--factors in 3-uniform hypergraphs.*

Given two (hyper)graphs F and H, an F-factor in H is a family of vertex-disjoint copies of F which cover all the vertices in H. Let K_4^- denote the 3-uniform hypergraph with 4 vertices and 3 edges. We show that for sufficiently large $n \in 4\mathbb{N}$, every 3-uniform hypergraph H on n vertices with minimum codegree at least $n/2 - 1$ contains a K_4^--factor. The minimum codegree here is best-possible and resolves a conjecture of Lo and Markström, who earlier proved an asymptotic version of this result. Our proof makes use of the absorbing method as well as a result of Keevash and Mycroft concerning almost perfect matchings in hypergraphs. (Received August 11, 2015)

1112-05-573 **Hemanshu Kaul*** (kaul@iit.edu), 10 W 32nd St., Chicago, IL 60616, and **Christodoulos Mitillos** (cmitillo@hawk.iit.edu). *Fall Coloring of Graphs.* Preliminary report.

Fall Coloring of a graph, also called its idomatic partition, asks for a partition of its vertex set into independent sets that are also dominating sets. Unlike typical graph theoretic invariants, the fundamental question is that of existence of such a coloring. Note that any such coloring requires at least chromatic number of colors.

We will construct graphs with arbitrary large difference between their chromatic number and the minimum number of colors in any of their fall colorings, answering a question of Dunbar et al. (2000). We will also give construction of graphs that can be fall colored with many different pre-specified number of colors with arbitrarily large gaps. A sharp sufficient condition on the minimum degree of a graph that guarantees its fall coloring and when a proper coloring is/isn't a fall coloring will be discussed. We will describe the fall colorings for some basic graph classes, graph products, and operators, especially in relation to a conjecture for fall coloring of perfect graphs. (Received August 11, 2015)

1112-05-577 **Brian K Miceli*** (bmiceli@trinity.edu), One Trinity Place, Mathematics Dept., San Antonio, TX 78212. *The Laplace Transform and Some Combinatorial Identities.*

By considering the Laplace transform of certain functions, we generate various well-established combinatorial identities, such as

$$\sum_{j=0}^{n}(-1)^j\binom{n}{j}=0.$$

This method yields new identities as well, which we will provide, along with as many combinatorial proofs as possible. (Received August 11, 2015)

1112-05-580 **Jinyu Huang** (jhuang14@hawk.iit.edu) and **Hemanshu Kaul*** (kaul@iit.edu), Illinois Institute of Technology, 10 W 32nd St., Chicago, IL 60616. *On Matroid Expansion Conjecture: Counting Bases of a Matroid.*

Matroid Bases generalize many fundamental combinatorial structures. It is a longstanding problem to design an efficient algorithm for counting the number of bases in a matroid. A natural Markov Chain Monte Carlo algorithm would sample bases from the base-exchange graph G of the matroid M. The vertex-set of G is the collection of all bases of M and two bases are adjacent in G if their symmetric difference is exactly two elements. It was conjectured by Mihail and Vazirani in 1989 that the cutset-expansion (or conductance) of any base-exchange graph is at least 1, which is called the Matroid-expansion conjecture. If this conjecture is true then the natural MCMC algorithm is in fact rapidly convergent and defines an FPRAS (fully-polynomial randomized approximation scheme) for efficiently counting the number of bases of a matroid.

We give polynomial (or constant) bounds on the second smallest eigenvalue, λ_2, of the discrete Laplacian of the Base-exchange graph (which implies a bound on its conductance) for base-transitive matroids, paving matroids, and balanced matroids. This implies that the Matroid expansion conjecture is true for paving matroids, balanced matroids, and their direct sums; extending the results of Feder and Mihail (1992) and Jerrum (2006). (Received August 11, 2015)

1112-05-585 **David Irwin** (irwin.315@osu.edu) and **Tao Jiang*** (jiangt@miamioh.edu), Dept. of Mathematics, Miami University, Oxford, OH 45056. *Turan numbers of linear sunflowers.*

An s-sunflower with core C is a collection of sets $A_1, A_2, ..., A_s$ such that $\forall i, j, i \neq j, A_i \cap A_j = C$. A linear s-sunflower is an s-sunflower whose core has size 1. Let $f(n, r, s)$ denote the largest size of a r-uniform set family on n elements that does not contain a linear s-sunflower. For all $r \geq 5$ and $s \geq 2$, Frankl and Furedi determined $f(n, r, s)$ asymptotically, leaving open the asymptotics of the 4-uniform case. Chung and Frankl determined the exact value of $f(n, 3, s)$, for all sufficiently large n. Here we solve the problem completely for all sufficiently large n, that is, we determine the exact value of $f(n, r, s)$ for all $r \geq 4, s \geq 2$, and sufficiently large n. Like in Frankl and Furedi, our main method is the delta system method. However, the 4-uniform case requires a combination of different methods. (Received August 11, 2015)

1112-05-586 **Patrick R Devlin*** (prd41@math.rutgers.edu), Department of Mathematics, Rutgers University, Piscataway, NJ 08854, and **Jeff Kahn**, Department of Mathematics, Rutgers University, Piscataway, NJ 08854. *On "stability" in the Erdős-Ko-Rado theorem.*

Denote by $K_p(n, k)$ the random subgraph of the usual Kneser graph $K(n, k)$ in which edges appear independently, each with probability p. Answering a question of Bollobás, Narayanan, and Raigorodskii, we show that there is a fixed $p < 1$ such that a.s. (i.e., with probability tending to 1 as $k \to \infty$) the maximum independent sets of $K_p(2k + 1, k)$ are precisely the sets $\{A \in V(K(2k + 1, k)) : x \in A\}$ (where $x \in [2k + 1]$). We also complete the

determination of the order of magnitude of the "threshold" for the above property for general k and $n \geq 2k+2$. This is new for $k \sim n/2$, while for smaller k it is a recent result of Das and Tran. Joint work with Jeff Kahn. (Received August 11, 2015)

1112-05-590 **Ross Churchley**, **Bojan Mohar** and **Hehui Wu*** (hhwu@olemiss.edu). *Packing of edge-disjoint odd (u,v)-trails.*

For a graph G and vertices $u, v \in V(G)$, let $\nu_{ot}(u,v)$ be the maximum number of edge-disjoint (u,v)-trails of odd length, and let $\tau_{ot}(u,v)$ be the minimum number of edges that intersect every odd (u,v)-trail in G. It is proved that $\nu_{ot}(u,v) \leq \tau_{ot}(u,v) \leq 8\nu_{ot}(u,v)$. The proof leads to a polynomial-time algorithm to find, for any given k, either k edge-disjoint odd (u,v)-trails or a set of fewer than $8k$ edges intersecting all odd (u,v)-trails. (Received August 11, 2015)

1112-05-595 **Jessica Striker*** (jessica.striker@ndsu.edu). *Permutation totally symmetric self-complementary plane partitions, and Catalan subsets.*

Alternating sign matrices and totally symmetric self-complementary plane partitions are equinumerous sets of objects for which no explicit bijection is known. In this talk, we identify a subset of totally symmetric self-complementary plane partitions corresponding to permutations, which is a subset of alternating sign matrices, by giving a statistic-preserving bijection. We use this bijection to define a new partial order on permutations, and prove the 132- and 213-avoiding permutation subposets are two distinct Catalan subposets: the Tamari lattice and the Dyck path containment order. (Received August 11, 2015)

1112-05-596 **Franco Saliola*** (saliola.franco@uqam.ca). *A Hopf-algebraic approach to random-to-random shuffling operators.*

Pick a card–any card!–from the deck, and remove it; then put it back anywhere in the deck. Repeating this process leads to a card shuffling technique known as the random-to-random shuffle. An important open problem is to determine how many of these shuffles are needed to randomize a deck of cards. This is controlled by the spectra of these shuffles.

By considering all the random-to-random shuffles simultaneously, we prove that their eigenspaces admit a beautiful recursive structure. This structure allows one to build eigenbases starting from bases for the kernels. Among other things, this results in complete combinatorial descriptions of the eigenvalues.

This recursive structure also hints at an approach that uses the Hopf-algebraic formalism. We will present some successes and challenges in this direction and in studying similar shuffling operators.

Part of this talk is based on joint work with Ton Dieker. (Received August 11, 2015)

1112-05-597 **Jessica Striker*** (jessica.striker@ndsu.edu). *Partition and plane partition promotion and rowmotion.*

In this talk, we discuss promotion and rowmotion actions on partitions and plane partitions, along with their bijective and dynamical properties. We give a previous result on the cyclic nature of rowmotion on partitions inside a box or staircase. We present a recent analog of this result, relating actions on plane partitions and increasing tableaux and exploring a new dynamical pseudo-periodicity phenomenon we call resonance. We welcome comments as to how this work may relate to monomial ideals of two and three variables. This is based on recent joint work with Kevin Dilks and Oliver Pechenik, as well as previous joint work with Nathan Williams. (Received August 11, 2015)

1112-05-603 **D. Christopher Stephens*** (chris.stephens@mtsu.edu), 1301 East Main Street, Murfreesboro, TN 37132. *An analog for linklessly embeddable graphs of a theorem of Tutte.*

One concept which aids in the investigation of planar graphs is the extra layer of "nearness" provided by the plane embedding (e.g., two vertices may be said to be "near" one another if they share a face, regardless of their graphical distance).

Another helpful concept is the Jordan Curve Theorem and the exploitation of separating cycles.

In this talk we attempt to generalize these ideas to linklessly embeddable graphs by proving an analog to a theorem of Tutte. (Received August 11, 2015)

1112-05-606 **Alexander Burstein*** (aburstein@howard.edu), Department of Mathematics, Howard University, Washington, DC 20059. *Unimodal inversion sequences and pattern-avoiding classes.* Preliminary report.

Several separate results have shown that the class of unimodal inversion sequences and four classes of permutations avoiding certain sets of patterns have the same enumeration sequence. We give bijections between those

classes, and in some cases different Lehmer codes for all permutations so that the unimodal codes correspond to the desired pattern-avoiding classes.

This is a joint work with Walter Stromquist. (Received August 11, 2015)

1112-05-615 **Mike Zabrocki***, Mike Zabrocki, York Univeristy, Mathematics and Statistics, Toronto, ON M3J1P3, Canada, and **Rosa Orellana**. *On symmetric group and partition algebra characters.* Preliminary report.

When Gl_n acts with the natural action on the k-fold tensor product of an n-dimensional representation, the centralizer algebra is the symmetric group algebra on k-letters. In this case the Schur functions are the characters of the irreducible Gl_n representations. Analogously, if we consider the symmetric group on n letters acting on the k-fold tensor product of the permutation representation, then the partition algebra is the centralizer algebra of this action. We consider the basis of the symmetric functions which are the characters of the S_n representations. We show that the combinatorics of the change of basis coefficients describe the decomposition of Gl_n modules into S_n modules and the structure coefficients are the Kronecker coefficients.

This is joint work with Rosa Orellana. (Received August 11, 2015)

1112-05-619 **Sinan Aksoy** and **Paul Horn*** (paul.horn@du.edu), Department of Mathematics, Aspen Hall, Room 717, 2280 S Vine Street, Denver, CO 80208. *Graphs with many strong orientations.*

Determining whether a graph has a strong orientation is a classical problem with a simple and satisfying answer given by Robbins' theorem. In this talk we discuss a related problem: when are most (or, really, almost all) of a graphs orientations strongly connected. A large minimum degree condition is clearly insufficient (unless the minimum degree is required to be extremely large), as some isoperimetric or connectivity property is also required. Connectivity alone, however, is also insufficient – a degree condition is clearly also required. We show however, that a suitable combination of these properties does give a sufficient condition. Furthermore our conditions turn out to be (extremely close to) best possible. (Received August 11, 2015)

1112-05-627 **Zachary Hamaker**, **Eric Marberg** and **Brendan Pawlowski*** (br.pawlowski@gmail.com). *Reduced involution words.*

Reduced involution words are certain analogues of reduced words for involutions in a Coxeter group. For permutations, Stanley symmetric functions and the Edelman-Greene correspondence show how to enumerate ordinary reduced words in terms of standard tableaux; similarly, we enumerate reduced involution words in terms of marked shifted tableaux. One can also define involution Schubert polynomials, which give cohomology class representatives for the orbit closures of the orthogonal or symplectic group acting on the complete flag variety, and we discuss some of the combinatorics of these polynomials. (Received August 11, 2015)

1112-05-629 **Jeong Hyun Kang*** (jkang@westga.edu), University of West Georgia, Department of Mathematics, Carrollton, GA 30118. *Equidistant set in $\mathbb{R}^d$ under ℓ_1-norm.* Preliminary report.

Kusner (1983) conjectured that the maximum size of a set whose elements are pairwise equidistant under the ℓ_1-norm in $\mathbb{R}^d$ is $2d$. If true, this would be sharp. The conjecture has been proved for $d = 3$ (in 1998) and $d = 4$ (in 2000). Alon and Pudlak gave an upper bound of $O(d \ln d)$ (in 2003).

We show that the Kusner conjecture is true if given an ℓ_1-equidistant set of cardinality at least $2d$ in $\mathbb{R}^d$ there exists a subset of size $3d/2$ on a single unit ℓ_1-sphere. Also, we show that every three points of an ℓ_1-equidistant set belong to a unit ℓ_1-sphere, and the centers of these induced unit spheres are contained in a particular hyperplane. This leads to new proofs of Kusner's conjecture for the cases of $d = 3$ and 4. (Received August 11, 2015)

1112-05-632 **Samantha Dahlberg*** (dahlbe14@msu.edu). *A Hopf Algebra on Involutions.* Preliminary report.

Let $\mathcal{I}_n$ be the set of involutions inside the symmetric group on $\{1, \ldots, n\}$. In this talk we will define a Hopf algebra on $I = \oplus_{n \geq 0} \mathbb{F}[\mathcal{I}_n]$ where $\mathbb{F}$ is a field. We find that this Hopf algebra is a sub-Hopf algebra of $NCSym$ the symmetric functions with non-commuting variables. We have a cancellation-free formula for the antipode of $NCSym$ which is derived using Takeuchi's formula and a sign-reversing involution. This is a technique which has recently been introduced by Benedetti and Sagan. This formula in turn gives us an antipode formula for I. (Received August 11, 2015)

1112-05-634 **Megan Martinez*** (mmartinez@ithaca.edu). *Pattern-Avoiding Inversion Sequences.* Preliminary report.

An inversion sequence is a sequence of nonnegative integers $e_1 e_2 \dots e_n$ such that $e_i < i$. These sequences are used to encode permutations in various ways, including Lehmer codes and inversion tables. During Permutation Patterns 2014, the concept of pattern-avoiding inversion sequences was introduced by Savage. We describe some recent results and open questions. This includes joint work with Sylvie Corteel, Carla Savage, and Michael Weselcouch. (Received August 11, 2015)

1112-05-640 **Samantha Dahlberg*** (dahlbe14@msu.edu), **Robert Dorward**, **Jonathan Gerhard**, **Thomas Grubb**, **Carlin Purcell**, **Lindsey Reppuhn** and **Bruce Sagan**. *Pattern avoidance in RGFs and Catalan analogues.* Preliminary report.

Wachs and White introduced four statistics on set partitions which are in bijection with restricted growth functions or RGFs. An RGF is a word $w = w_1 w_2 \dots w_n$ such that $w_1 = 1$ and $w_i \leq 1 + \max(w_1 w_2 \dots w_{i-1})$. It is known that if $R_n(v)$ denotes the collection of length n RGFs which avoid v, then $\#R_n(1212) = \#R_n(1221) = C_n$ the Catalan numbers. The generating functions we get from using Wachs and White's statistics on these sets are all analogues of the Catalan numbers, some of which have been previously studied. We find a connection to two-colored Motzkin paths. (Received August 11, 2015)

1112-05-645 **Jozsef Balogh**, **Hong Liu*** (hliu36@illinois.edu), **Sarka Petrickova** and **Maryam Sharifzadeh**. *The typical structure of maximal triangle-free graphs.*

Recently, settling a question of Erdős, Balogh and Petříčková showed that there are at most $2^{n^2/8+o(n^2)}$ n-vertex maximal triangle-free graphs, matching the previously known lower bound. Here we characterize the typical structure of maximal triangle-free graphs. We show that almost every maximal triangle-free graph G admits a vertex partition $X \cup Y$ such that $G[X]$ is a perfect matching and Y is an independent set.

Our proof uses the Ruzsa-Szemerédi removal lemma, the Erdős-Simonovits stability theorem, and recent results of Balogh-Morris-Samotij and Saxton-Thomason on characterization of the structure of independent sets in hypergraphs. The proof also relies on a new bound on the number of maximal independent sets in triangle-free graphs with many vertex-disjoint P_3's, which is of independent interest.

Joint work with József Balogh, Šárka Petříčková and Maryam Sharifzadeh. (Received August 11, 2015)

1112-05-658 **Art Duval**, **Bennet Goeckner*** (bennet@ku.edu), **Caroline Klivans** and **Jeremy Martin**. *Further developments on decompositions of Cohen-Macaulay simplicial complexes.*

Stanley conjectured in 1979 that every Cohen-Macaulay simplicial complex is partitionable. This conjecture, which would have provided an interpretation of h-vectors of Cohen-Macaulay complexes, was recently disproved by Duval, Klivans, Martin, and the speaker. The conjecture is still open for *balanced* Cohen-Macaulay complexes. Duval and Zhang have shown that the h-vector of a Cohen-Macaulay simplicial complex gives enumerative information about a certain decomposition weaker than a partitioning. In this talk, I will investigate whether the result of Duval and Zhang translates to balanced complexes and flag h-vectors. (Received August 11, 2015)

1112-05-660 **Jason Williford*** (jwillif1@uwyo.edu), University of Wyoming, Department of Mathematics, 1000 E. University Ave., Laramie, WY 82072. *Nonexistence Conditions for Directed Strongly-Regular Graphs.*

A directed strongly-regular graph with parameters (v, k, t, λ, μ) is a regular digraph where all out-degrees and in-degrees are k, each vertex is in t 2-cycles, satisfying the following: if there is an arc from x to y then there are λ directed 2-paths from x to y, and if there is no arc from x to y then there are μ directed 2-paths from x to y. Similar to strongly-regular graphs, there are many parameter sets for which the question of existence/nonexistence is open. In this talk we will survey the known nonexistence conditions, and give a couple of new conditions which rule out certain parameter sets. (Received August 11, 2015)

1112-05-672 **Russ Woodroofe*** (rwoodroofe@math.msstate.edu). *Unimodal f-vectors and h-vectors of trees.* Preliminary report.

Alavi, Malde, Schwenk, and Erdős conjectured in 1987 that the f-vector of the independence complex of any tree is unimodal. I'll show that the final segment of the f-vector obeys a certain partial unimodality property, and give new simple proofs that the conjecture holds for certain classes of trees. (Received August 11, 2015)

1112-05-677 **Xiaofeng Gu***, Department of Mathematics, University of West Georgia, 1601 Maple Street, Carrollton, GA 30118. *Packing spanning trees and spanning 2-connected k-edge-connected essentially $(2k-1)$-edge-connected subgraphs.*

It is proved that every $(4kp-2p+2q)$-connected graph contains p spanning subgraphs G_i for $1 \leq i \leq p$ and q spanning trees such that all $p+q$ subgraphs are pair-wise edge-disjoint and such that each G_i is k-edge-connected, essentially $(2k-1)$-edge-connected, and $G_i - v$ is $(k-1)$-edge-connected for all $v \in V(G)$. This extends the well-known result of Nash-Williams and Tutte on packing spanning trees, a theorem that every $6p$-connected graph contains p edge-disjoint spanning 2-connected subgraphs, and a theorem that every $(6p+2q)$-connected graph contains edge-disjoint p spanning 2-connected subgraphs and q spanning trees. (Received August 11, 2015)

06 ► Order, lattices, ordered algebraic structures

1112-06-111 **Tony Shaska*** (shaska@oakland.edu), Rochester, MI 48309. *Theta functions and symmetric weight enumerators for codes over imaginary quadratic fields.*

We study codes over imaginary quadratic fields, their weight enumerators and theta functions. We present new examples of non-equivalent codes over rings of characteristic $p = 2$ and $p = 5$ which have the same theta functions. We also look at a generalization of codes over imaginary quadratic fields, providing examples of non-equivalent pairs with the same theta function for $p = 3$ and $p = 5$. (Received July 24, 2015)

08 ► General algebraic systems

1112-08-526 **Jason Morton*** (morton@math.psu.edu). *An abstract approach to network models of uncertainty.* Preliminary report.

I'll discuss some design considerations and theoretical questions surrounding a generic computer algebra system applicable to network models of uncertainty. (Received August 10, 2015)

1112-08-630 **Caroline Kettlestrings*** (csjacobs24@yahoo.com) and **Harvey I Blau**. *Classification of Class Three Nilpotent Table Algebras.*

We determine up to exact isomorphism the class three nilpotent commutative standard integral table algebras of order p^3, for an arbitrary prime p. We discuss the consequences for p-valenced association schemes of order p^3 and for p-Schur rings over abelian groups of order p^3. (Received August 11, 2015)

11 ► Number theory

1112-11-15 **Eyal Kaplan***, kaplaney@gmail.com. *The characterization of theta-distinguished representations of GL(n).*

Consider a pair of exceptional representations in the sense of Kazhdan and Patterson, of a metaplectic double cover of GL(n). The tensor of these representations is a (very large) representation of GL(n). We characterize its irreducible generic quotients. In the square-integrable case, these are precisely the representations whose symmetric square L-function has a pole at s=0. Our proof of this case involves a new globalization result. In the general case these are the representations induced from distinguished data or pairs of representations and their contragredients. The combinatorial analysis is based on a complete determination of the twisted Jacquet modules of exceptional representations. As a corollary, an exceptional representation is shown to admit a new "metaplectic Shalika model". (Received May 18, 2015)

1112-11-39 **Bruce C Berndt*** (berndt@illinois.edu). *Not-So-Well-Known Influences of Ramanujan and Hardy on Each Other.*

The joint work of Hardy and Ramanujan on the circle method, partitions, and probabilistic number theory are well-known, and we shall not dwell on these monumental collaborations in this talk. Instead, we concentrate on interactions that have received less attention. Many are connected with entries in either Ramanujan's earlier notebooks or his lost notebook. Topics to be discussed are: Ramanujan's knowledge of the residue theorem, the classical circle problem of Gauss, Ramanujan's knowledge (or lack of knowledge) of the Riemann Hypothesis,

integrals involving the Ξ-function of Riemann, self-reciprocal Fourier cosine transforms, modular integral identities and L-functions, the Rogers-Ramanujan continued fraction, diophantine approximation, and comments of Hardy and Gertrude Stanley on pages in Ramanujan's lost notebook. (Received June 29, 2015)

1112-11-44 **Edray Herber Goins*** (egoins@math.purdue.edu), Mathematical Sciences Building, 150 North University Street, West Lafayette, IN 47907-2067. *Belyĭ Maps on Elliptic Curves and Dessin d'Enfants on the Torus.* Preliminary report.

A Belyĭ map $\beta : \mathbb{P}^1(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$ is a rational function with at most three critical values; we may assume these values are $\{0, 1, \infty\}$. A Dessin d'Enfant is a planar bipartite graph obtained by considering the preimage of a path between two of these critical values, usually taken to be the line segment from 0 to 1. Such graphs can be drawn on the sphere by composing with stereographic projection: $\beta^{-1}\big([0,1]\big) \subseteq \mathbb{P}^1(\mathbb{C}) \simeq S^2(\mathbb{R})$. Replacing $\mathbb{P}^1$ with an elliptic curve E, there is a similar definition of a Belyĭ map $\beta : E(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$. The corresponding Dessin d'Enfant can be drawn on the torus by composing with an elliptic logarithm: $\beta^{-1}\big([0,1]\big) \subseteq E(\mathbb{C}) \simeq \mathbb{T}^2(\mathbb{R})$.

In this talk, we discuss the problems of (1) constructing examples of Belyĭ maps for elliptic curves and (2) drawing Dessins d'Enfants on the torus. This is work part of PRiME (Purdue Research in Mathematics Experience) with Leonardo Azopardo, Sofia Lyrintzis, Bronz McDaniels, Maxim Millan, Yesid Sánchez Arias, Danny Sweeney, and Sarah Thomaz with assistance by Hongshan Li and Avi Steiner. (Received July 03, 2015)

1112-11-66 **Leonardo Rafael Azopardo*** (lazopard@purdue.edu), 300 N. Salisbury Street #22, West Lafayette, IN 47906, **Maxim S Millan** (millanm@purdue.edu), 201 West Stadium Avenue, West Lafayette, 47906, and **Sarah Thomaz**. *Visualizing Dessins d'Enfants on the Torus.* Preliminary report.

A Belyĭ map $\beta : \mathbb{P}^1(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$ is a rational function with at most three critical values; we may assume these values are $\{0, 1, \infty\}$. A Dessin d'Enfant is a planar bipartite graph obtained by considering the preimage of a path between two of these critical values, usually taken to be the line segment from 0 to 1. Replacing $\mathbb{P}^1$ with an elliptic curve E, there is a similar definition of a Belyĭ map $\beta : E(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$. The corresponding Dessin d'Enfant can be drawn on the torus by composing with an elliptic logarithm: $\beta^{-1}\big([0,1]\big) \subseteq E(\mathbb{C}) \simeq \mathbb{T}^2(\mathbb{R})$.

In this project, we use the open source `Sage` to write code which takes an elliptic curve E and a Belyĭ map β to return a Dessin d'Enfant on the torus in two and three dimensions. Following a 2013 paper by Cremona and Thongjunthug, we make the elliptic logarithm $E(\mathbb{C}) \simeq \mathbb{C}/\Lambda$ explicit using a modification of the arithmetic-geometric mean, then compose with a canonical one-to-one correspondences $\mathbb{C}/\Lambda \simeq \mathbb{T}^2(\mathbb{R})$. (Received July 14, 2015)

1112-11-69 **Bronz D McDaniels*** (mcdanie3@purdue.edu), 1196 Third Street, West Lafayette, IN 47906, and **Danny Sweeney** and **Sofia Lyrintzis** (soros01@students.ipfw.edu), 124 Westwood Drive, West Lafayette, IN 47906, and **Yesid Sanchez** (yasancheza@unal.edu.co), Arnold Drive, 150-12, West Lafayette, IN 47906. *Examples of Belyĭ Maps for Elliptic Curves.* Preliminary report.

A Belyĭ map $\beta : \mathbb{P}^1(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$ is a rational function with at most three critical values; we may assume these values are $\{0, 1, \infty\}$. Replacing $\mathbb{P}^1$ with an elliptic curve $E : \ y^2 = x^3 + A\,x + B$, there is a similar definition of a Belyĭ map $\beta : E(\mathbb{C}) \to \mathbb{P}^1(\mathbb{C})$.

This project seeks to determine examples of Belyĭ maps for elliptic curves. We have shown that given any elliptic curve E there exist infinitely many Belyĭ maps of degree 2; they are in the form $\beta(x, y) = (a\,x+b)/(c\,x+d)$. We have also shown that any elliptic curve has at least one Belyĭ map of degree 3 with critical values $\{0, 1, \infty\}$. After placing the curve in Hessian normal form $y^2 + a_1\,x\,y + a_3\,y = x^3$, the Belyĭ map is in the form

$$\beta(x,y) = \frac{\big(2\,a_1^3 - 27\,a_3 + 2\,\sqrt{a_1^6 - 27\,a_1^3\,a_3}\big)\,y - 27\,a_3^2}{\big(2\,a_1^3 - 27\,a_3 - 2\,\sqrt{a_1^6 - 27\,a_1^3\,a_3}\big)\,y - 27\,a_3^2} \qquad \text{for } a_1 \neq 0.$$

This work is part of PRiME (Purdue Research in Mathematics Experience). (Received July 15, 2015)

1112-11-173 **Beth Romano*** (romanob@bc.edu). *The Local Langlands Correspondence: New Examples from the Epipelagic Zone.*

Let G be a split reductive group over a finite extension k of $\mathbb{Q}_p$. The Local Langlands Correspondence (LLC) predicts that for every complex representation π of G there should be a corresponding field extension of k whose structure reflects certain properties of π. The LLC has been proven in many cases for large primes p, but remains mysterious when p is small. In recent work, Jessica Fintzen and I have found new supercuspidal representations for small p, and in some cases I have found the corresponding field extensions. In my talk I will give explicit examples for the case $G = G_2$. (Received August 01, 2015)

1112-11-175 **Bruce Reznick*** (reznick@math.uiuc.edu), Department of Mathematics, 1409 W. Green St., Urbana, IL 61801. *Quotients of sums of distinct powers of three.* Preliminary report.

Let A denote the set of Newman polynomials, $\sum c_i x^i, c_i \in \{0,1\}$. Which integers m may be written as $m = \frac{p(3)}{q(3)}$, where $p, q \in A$? How often can this happen? Interesting questions arise under the restrictions $q \mid p$ and $\frac{p}{q} \in A$. This problem arises in the study of the Cantor set, in ongoing research projects of the speaker with Katie Anders, Jayadev Athreya and Jeremy Tyson. (Received August 01, 2015)

1112-11-191 **Fan Zhou*** (zhou.1406@math.osu.edu), 231 West 18th Ave, Columbus, OH 43210. *Double Dirichlet Series and Voronoi Formula.*

We present a proof of Voronoi formula for coefficients of a large class of L-functions, in the style of the classical converse theorem of Weil. Our formula applies to Maass cusp forms, Rankin-Selberg convolutions, and certain isobaric sums. Our proof is based on the functional equations of L-functions twisted by Dirichlet characters and does not directly depend on automorphy and hence has wider application than previous proofs. The key ingredient is the construction of a double Dirichlet series associated with these coefficients. This is joint work with Eren Mehmet Kıral. (Received August 03, 2015)

1112-11-227 **Tathagaata Basak*** (tathagat@iastate.edu), 450 Carver Hall, Iowa State University, Ames, IA 50011. *Modular lattices from finite projective planes.*

Let q be a prime power. Using geometry of the finite projective plane $\mathbb{P}^2(\mathbb{F}_q)$ we construct a Hermitian Lorentzian lattice L_q of dimension (q^2+q+2) defined over a certain number ring that depends on q. We show that infinitely many of these lattices are modular, that is, the dual lattice of L_q is isometric to a scaled copy of L_q. Under certain conditions on q, the Lorentzian lattice L_q yields an even self dual positive definite $2q(q+1)$ dimensional $\mathbb{Z}$-lattice M_q whose automorphism group contains the automorphisms of $\mathbb{P}^2(\mathbb{F}_q)$. General conjectures about prime numbers imply that there are infinitely many such prime numbers $q = 3, 47, 59, 71, 131 \cdots$. We find that M_3 is the Leech lattice and automorphism group of the Lorentzian lattice L_3 seems to be closely related to the monster simple group. (Received August 05, 2015)

1112-11-247 **Xiang-dong Hou***, Department of Mathematics abd Statistics, University of South Florida, Tampa, FL. *Polynomials Meeting Ax's Bound.* Preliminary report.

Let $f \in \mathbb{F}_q[X_1, \ldots, X_n]$ with $\deg f = d > 0$ and let $Z(f) = \{(x_1, \ldots, x_n) \in \mathbb{F}_q^n : f(x_1, \ldots, x_n) = 0\}$. Ax's theorem states that $|Z(f)| \equiv 0 \pmod{q^{\lceil n/d \rceil - 1}}$, that is, $\nu_p(|Z(f)|) \geq m(\lceil n/d \rceil - 1)$, where $p = \operatorname{char} \mathbb{F}_q$, $q = p^m$, and ν_p is the p-adic valuation. In this paper, we determine a condition on the coefficients of f that is necessary and sufficient for f to meet Ax's bound, that is, $\nu_p(|Z(f)|) = m(\lceil n/d \rceil - 1)$. As an application, we find several counting formulas concerning the weight enumerators of certain Reed-Muller codes. (Received August 05, 2015)

1112-11-259 **Feydoon Shahidi***, Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907. *On equality of local factors for an arbitrary representation of GL(n,C).*

In this talk we will briefly look at the proof of the equality of Artin factors attached to the second exterior and symmetric power representations of GL(n,C), the L-group of GL(n), and those defined by Langlands-Shahidi method through the local Langlands correspondence, recently given by Cogdell-Shahidi-Tsai. We will then set up certain axioms which will allow us to prove the equality for an arbitrary representation of GL(n,C). Among the axioms is that of multiplicativity in the analytic side which brings in the use of Schur functor. We will discuss this through examples, icluding exterior cubes and more. (Received August 06, 2015)

1112-11-300 **Salim Ali Altug*** (altug@math.columbia.edu). *Explicit forms of the trace formula and analytic number theory.*

I will report on a recent research on the Arthur-Selberg trace formula for $GL(2)$. The main result is an explicit form of the (elliptic part of the) formula that is suitable for applications of non-comparative nature, mainly to problems of or related to analytic number theory. I will also discuss how certain distinguished representations appear in the elliptic part and their relation to analytic problems, in particular to beyond endoscopy. (Received August 07, 2015)

1112-11-316 **Matthias Strauch*** (mstrauch@indiana.edu), Indiana University, Department of Mathematics, 831 E. Third St, Bloomington, IN 47405. *Locally analytic representations and arithmetic differential operators.*

This talk is about locally analytic representations of p-adic reductive groups. If (π, V) is such a representation of a group G, then, for every $v \in V$, the orbit map $G \to V, g \mapsto \pi(g).v$, can be expanded locally as a V-valued power series on G. Examples of such representations are smooth representations and finite-dimensional algebraic

representations, as well as tensor products of those. Moreover, given a locally analytic representation of a Levi subgroup of a given reductive group G, one can form the parabolically induced representation.

We will be presenting a result which says that the category of admissible locally analytic representations of a split p-adic reductive group G is (anti-)equivalent to a certain category of G-equivariant systems of sheaves of arithmetic D-modules on formal models of the flag variety of G. This builds on work of C. Huyghe who proved a version of the Beilinson-Bernstein localization theorem for arithmetic differential operators on smooth formal models of flag varieties. It is independent of but related to work of K. Ardakov and S. Wadsley on differential operators on rigid analytic spaces.

This is joint work with C. Huyghe, D. Patel and T. Schmidt. (Received August 07, 2015)

1112-11-333 **Ellen Eischen*** (eeischen@uoregon.edu). *p-adic families of Eisenstein series and applications.*

One approach to studying the p-adic behavior of L-functions relies on construction of certain p-adic families of Eisenstein series. I will introduce a construction of such p-adic families. I will also mention some applications to number theory and beyond. (Received August 07, 2015)

1112-11-335 **Jiwon Kim***, kim609@indiana.edu. *Fixed points and period spaces and conjugacy classes.*

Fixed points and period spaces and conjugacy classes

Jiwon Kim
Department of Mathematics, Indiana University

Abstract Let $\mathcal{F}^{wa} = \mathcal{F}^{wa}(\mathbb{G}, \mathcal{N})$ be a p-adic period space, and $J^{\mathbb{G}} = \underline{Aut}^{\otimes}(N^{\mathbb{G}})$ be the associated automorphism group of the G-isocrystal. Then we get that $J^{\mathbb{G}}$ is an inner form of G. Let j be a regular elliptic element $J^{\mathbb{G}}(\mathbb{Q}_p)$, and denote by $Fix(j|\mathcal{F}^{wa})$ the set of fixed points of j on $\mathcal{F}^{wa}$. Let $x_0 \in Fix(j|\mathcal{F}^{wa})$ be a 'base point'. One can then associate to any $x \in Fix(j|\mathcal{F}^{wa})$ of j a rational conjugacy class in $G_{\mathcal{F}_{x_0}}$. I study this map from $Fix(j|\mathcal{F}^{wa})$ to the set of rational conjugacy classes in $G_{\mathcal{F}_{x_0}}$.

(Received August 08, 2015)

1112-11-342 **Yeansu Kim*** (yeansu-kim@uiowa.edu), 14 MacLean Hall, Iowa city, IA 52242-1419. *The generic Arthur packet conjecture for classical groups and GSpin groups.*

Recently, Heiermann and I have constructed the local Langlands parameter that corresponds to an irreducible admissible generic representation of $GSpin$ groups (the generic local Langlands correspondence for $GSpin$ groups). I further study the structure of the L-packet which contains a generic representation. As an application, I prove the strong version of the generic Arthur packet conjecture in the cases of classical groups and $GSpin$ groups. The strong version of the generic Arthur packet conjecture states that if the L-packet attached to an Arthur parameter has a generic member, then it is a tempered L-packet. Note that we first use Shahidi's following result: If L-functions from Langlands-Shahidi method for a connected reductive group G are Artin L-functions through the local Langlands correspondence, the week version of the generic Arthur packet conjecture is true for G. (Received August 08, 2015)

1112-11-436 **Peter Sarnak*** (sarnak@math.princeton.edu), Department of Mathematics, Princeton University, Princeton, NJ 08544. *Markoff Surfaces, Numbers and Strong Approximation.*

Abstract : Markoff numbers are the coordinates of the integer solutions to Markoff's equation in affine 3-space,and they arise in many different contexts . We review some of these and then discuss the congruence properties (strong approximation) of integral points on such affine surfaces. Among the techniques developed for this analysis are ones connected to the classification of algebraic Painlave VI equations . (Received August 10, 2015)

1112-11-455 **Tonghai Yang*** (thyang@math.wisc.edu), 480 Lincoln Dr., Madison, WI 53706. *Regularized theta liftings and CM values.* Preliminary report.

In 80's, Gross and Zagier proved the so-called striking Gross-Zagier formula and the Gross-Zagier factorization formula for singular moduli. In the process, they constructed some cool Green function of CM points. In the proof of the Moonshine conjecture in 90s, Borcherds constructed automorphic forms on some Shimura varieties using regularized theta liftings from weakly holomorphic modular forms. It turns out that this idea of regularized

theta lifting (with a little generalization) can be used to construct Gross and Zagier's Green functions in more general Shimura varieties. They are very convenient to compute the CM values and Period integrals, can be used to prove high dimensional analogue of the Gross-Zagier formula and Gross-Zagier factorizarion formula. We will give a brief survey on this line of work. (Received August 10, 2015)

1112-11-462 **Tong Liu*** (tongliu@math.purdue.edu) and **Bryden Cais**. *F-crystalline representations and Kisin modules.*

Kisin module is very useful to study crystalline representations. In this talk, we extend the theory of Kisin modules and crystalline representations to allow more general coefficient fields and lifts of Frobenius. In particular, we construct a general class of totally wildly ramified extensions K_∞/K so that the functor $V \mapsto V|_{G_\infty}$ is fully-faithfull on the category of crystalline representations. We also establish a new classification of Barsotti-Tate groups via Kisin modules of height 1. This is a joint work with Bryden Cais. (Received August 10, 2015)

1112-11-464 **Luca Candelori** and **Cameron Franc*** (francc@umich.edu). *Geometric foundations of the theory of vector valued modular forms.*

We will report on recent joint work with Luca Candelori on the construction of certain vector bundles on the moduli stack of elliptic curves whose global sections are vector valued modular forms. This perspective yields standard geometric proofs of many known results on vector valued modular forms. We will review these results, and discuss new directions in the subject indicated by the geometric perspective. (Received August 10, 2015)

1112-11-472 **Niccolò Ronchetti***, Department of Mathematics, 450 Serra Mall, Stanford University, Stanford, CA 94305. *Local base change via Tate cohomology.*

In this talk we describe a new way to realize cyclic base change (a special case of Langlands functoriality) for prime degree extensions of characteristic zero local fields. Let E/F be a prime degree l Galois extension of local fields of residue characteristic $p \neq l$. Let π be an irreducible cuspidal l-adic representation of $\mathrm{GL}_n(F)$ and ρ be an irreducible cuspidal l-adic representation of $\mathrm{GL}_n(E)$ which is Galois-invariant. Under some minor technical conditions on π and ρ (for instance, we assume that both are level zero) we prove that the mod l-reductions $r_l(\pi)$ and $r_l(\rho)$ are in base change if and only if the Tate cohomology of ρ with respect to the Galois action is isomorphic, as a modular representation of $\mathrm{GL}_n(F)$, to the Frobenius twist of $r_l(\pi)$.
This proves a special case of a conjecture of Treumann and Venkatesh as they investigate the relationships between linkage and Langlands functoriality. (Received August 10, 2015)

1112-11-497 **Baiying Liu***, School of Mathematics, Institute for Advanced Study, Einstein Drive, Simonyi Hall, Princeton, NJ 08540. *On cuspidality of global Arthur packets of quasi-split classical groups.* Preliminary report.

Based on the theory of endoscopy, Arthur classified the automorphic discrete spectrum of quasi-split classical groups up to global Arthur packets parametrized by Arthur parameters. Towards studying representations in each Arthur packet, a natural question one may ask is that whether a given Arthur packet has cuspidal representations or not. In this talk, I will introduce some recent progress on this aspect, which is based on relations between the structure of Fourier coefficients of automorphic forms in an Arthur packet and the structure of the corresponding Arthur parameter. This work is joint with Dihua Jiang. (Received August 10, 2015)

1112-11-514 **Wushi Goldring*** (wushijig@gmail.com) and **Jean-Stefan Koskivirta**. *Strata Hasse invariants, Hecke algebras and Galois representations.*

I will try to motivate and then state some of the results from my joint work with Jean-Stefan Koskivirta which bears the same name and is available at arXiv:1507.05032. For each Ekedahl-Oort stratum of a general Hodge-type Shimura variety, we construct a Hecke-equivariant section of the Hodge line bundle which cuts out the smaller strata in its closure. We call these sections "group-theoretical Hasse invariants." Using them as our main tool, we are able to: (1) Attach Galois representations to many automorphic representations with non-degenerate limit of discrete series archimedean component, generalizing work of Deligne-Serre, Taylor, Jarvis, Goldring and Goldring-Nicole (2) Attach pseudo-representations to torsion classes in the coherent cohomology of many Hodge-type Shimura varieties, generalizing the work of Emerton-Reduzzi-Xiao (3) Prove that all Ekedahl-Oort strata are affine, both for a general compact Shimura variety of Hodge-type and for the minimal compactification of a Siegel-type Shimura variety, thereby proving a conjecture of Oort (4) Generalize (part of) Serre's letter to Tate on mod p forms to general Hodge-type Shimura varieties, refining (parts of) previous results in some PEL cases due to Ghitza and Reduzzi. (Received August 10, 2015)

1112-11-538 **Ramin Takloo-Bighash*** (rtakloo@uic.edu), Dept of Mathematics, Statistics, and Computer Science, Univ of IL at Chicago, 851 S Morgan St (M/C 249), Chicago, IL 60607. *Distribution of rational points on one sided compactifications of* PGL(2). Preliminary report.

In this talk I will report on some recent and ongoing works joint with Sho Tanimoto where we study the distribution of rational points of bounded height on some one sided equivariant compactifications of the group PGL(2) using methods of automorphic forms. An interesting feature of our results is that the main contribution to the pole of the counting zeta function function is not from the trivial representation. This is in sharp contrast with many of the previous works in this subject. (Received August 11, 2015)

1112-11-609 **David Goldberg** and **Dani Szpruch***, dani.szpruch@gmail.com. *Plancherel measure for coverings of p-adic SL(2,F).*

The Plancherel measure is a certain meromorphic function associated with a parabolic induction on a quasi-split reductive group defined over a local field. It is related to L and gamma-functions. Among other applications, one can use it to determine the reducibility points on the unitary axis. In cases where the inducing data is generic, one computes this function using the Langlands-Shahidi method exploiting the uniqueness of Whittaker model. In this talk we shall discuss the computation of the Plancherel measure in the context of coverings of p-adic SL(2), although uniqueness of Whittaker model fails. We shall show that in these metaplectic cases the Plancherel measure is a product of gamma functions and deduce some irreducibility results. (Received August 11, 2015)

1112-11-612 **Patrick Allen*** (pballen@illinois.edu). *Automorphic points in Mazur's deformation space.*

Mazur's deformation theory of Galois representations has played a central role in the study of Langlands reciprocity for number fields. For a fixed mod p automorphic Galois representation, p-adic automorphic Galois representations lifting it determine points in Mazur's deformation space. In favourable situations, we expect these automorphic points to be Zariski dense. In the case of modular forms and under some technical conditions, Böckle showed that every component of deformation space contains a smooth modular point, which then implies their Zariski density when coupled with the infinite fern of Gouvêa and Mazur. I will discuss an improvement and generalization of Böckle's result. When combined with work of Chenevier, this implies new results on the Zariski density of automorphic points in deformation space. (Received August 11, 2015)

1112-11-633 **Mohammad Hadi Hedayatzadeh***, hedayatzadeh@purdue.edu. *The wedge map on the Lubin-Tate space.*

p-divisible groups are smooth formal groups which naturally arise as limits of p-power torsion in algebraic groups. The Serre-Tate theorem states that the deformations of an abelian variety is equivalent to the deformations of its p-div. group, and so there is a deep connection between modular forms, which live in the cohomology of moduli spaces of abelian varieties (Shimura varieties) and deformations of p-div. groups (Rapoport-Zink spaces). These spaces appear naturally in the Langlands program. Indeed, the local Langlands correspondence for GLn is realized in the cohomology of Lubin-Tate space. Kottwitz' conjecture posits that certain cases of local Langlands correspondence (for more general reductive groups) are realized in the cohomology of Rapoport-Zink spaces and whether they contain supercuspidal representations. I will talk about p-div. groups and their deformations. I will then discuss my recent proof of the existence of exterior powers of p-div. groups and explain how their construction defines a natural map between certain Rapoport-Zink spaces. If time permits, I will also talk about the applications to the study of certain supercuspidal representations appearing in the cohomology of Rapoport-Zink spaces. (Received August 11, 2015)

1112-11-642 **Ana Caraiani*** (caraiani.ana@gmail.com), 20 Madison St, Princeton, NJ 08542, and **Matthew Emerton**, **Toby Gee**, **David Geraghty**, **Vytautas Paskunas** and **Sug Woo Shin**. *Local and global aspects of p-adic Langlands for $GL_2(Q_p)$.*

I will discuss joint work with Emerton, Gee, Geraghty, Paskunas and Shin, which gives a new, short proof (in almost all cases) of the fact that the p-adic local Langlands correspondence for $\mathrm{GL}_2(Q_p)$ satisfies local-global compatibility. The method relies on Taylor-Wiles patching of completed cohomology and the notion of projective envelope. (Received August 11, 2015)

12 ► Field theory and polynomials

1112-12-87 **Tom Blackford*** (jt-blackford@wiu.edu), Department of Mathematics, Western Illinois University, Macomb, IL 61455. *Galois Variance of Constacyclic Codes.* Preliminary report.
A linear code over F_{q^m} is a subspace of $(F_{q^m})^n$, and has two important associated subcodes: the subfield subcode and the trace subcode, both of which are in $(F_q)^n$. These subcodes can be used to measure the Galois variance of the original code. For example, it is already known that a code is Galois invariant if and only if its subfield and trace subcodes are equal. We will look at the particular case of λ-cyclic codes over F_{q^m} (where $\lambda \in F_q^\times$), their images under the Frobenius automorphism, and their subfield and trace subcodes. In particular, we will determine all λ-cyclic codes C such that the vector space $(F_{q^m})^n$ is a direct sum of the Galois images of C. (Received July 21, 2015)

1112-12-95 **Vivek Mukundan*** (vmukunda@purdue.edu), 150 N. University Street, Office 1037, West Lafayette, IN 47906, and **Jacob A Boswell**. *Rees Algebras and Almost Linearly Presented Ideals.*
Consider a grade 2 perfect ideal I in $R = k[x_1, \cdots, x_d]$ which is generated by forms of the same degree. Assume that the presentation matrix φ is almost linear, that is, all but the last column of φ consist of entries which are linear. For such ideals, we find explicit forms of the defining ideal of the Rees algebra $\mathcal{R}(I)$. We also introduce the notion of iterated Jacobian duals and present properties such as Cohen-Macaulayness, regularity, relation type of the Rees algebra of ideals whose second analytic deviation is one. (Received August 08, 2015)

1112-12-123 **Rachel Davis*** (davis705@math.purdue.edu), West Lafayette, IN 47907, and **Edray Herber Goins**. *Galois Theory of a Quaternion Group Origami.* Preliminary report.
Let E be an elliptic curve over $\mathbb{Q}$. An origami is a pair (C, f), where C is a curve and $f : C \to E$ is a map, branched only above one point. We study an origami with deck transformation group the group of quaternions, a non-abelian group of order 8. Next, we adjoin the coordinates of the pre-images of a rational point to $\mathbb{Q}$ and study the Galois theory of the resulting field extension and the relationship to the usual division fields of the elliptic curve. (Received July 27, 2015)

1112-12-137 **Neville Fogarty*** (neville.fogarty@uky.edu), Department of Mathematics, 715 Patterson Office Tower, University of Kentucky, Lexington, KY 40506, and **Heide Gluesing-Luerssen**. *A Circulant Approach to Skew-Constacyclic Codes.*
We introduce a type of skew-generalized circulant matrices that captures the structure of a skew-polynomial ring $\mathbb{F}[x;\theta]$ modulo the left ideal generated by a polynomial of the form $x^n - a$. This allows us to develop an approach to skew-constacyclic codes based on skew-generalized circulants. We show that for the code-relevant case, the transpose of a skew-generalized circulant is also a skew-generalized circulant. This recovers the well-known result that the dual of a skew-constacyclic code is also a skew-constacyclic code. (Received August 03, 2015)

1112-12-550 **Stefan Müeller*** (stefan.mueller@ricam.oeaw.ac.at). *Sign conditions for injectivity of generalized polynomial maps.*
We give necessary and sufficient conditions in terms of sign vectors for the injectivity of families of polynomial maps with arbitrary real exponents defined on the positive orthant. Our work relates and extends existing injectivity conditions expressed in terms of Jacobian matrices and determinants. In the context of chemical reaction networks with power-law kinetics, our results can be used to preclude as well as to guarantee multiple positive steady states. In the context of real algebraic geometry, our work allows the first partial multivariate generalization of the classical Descartes' rule, which bounds the number of positive real roots of a univariate real polynomial in terms of the number of sign variations of its coefficients. (Received August 11, 2015)

13 ► Commutative rings and algebras

1112-13-48 **Yu Xie*** (xieyucn@gmail.com), Department of Mathematics and Statistics, Penn State Altoona, Altoona, PA 16601. *Generalized mixed Hilbert multiplicities.* Preliminary report.
I am going to talk about how to generalize the concept of classical mixed multiplicities to any ideals and apply them to intersection theory and singularity theory. (Received July 05, 2015)

1112-13-62 **Michael R DiPasquale*** (mdipasq@okstate.edu), OSU-Mathematics, 401 MSCS Building, Stillwater, OK 74078. *A Chain Complex for Generalized Splines and Freeness of Graphic Multi-Arrangements.* Preliminary report.

Given a graph equipped with a labeling of its edges by ideals of a polynomial ring, the ring of generalized splines is the set of assignments of polynomials to the vertices such that polynomials corresponding to adjacent vertices are congruent modulo the ideal labeling the corresponding edge. For a graph equipped with such an edge-labeling, we introduce a chain complex in the spirit of Schenck-Stillman's complex for classical splines, whose first cohomology is the ring of generalized splines.

As an application, the module of derivations of a graphic multi-arrangement may naturally be interpreted as a ring of generalized splines on an appropriately labelled graph. We show that freeness of graphic multi-arrangements can be detected by the vanishing of the cohomologies of the associated chain complex. More generally, bounds on the projective dimension of the module of derivations of a graphic multi-arrangement may be obtained from the projective dimension of the cohomologies of this complex. (Received August 10, 2015)

1112-13-63 **Sonja Petrović*** (sonja.petrovic@iit.edu), **Apostolos Thoma** and **Marius Vladoiu**. *Bouquet algebra of toric ideals.*

To any toric ideal I_A, encoded by an integer matrix A, we associate a matroid structure called *the bouquet graph* of A and introduce another toric ideal called *the bouquet ideal* of A. We show how these objects capture the essential combinatorial and algebraic information about I_A. Passing from the toric ideal to its bouquet ideal reveals a structure that allows us to classify several cases. For example, on the one end of the spectrum, there are ideals that we call *stable*, for which bouquets capture the complexity of various generating sets and the minimal free resolution. On the other end of the spectrum lie toric ideals whose various bases (e.g. Markov, Gröbner, Graver bases) coincide. Apart from allowing for classification-type results, bouquets provide a way to construct families of examples of toric ideals with various interesting properties, e.g., robust, generic, unimodular. The new bouquet framework can be used to provide a characterization of toric ideals whose Graver basis, the universal Gröbner basis, any reduced Gröbner basis and any minimal generating set coincide. We also show that the toric ideal of a general matrix A can be encoded by that of a 0/1 matrix while preserving complexity of its bases. (Received July 13, 2015)

1112-13-71 **Adam Van Tuyl*** (vantuyl@math.mcmaster.ca), Department of Mathematics and Sciences, McMaster University, Hamilton, Ontario L8S 4L8, Canada. *Revisiting a conjecture of Villarreal on Cohen-Macaulay graphs.* Preliminary report.

This year marks the 25th anniversary of the publication of R. Villarreal's paper *Cohen-Macaulay Graphs* (manuscripta math. 1990). It was in this paper that the definition of an edge ideal was first introduced. In this talk I will focus on a conjecture about Cohen-Macaulay graphs that appeared in this paper and discuss its current status. Precisely, let $I(G)$ be the edge ideal of a graph G in a polynomial ring $R = k[x_1, \ldots, x_n]$, and suppose that $R/I(G)$ is a Cohen-Macaulay ring. Villarreal conjectured that there is a vertex x such that $R/I(G \setminus x)$ was also Cohen-Macaulay. In fact, it was conjectured that the set of all vertices with this property forms a dominating set of G. It has been known for awhile that this conjecture is false. I'll present some new counter-examples. I will also present some evidence that the conjectures may still hold if we assume the stronger condition that the simplicial complex associated to $I(G)$ via the Stanley-Reisner correspondence is a vertex decomposable simplicial complex. This talk is based upon joint work with K.N. Vander Meulen (Redeemer) and J. Baker, an NSERC USRA student. (Received July 15, 2015)

1112-13-108 **Alessandro De Stefani*** (ad9fa@virginia.edu), University of Virginia, Charlottesville, VA 22904. *A counterexample to a conjecture of Ding.*

In 1993, Songqing Ding conjectured that the index of a Gorenstein local ring is always equal to its generalized Löewy length. The index is a numerical invariant defined in terms of Auslander's delta invariant, while the generalized Löewy length is the minimal Löewy length of an Artinian reduction of the ring. The purpose of this talk is to disprove Ding's conjecture, by presenting one-dimensional complete intersections for which the index is strictly less than the generalized Löewy length. (Received July 24, 2015)

1112-13-156 **Rebecca R.G.*** (rirg@umich.edu). *Closure operations that induce big Cohen-Macaulay modules and algebras.* Preliminary report.

Geoffrey Dietz introduced a set of axioms for a closure operation on a complete local domain so that if such a closure operation exists, the ring has a big Cohen-Macaulay module. These are called Dietz closures. In characteristic $p > 0$, solid closure, tight closure, and plus closure are all Dietz closures.

I will show that under mild conditions, a ring R is regular if and only if all Dietz closures on R are trivial. The proof of this statement leads to results relating Dietz closures to more familiar closures such as integral closure and regular closure. I will also discuss a new axiom for a closure operation such that the existence of a Dietz closure satisfying this additional axiom is equivalent to the existence of a big Cohen-Macaulay algebra. (Received July 30, 2015)

1112-13-167 **Sema Gunturkun***, University of Michigan, Ann Arbor, MI. *A description of Boij-Söderberg decomposition for lex ideals.* Preliminary report.

Boij-Söderberg theory describes the scalar multiples of Betti diagrams of graded modules over a polynomial ring as a linear combination of pure diagrams with positive coefficients. There are a few results that describe Boij-Söderberg decompositions explicitly. In this talk, we demonstrate a neat pattern for Boij-Söderberg decomposition for lex ideals and characterize it by using Boij-Söderberg decompositions of some other related lex ideals. (Received July 31, 2015)

1112-13-172 **Mark Johnson***, Department of Mathematical Sciences, 1 University of Arkansas, Fayetteville, AR 72701. *Serre's Condition R_k for sums of geometric links.*

We show that if the intersection of a Cohen-Macaulay subscheme with one of its geometric links has a small dimensional singular locus, then the scheme is a complete intersection locally. (Received August 01, 2015)

1112-13-180 **Kuei-Nuan Lin***, kul20@psu.edu, and **Paolo Mantero**. *Projective Dimensions of Square-Free Monomial Ideals.* Preliminary report.

We associate square-free monomial ideals with hypergraphs that is first introduced by Kimura-Terai-Yoshida. We are able to find the projective dimension of a hypergraph when each of its disjoint pieces has at most one cycle. This is joint work with Paolo Mantero. (Received August 02, 2015)

1112-13-228 **Claudiu Raicu*** (craicu@nd.edu), Notre Dame, IN 46556, and **Jerzy Weyman**. *Local cohomology with support in ideals of symmetric minors and Pfaffians.*

I will describe the local cohomology modules of the ring of polynomial functions on the vector space of (skew-)symmetric matrices, with support in ideals generated by symmetric minors/Pfaffians. The said modules have a rich structure: they are D-modules (of finite length), as well as representations of the general linear group. Both of these structural aspects play an important role in the calculation of local cohomology. (Received August 05, 2015)

1112-13-234 **Sara Faridi*** (faridi@mathstat.dal.ca). *Resolutions of monomial ideals.*

In this talk we will discuss various aspects of simplicial resolutions of monomial ideals: complexes supporting a resolution, using f-vectors of simplicial complexes to find Betti numbers, and detecting Betti numbers from facet covers. (Received August 05, 2015)

1112-13-269 **Bjørn Ian Dundas**, **Ayelet Lindenstrauss*** (alindens@indiana.edu) and **Birgit Richter**. *Calculations of Higher Topological Hochschild Homology.*

For R a commutative ring, M an R-module, and $X.$ a pointed simplicial set, J.-L. Loday defined a simplicial R-module $\mathcal{L}_{X.}(R;M)$ which in each simplicial degree n consists of a tensor product, indexed by all the n-simplices in X_n, of copies of R, except that over the base point one has a copy of M. The homology groups of $\mathcal{L}_{X.}(R;M)$ with respect to $d=\sum_{i=0}^{n}(-1)^i d_i$ are homotopy invariants of $|X.|$. Taking $X.$ to be the minimal model of S^1, one recovers the standard Hochschild complex for R with coefficients in M. Using $X.=S^n$ instead, one gets higher Hochschild homology groups. One can do the same thing when $\mathbf{R}$ is a commutative ring spectrum and $\mathbf{M}$ an $\mathbf{R}$-module to get the higher topological Hochschild homology groups. If $\mathbf{R}$ and $\mathbf{M}$ are Eilenberg-Mac Lane spectra, taking the sphere spectrum as the ground ring spectrum gives a finer invariant than using an Eilenberg-Mac Lane spectrum, which recovers the algebraic case. I will discuss basic higher Hochschild homology calculations, our calculation of $\mathrm{T}HH^{[n]}(\mathbb{Z};\mathbb{F}_p)$, as well as a calculation of $\mathrm{T}HH^{[n]}(\mathbb{F}_p)$. (Received August 06, 2015)

1112-13-278 **Steven Dale Cutkosky*** (cutkoskys@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Epsilon Multiplicity as a limit.*

We discuss a proof showing that under very general conditions, the epsilon multiplicity of a module, which is defined as a limsup, is in fact a limit. (Received August 06, 2015)

1112-13-287 **Chris Francisco*** (chris.francisco@okstate.edu), Department of Mathematics, 401 MSCS, Oklahoma State University, Stillwater, OK 74078, and **Jeffrey Mermin** and **Jay Schweig**. *Borel ideals and discrete geometry.*

We describe explicit bijections between Eliahou-Kervaire symbols of certain Borel ideals and pointed psuedo-triangulations of the single chain, objects of interest in discrete geometry. Binary trees serve as a convenient intermediary between the two types of objects. (Received August 06, 2015)

1112-13-301 **Christine Berkesch Zamaere*** (cberkesc@math.umn.edu), Minneapolis, MN, and **Jens Forsgard** and **Laura Felicia Matusevich**. *A-hypergeometric solution sheaves.*

A-hypergeometric systems are the D-module counterparts of toric ideals, and their behavior is linked closely to the combinatorics of toric varieties. I will discuss recent work that aims to explain the behavior of the solutions of these systems as their parameters vary. Our goal, which can be achieved in special cases, is to stratify the parameter space so that solutions are locally analytic within each (connected component of a) stratum. In cases with nice combinatorics, we show that the solutions are closely related to certain local cohomology modules. (Received August 07, 2015)

1112-13-302 **Katie Ansaldi***, University of Notre Dame, Department of Mathematics, 255 Hurley Hall, Notre Dame, IN 46556, and **Nicholas Clarke** and **Luigi Ferraro**. *Regularity of Tor for Weakly Stable Ideals.*

Let R be a standard graded polynomial ring over a field. Eisenbud, Huneke, and Ulrich proved a bound for the regularity of $\operatorname{Tor}_i^R(R/I, R/J)$ provided that the dimension of $\operatorname{Tor}_i^R(R/I, R/J) \leq 1$, but there are examples where the bound does not hold in general. We prove that for weakly stable ideals the expected bound holds. (Received August 07, 2015)

1112-13-306 **Adam Boocher*** (boocher@math.utah.edu), **Alessio D'Alì**, **Eloísa Grifo**, **Jonathan Montaño** and **Alessio Sammartano**. *Deviations of Graded Algebras.*

The deviations of a graded algebra are a sequence of integers that determine the Poincaré series of its residue field and arise as the number of generators of certain DG algebras. In a sense, deviations measure how far the ring is from being a complete intersection. We study extremal deviations among those of algebras with a fixed Hilbert series. We prove that, like the Betti numbers, deviations do not decrease when passing to initial and lex-segment ideals. We also prove that deviations grow exponentially for Golod rings and for algebras presented by certain edge ideals. Combinatorial considerations, including some open questions will be discussed. (Received August 07, 2015)

1112-13-318 **Robert Krone*** (rckrone@gmail.com), Department of Math & Stats, Jeffery Hall, University Ave., Kingston, Ontario K7L3X1, Canada. *Equivariant Gröbner bases of toric ideals.*

We consider a large class of monomial maps respecting an action of the infinite symmetric group. Previous work showed that the toric ideals arising as their kernels are finitely generated up to symmetry, but did not offer an effective algorithm for computing generating sets. We show that every such symmetric toric ideal also has a finite equivariant Gröbner basis for a particularly chosen monomial order. We can modify existing equivariant Gröbner basis algorithms to guarantee termination in the case that a finite equivariant Gröbner basis exists. Finally, using elimination we can compute equivariant Gröbner bases of the toric ideals in question, given the monomial map that they arise from. (Received August 07, 2015)

1112-13-334 **Thanh Q Vu*** (tvu@unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Fourth Veronese embeddings of projective spaces.*

I will introduce the notion of Betti splitting in studying syzygies of Veronese embeddings of projective spaces with special attention to the case of fourth Veronese. In particular, I will show how to deduce the Ottaviani-Paoletti conjecture for this particular case using Betti splittings. (Received August 07, 2015)

1112-13-354 **Luigi Ferraro*** (lferraro2@math.unl.edu), NE. *On the bimodule structure of bounded cohomology.*

Stable cohomology is a $\mathbb{Z}$-graded multiplicative cohomology theory generalizing Tate cohomology and first defined by Pierre Vogel. It is connected through a short exact sequence to the absolute cohomology and another cohomology theory called bounded cohomology. In this talk we investigate the structure of the bounded cohomology as a graded bimodule using the Hopf algebra structure of the Ext algebra. We use the information on the bimodule structure of the bounded cohomology to study the stable cohomology algebra as a trivial extension algebra. (Received August 08, 2015)

1112-13-365 **Wenbo Niu*** (wenboniu@uark.edu). *Conductor ideals vs multiplier ideals on a singular curve.*

On a singular algebraic curve, one can define a new notion of multiplier ideals, which is called Mather-Jacobian multiplier ideal. In this talk, we compare the conductor ideal with a special multiplier ideal on a singular curve. We obtain a criterion when this curve is a local complete intersection. This is joint work with Bernd Ulrich. (Received August 09, 2015)

1112-13-388 **Bill Robinson*** (wrobinson@monmouthcollege.edu) and **Uwe Nagel**. *A Determinantal Identity and its Applications to Determinantal Ideals.*

In our study of skew tableau determinantal ideals, we have discovered a versatile determinantal identity. In this talk we will present the new identity and identify a few of its applications. These include constructing elementary biliaisons for various classes of determinantal ideals, and computing Gröbner bases for a special type of skew tableau ideals. (Received August 09, 2015)

1112-13-389 **Matthew Toeniskoetter***, mtoenisk@purdue.edu, and **William Heinzer** and **Bruce Olberding**. *Valuations and Invariants Associated With Directed Unions of Local Quadratic Transforms.*

We examine ideal-theoretic properties of the directed union S of an infinite sequence of local quadratic transforms of a regular local ring. We associate a boundary valuation ring V to the sequence and examine its relation to S and to the complete integral closure of S. We define an associated invariant τ and describe how τ determines the structure of V and S, namely the rank of V, whether S is archimedean, and whether S is completely integrally closed. (Received August 09, 2015)

1112-13-402 **Giulio Caviglia***, Mathematics Department, Purdue University, 150 N. University Street, West Lafayette, IN 47906. *Some quadratic Gorenstein rings which are Koszul.* Preliminary report.

Conca Rossi and Valla have shown that a generic Gorenstein ring with h-polynomial $1+nz+nz^2+z^3$ is Koszul. Furthermore they showed, without the generic assumption, that for $n=3$ and $n=4$ being quadratic is equivalent to being Koszul. We will show the same result for $n=5$. (Received August 09, 2015)

1112-13-437 **Eliana Maria Duarte Gelvez*** (emduart2@illinois.edu), Department of Mathematics, 1409 W. Green Street, Urbana, IL 61801. *Implicitization of tensor product surfaces.*

A tensor product surface is the image of a rational map $\mathbb{P}^1 \times \mathbb{P}^1 - \to \mathbb{P}^3$. Such surfaces arise in geometric modeling and in this context it is useful to know the implicit equation of the closure of the image. In this talk I will present recent progress on improving syzygy based algorithms to determine the implicit equation of the surface. (Received August 10, 2015)

1112-13-440 **Rachelle Bouchat*** (rbouchat@iup.edu), 210 South Tenth Street, Department of Mathematics, Straight Hall, Room 208, Indiana, PA 15701, and **Tricia Brown**. *Minimal Free Resolutions of Path Ideals of Rooted Trees.* Preliminary report.

Given a rooted tree graph, we consider the path ideals associated to the graph. We will describe the multi-graded Betti numbers of certain classes of path ideals of rooted trees using collections of subtrees and subforests based on the degree of the vertices relative to their level in the rooted tree. Additionally, a constructive approach for building trees will be presented, where the building operations' effect on the projective dimension of the associated path ideal will be detailed. (Received August 10, 2015)

1112-13-449 **Mufit Sezer** and **Wenliang Zhang*** (wlzhang@uic.edu), 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60607. *Gorensteinness of modular coinvarinats.*

Let V be a finite dimensional representation of a finite abelian group G over a field k. If the characteristic of k doesn't divide the order of G (i.e. a non-modular representation), it is known that the ring of coinvariants is Gorenstein if and only if the ring of invariants is a polynomial ring. I'd like to discuss related questions and results for modular representations. This is joint work with Mufit Sezer. (Received August 10, 2015)

1112-13-463 **Kevin Tucker*** (kftucker@uic.edu). *On the limit as $p \to \infty$ of the Hilbert-Kunz Multiplicity.*

In many ways, for a fixed characteristic, the Hilbert-Kunz multiplicity is a rather complicated invariant of singularities. It can take on irrational values, though an explicit example is yet unknown. It is easy to estimate in practice, and very difficult to compute and interpret precisely. In some cases, for rings arising from a reduction to positive characteristic, it is known that the Hilbert-Kunz multiplicities approach a limit as $p \to \infty$. One can

hope that these limits exist in general, that the limit may be simpler and easier to interpret than in a fixed characteristic. In this talk, I will review some of the known examples, and discuss some related limits and progress towards showing the existence of the limit Hilbert-Kunz multiplicity. (Received August 10, 2015)

1112-13-525 **Christopher A Francisco**, **Jeff Mermin*** (mermin@math.okstate.edu) and **Jay Schweig**. *Pure resolutions from lcm lattices.*

We characterize the lattices that can occur as the lcm lattice of a monomial ideal with pure resolution. (Received August 10, 2015)

1112-13-561 **Amanda Beecher** (abeecher@ramapo.edu), 505 Ramapo Valley Road, Mathematics Convening Group, ASB-017, Mahwah, NJ 07430, **Timothy B. P. Clark*** (tbclark@loyola.edu), 4501 N Charles Street, Department of Mathematics and Statistics, Knott Hall 316b, Baltimore, MD 21211, and **Alexandre Tchernev** (tchernev@albany.edu), 1400 Washington Avenue, Department of Mathematics and Statistics, ES 137B, Albany, NY 12222. *Posets underlying resolutions of multigraded modules.* Preliminary report.

We interpret combinatorially several aspects of the third author's T-resolution of a multigraded module M. Indeed, bases for the modules in this resolution are given by the homology of open intervals in a subposet of a lattice associated to the matroid underlying a free presentation of M. Furthermore, the incidence structure of this *reduced lattice of T-flats* encodes much of the mapping structure of the T-resolution. (Received August 11, 2015)

1112-13-570 **Bethany Kubik**, University of Minnesota Duluth, and **Sean Sather-Wagstaff*** (ssather@clemson.edu), Clemson University. *Path ideals of weighted graphs.*

We introduce and study the weighted r-path ideal of a weighted graph G_ω, which is a common generalization of Conca and De Negri's r-path ideal for unweighted graphs and Paulsen and Sather-Wagstaff's edge ideal of the weighted graph. Over a field, we explicitly describe primary decompositions of these ideals, and we characterize Cohen-Macaulayness of these ideals for trees (with arbitrary r) and complete graphs (for $r = 2$). (Received August 11, 2015)

1112-13-654 **Jennifer Biermann*** (jbierman@mtholyoke.edu), **Augustine O'Keefe** and **Adam Van Tuyl**. *Regularity of toric edge ideals.* Preliminary report.

We investigate the regularity of toric edge ideals arising from perfect elimination bipartite graphs. (Received August 11, 2015)

14 ► Algebraic geometry

1112-14-21 **S. Allen Broughton*** (brought@rose-hulman.edu), Department of Mathematics, Rose-Hulman Institute of Technology, Terre Haute, IN 47803. *Symmetric surfaces with quasi-platonic $PSL(2,q)$ action.* Preliminary report.

A quasi-platonic action of the group G on the Riemann surface S is a conformal action of G on S such that S/G is a sphere and the projection $S \to S/G$ is branched over three points. The surface S is called symmetric if there is an anti-conformal involution ϕ of S, called a symmetry. Equivalently, S has a defining equation with real coefficients, and so the mirror (fixed point subset) of ϕ is a real curve. We are particularly interested in the case where $G = PSL(2,q)$ and ϕ normalizes the G-action. In this case S, typically carries a tiling by hyperbolic triangles and the group generated by the reflection in the sides of the triangles is $G^* = \langle \phi \rangle \ltimes G$. In this talk we describe the quasi-platonic actions of $PSL(2,q)$ admitting a normalizing symmetry ϕ. We address three questions about symmetries: The number of conjugacy classes of symmetries in G^*, the number of ovals in the mirror of a symmetry, and whether the mirror of the symmetry separates the surface. (Received May 29, 2015)

1112-14-25 **Milagros Izquierdo*** (milagros.izquierdo@liu.se), Department of Mathematics, Linköping University, 58183 Linköping, Sweden, and **Antonio F. Costa** (acosta@mat.uned.es) and **Ana M. Porto** (asilva@mat.uned.es). *On Branch Loci of Moduli Spaces of Hyperelliptic Klein Surfaces with.*

In 1982 Mika Seppälä showed that the space of hyperelliptic Riemann surfaces of given genus is connected. In this work we study branch loci of moduli spaces of hyperelliptic Klein surfaces with one boundary component. The behavior is very different whether the surfaces are orientable or not: while branch loci in spaces of orientable hyperelliptic Klein surfaces with one boundary component are connected, the branch locus of moduli space of non-orientable hyperelliptic Klein surfaces with one boundary component are disconnected. In fact it consists

of g/2 components for even genera g, and (g-1)/2 components for odd genera. This is a joint work with Antonio F. Costa and Ana M. Porto (Received June 01, 2015)

1112-14-35 **Gabino Gonzalez-Diez*** (gabino.gonzalez@uam.es), Departamento de Matematicas, Universidad Autonoma de Madrid, Ciudad Universitaria de Cantoblanco, 28049 Madrid, Madrid, Spain. *The action of the absolute Galois group on quasiplatonic curves.*

A triangle (or quasiplatonic) curve of type (l,m,n) is a complex curve C admitting a group G of automorphisms such that the quotient C/G is an orbifold of genus zero with three branching values of mutiplicities l,m and n. By Belyi's theorem all such curves are defined over a number field and so the absolute Galois group acts on (the isomorphism classes of) them.

Let C be any given hyperbolic triangle curve defined over the rationals such as Klein's or Fermat's. We will show that the absolute Galois group acts faithfully on the set of triangle curves which are unramified normal covers of C. In particular it acts faithfully on quasiplatonic curves of any given hyperbolic type. This is joint work with Andrei Jaikin-Zapirain. (Received June 19, 2015)

1112-14-85 **Roy Joshua*** (joshua.1@math.osu.edu), Roy Joshua, Department of Mathematics, The Ohio State University, 231 West 18th Ave, Columbus, OH 43210, and **Reza Akhtar** (reza@calico.mth.muohio.edu), Department of Mathematics, Miami University, Oxford, OH 45056. *Quantum stabilizer codes from toric varieties.*

In this talk, we explore the construction of algebraic codes from toric varieties using toric residues. Though algebraic codes have been constructed from toric varieties, they have largely been evaluation codes, where one evaluates the sections of a line bundle at a collection of rational points. Instead of evaluating sections of a line bundle at rational points, we compute the residues of differential forms at these points. We show that this method produces codes that are close to the dual of those produced by the first technique. We conclude by studying several examples, and also discussing applications of this technique to the construction of quantum stabilizer codes. (Received July 19, 2015)

1112-14-94 **Anatoly Libgober*** (libgober@uic.edu), IL. *Linear sections of Pfaffians.*

This is report on recent joint work with L.Borisov on calculation of stringy Hodge numbers of linear sections of Pfaffians. The results involve a study of singularities of Pfaffians, their resolutions, and identities for q-hypergeometric functions. They provide indirect confirmation of conjectures on double mirrors and some of A.Kuznetsov conjectures on homological projective duality. (Received July 22, 2015)

1112-14-97 **Eugene Gorsky***, Department of Mathematics, University of California Davis, One Shields Avenue, Davis, CA 95616, and **Andras Nemethi**. *Heegaard Floer homology of algebraic links.*

Campillo, Delgado and Gusein-Zade expressed the Alexander polynomial of an algebraic link in terms of the multi-dimensional semigroup of the corresponding plane curve singularity. We categorify their result and compute the minus-version of the Heegaard-Floer link homology in similar terms. (Received July 23, 2015)

1112-14-150 **Alicia Dickenstein*** (alidick@dm.uba.ar), Dto. de Matematica, FCEN, Universidad de Buenos Aires, Ciudad Universitaria, Pab. I, C1428EGA Buenos Aires, Argentina, and **Mercedes Perez Millan**. *MESSI biological systems.* Preliminary report.

We introduce a general framework for biological systems that describe Modifications of type Enzyme-Substrate or Swap with Intermediates, which we call MESSI systems. Examples of MESSI systems are the sequential distributive or processive multisite phosphorylation networks, phosphorylation cascades, and the bacterial EnvZ/OmpR network. Assuming mass-action kinetics, we present a unified study of steady states and conservation laws of these systems (inspired by [Feliu and Wiuf 2013; Perez Millan, Dickenstein, Shiu and Conradi 2012; Thomson and Gunawardena 2009]). (Received July 30, 2015)

1112-14-152 **Alejandro Melle-Hernández*** (amelle@ucm.es), Dept. of Algebra, Faculty of Mathematical Sciences, Complutense University of Madrid, 28040 Madrid, Spain. *Higher order generalized Euler characteristics of a complex quasi-projective manifold with a finite group action and some generating series.* Preliminary report.

Euler characteristics of a given order k is a generalization of the so-called orbifold Euler characteristic (for a space with a finite group action) introduced by physisists. For a complex quasi-projective manifold X with a finite group G action, we define a generalized Euler characteristics of order k of the pair (X, G) (a sort of their motivic versions) with values in the Grothendieck ring of complex quasi-projective varieties extended by the rational powers of the class of the affine line. The geometric description of the power structure over such a ring allows

us to compute, for a fixed k, the generating series whose n coeffcient is the generalized Euler characteristics of a fixed order k of the n-wreath product orbifolds $(X^n, G^n \wr S_n)$ in terms of some local data (not depending on X) to the power -k-th generalized Euler characteristics of the pair (X, G). This talk is based on some joint works with S.M. Gusein-Zade and I.Luengo. (Received July 30, 2015)

1112-14-176 **Arnold H Yim*** (ayim@purdue.edu), Department of Mathematics, Purdue University, 150 N University St, West Lafayette, IN 47907. *Homological Properties of Determinants Arrangements.*

An important aspect of a divisor Y on a complex analytic manifold X is its *singular locus*. One can view the divisor Y as "well-behaved" if the singular locus consists of isolated points, or if the singular locus is perhaps large but "not very complicated" in a suitable sense. In this talk, we take the latter position. The best possible case in this view is that of normal crossings where the singular locus looks locally like a union of coordinate hyperplanes. By studying the logarithmic flows on X that stabilize (are tangent to) Y, one can understand just how complex the singular locus is. In particular, if the collection of these logarithmic flows form a free module, then the singular locus is simple and we say that the divisor is a free divisor.

Free divisors show up naturally in many different settings. For example, many of the classically arising hyperplane arrangements (such as braid arrangements and Coxeter arrangements) are free. Though much is known for hyperplane arrangements, things become more difficult when we consider arrangements of more general hypersurfaces. In this talk, we explore freeness for determinantal arrangements (arrangements defined by minors of a generic matrix) and generalize some of the classical results in this new setting. (Received August 01, 2015)

1112-14-226 **Sebastian Bozlee** and **Aaron Wootton*** (wootton@up.edu), 5000 North Willamete Blvd., Portland, OR 97203. *Sufficiency of the Riemann-Hurwitz Formula for the Existence of a Group Action.*

The topological data of a group action on a compact Riemann surface can be encoded using a tuple $(h;m_1,\ldots,m_s)$ called its signature. There are two arithmetic conditions on a tuple necessary for it to be a signature: the Riemann–Hurwitz formula is satisfied and each m_i equals the order of a non-trivial group element. We consider the problem of when satisfaction of these two conditions is in fact sufficient for the existence of a group action with a given signature. (Received August 04, 2015)

1112-14-328 **Donu Arapura***, Dept Math, Purdue University, West Lafayette, IN 47905. *Étale fundamental groups of smooth and normal projective varieties.*

By way of background, I will say a few words about some structural results for Kähler groups (fundamental groups of compact Kähler manifolds) proved over 20 years, by Gromov, Bressler-Ramachandran and me. Then I want to discuss an extension to fundamental groups of projective varieties in positive characteristic. My original argument, which appears in Compositio, applies only to smooth varieties. But I have recently found a different argument, that extends to normal varietes. I will try to explain if I have time. (Received August 07, 2015)

1112-14-338 **Marta Casanellas** and **Jesús Fernández-Sánchez*** (jesus.fernandez.sanchez@upc.edu), Matemàtica Aplicada I, ETSEIB, Av. Diagonal 647, 08028 Barcelona, Catalunya, Spain, and **Mateusz Michałek**. *Complete intersections for equivariant models.*

Evolutionary models are needed to study the evolution between nucleotide sequences. Some of the most usual models fit into the *equivariant* definition introduced in terms of the action of a permutation group in the set of nucleotides. *Phylogenetic invariants* are constraints satisfied by the joint probabilities of nucleotide patterns at the leaves of a phylogenetic tree evolving under a given evolutionary model. They have shown to be useful to characterize the model as well as to design methods for phylogenetic inference.

We study and construct phylogenetic invariants of some well-known equivariant phylogenetic models and the general Markov Model. These invariants allow us to describe a (Zariski open) neighbourhood of the no-evolution points in the model as a complete intersection. In other words, we provide a minimal possible number of explicitly constructed phylogenetic invariants that determine the model at biologically meaningful points. Our work is inspired by previous inductive constructions of phylogenetic invariants. It is motivated mostly by applications, as the number of phylogenetic invariants we construct is much lower than the number needed to generate the ideal of the corresponding variety. (Received August 08, 2015)

1112-14-345 **Ivan Soprunov*** (i.soprunov@csuohio.edu), 2121 Euclid Ave, Cleveland, OH 44115.
Self-dual codes from smooth Fano polytopes. Preliminary report.

We consider a class of evaluation codes called toric complete intersection codes (TCIC), which is a natural generalization of the Reed-Muller code from the projective space to other toric varieties. A TCIC is given by evaluating a space of m-variate Laurent polynomials over the solution set of a system of m polynomials with prescribed Newton polytopes $P_1, \ldots, P_m$ in $\mathbb{R}^m$. We investigate when a TCIC is self-dual. Previously, together with Pinar Celebi Demirarslan we showed that when $m = 2$ and P_1, P_2 are dilates of a single polygon P then a self-dual TCIC exists if and only if P is lattice equivalent to one of the 16 Fano polygons. I will talk about this connection for higher-dimensional smooth Fano polytopes. (Received August 08, 2015)

1112-14-350 **T. Shaska*** (shaska@oakland.edu) and **L. Beshaj**. *Julia quadratic of superelliptic Riemann surfaces.*

We will give a brief review of how to algebraically determine the Julia quadratic of superelliptic Riemann surfaces. Computations for surfaces of genus 2 and 3 will be shown. Moreover, we will compare such computations with the case when the superelliptic surface has extra automorphisms. (Received August 08, 2015)

1112-14-410 **Elisenda Feliu***, Universitetsparken 5, 2100 Copenhagen, Denmark. *Injectivity, multiple zeros and multistationarity in reaction networks.*

Polynomial dynamical systems are widely used to model and study real phenomena. In biochemistry, they are the preferred choice for modelling the concentration of chemical species in reaction networks with mass-action kinetics. These systems are typically parametrized by many (unknown) parameters.

A goal is to determine the positive steady states of the system, which are the positive solutions to a parametrized system of generalized polynomial equations. In recent years, methods from computational algebra have been developed to understand these solutions, but our knowledge is still limited.

In the talk I will present a new method, based on so-called injectivity, to preclude or assert that multiple positive solutions exist. The results apply to generalized polynomials and variables can be restricted to the linear, parameter-independent first integrals of the dynamical system.

The content of the talk is based on the paper: Feliu E (2014) "Injectivity, multiple zeros and multistationarity in reaction networks", Proceedings of the Royal Society A, 471, 20140530. (Received August 10, 2015)

1112-14-423 **Botong Wang*** (wang_botong@hotmail.com). *Cohomology jump loci of small ball complement of hypersurfaces.*

Let $(X, 0) \subset (\mathbb{C}^n, 0)$ be a germ of an algebraic hypersurface at the origin. Let B be a small ball in $\mathbb{C}^n$ centered at the origin. We are interested in the topology of the complement $B \setminus X$. We will relate the topological cohomology jump loci with some D-module theoretic cohomology jump loci. The main result is a structure theorem about the topological cohomology jump loci. This is a joint work with Nero Budur. (Received August 10, 2015)

1112-14-428 **Gary Kennedy**, 1760 University Drive, Mansfield, OH 44906, and **Lee J McEwan*** (mcewan.1@osu.edu), 1760 University Drive, Mansfield, OH 44906. *On The Milnor Fiber of a Quasi-Ordinary Hypersurface.* Preliminary report.

We give an explicit topological description of the Milnor fiber, and its boundary, of a quasi-ordinary hypersurface. Our description generalizes the classical construction of the Milnor fiber of a plane curve singularity, in terms of canonical pieces that are invariant under, and acted on finitely by, the monodromy. In this more general setting, there are several monodromies. Among our results is a recursive formula (in terms of the characteristic tuples) for the Betti numbers of both the Milnor fiber and its boundary. (Received August 10, 2015)

1112-14-458 **Jose Cogolludo***, C. Pedro Cerbuna 12, 50009 Zaragoza, Zaragoza, Spain, and **Jorge Martin-Morales** (jorge@unizar.es), Academia General Militar, Ctra. de Huesca s/n., 50090 Zaragoza, Zaragoza, Spain. *Curve invariants on quotient surface singularities and lattice counting problems.*

The purpose of this talk is to describe some invariants of curve singularities on normal surfaces, in particular quotient surface singularities, using Q-resolutions. Such invariants allow for the computation of genus formulas for curves on weighted projective planes and log-canonical thresholds.

We will also show a numerical Adjunction Formula that can be used for the calculation of rational lattice point counting formulas and their Ehrhart quasi-polynomials. (Received August 10, 2015)

1112-14-480 **Dima Arinkin**, **Andrei Caldararu*** (andreic@math.wisc.edu) and **Marton Hablicsek**.
Azumaya spaces and deformation quantization. Preliminary report.

In this talk I shall argue that in positive characteristic there is a strong similarity between deformation quantization (passing from the commutative algebra of functions on the cotangent bundle to the ring of differential operators) and non-commutative deformations in the sense of Azumaya spaces (spaces endowed with a sheaf of Azumaya algebras). As an application I shall sketch a proof of the classical Deligne-Illusie result about the degeneration of the Hodge-de Rham spectral sequence in positive characteristic. (Received August 10, 2015)

1112-14-556 **Jose Israel Rodriguez*** (jo.ro@nd.edu). *The maximum likelihood degree for rank 2 matrices via Euler characteristics.*

The maximum likelihood degree (ML degree) measures the algebraic complexity of a fundamental computational problem in statistics: maximum likelihood estimation on a statistical model. Work by June Huh, relates the ML degree of an algebraic variety (statistical model) to an Euler characteristic in the smooth case. More recent work by Nero Budur and Botong Wang relate a weighted sum of ML degrees to an Euler characteristic in the singular case. The new work presented here proves a closed form expression for the ML degree of 3 × n rank at most 2 matrices (this variety corresponds to a mixture of 2 independence models in statistics). This result solves a conjecture by Hauenstein, [], and Sturmfels based on computations with the numerical algebraic geometry software Bertini. The talk will have a running example based on "DiaNA's dice" to bridge statistics, Euler characteristics, combinatorics, and applied algebraic geometry. Joint work with Botong Wang. (Received August 11, 2015)

1112-14-635 **Nathan Bliss*** (nbliss2@uic.edu), Mathematics & Comp Sci MC 249, 851 S Morgan St, Chicago, IL 60607, and **Jan Verschelde**. *A Symbolic-Numeric Method for Higher-Dimensional Newton-Puiseux Expansions.*

The Newton-Puiseux algorithm in two dimensions can be viewed as a special case of the fundamental theorem of tropical algebraic geometry. We examine the question of the algorithm's generalization to higher dimensions, highlighting possible optimizations of the polyhedral portion of the algorithm. We then demonstrate a symbolic-numeric Newton-Puiseux method for space curves in any dimension. (Received August 11, 2015)

15 ► Linear and multilinear algebra; matrix theory

1112-15-57 **Paul M Terwilliger*** (terwilli@math.wisc.edu), 480 Lincoln Drive, Madison, WI 53706. *Lowering-Raising Triples of Linear Transformations.*

Fix a nonnegative integer d. Let $\mathbb{F}$ denote a field, and let V denote a vector space over $\mathbb{F}$ with dimension $d+1$. By a decomposition of V we mean a sequence $\{V_i\}_{i=0}^d$ of one-dimensional subspaces whose direct sum is V. Let $\{V_i\}_{i=0}^d$ denote a decomposition of V. A linear transformation $A \in \mathrm{End}(V)$ is said to lower $\{V_i\}_{i=0}^d$ whenever $AV_i = V_{i-1}$ for $1 \leq i \leq d$ and $AV_0 = 0$. The map A is said to raise $\{V_i\}_{i=0}^d$ whenever $AV_i = V_{i+1}$ for $0 \leq i \leq d-1$ and $AV_d = 0$. A pair of elements A, B in $\mathrm{End}(V)$ is called lowering-raising (or LR) whenever there exists a decomposition of V that is lowered by A and raised by B. A triple of elements A, B, C in $\mathrm{End}(V)$ is called LR whenever any two of A, B, C form an LR pair. We classify up to isomorphism the LR triples. There are nine infinite families of solutions. We show that each solution A, B, C satisfies some relations that resemble the defining relations for $U_q(\mathfrak{sl}_2)$ in the equitable presentation. (Received July 11, 2015)

1112-15-439 **Iwan M. Duursma*** (duursma@math.uiuc.edu), Department of Mathematics, Univ of Illinois at Urbana-Champaign, 1409 W. Green Street (MC-382), Urbana, IL 61801-2975. *Bruhat Decompositions and the Koetter and Vardy Conjecture.* Preliminary report.

The Koetter and Vardy construction for minimal linear tail-biting trellises makes use of so-called characteristic generators for the row space of a matrix. We give a novel description of their properties. Gluesing-Luerssen and Weaver have shown that some of the duality properties conjectured by Koetter and Vardy are not true in general. We show that the original conjecture is true after a minor adjustment. (Received August 10, 2015)

16 ► Associative rings and algebras

1112-16-20 **Pedro A Guil Asensio**, **Derya Keskin Tutuncu** and **Ashish K Srivastava*** (asrivas3@slu.edu), 221 N. Grand Blvd., Saint Louis, MO 63103. *Modules invariant under automorphisms of their covers and envelopes.*

We will discuss the theory of modules which are invariant under automorphisms of their covers and envelopes. When applied to specific cases like injective envelopes, pure-injective envelopes, cotorsion envelopes, projective covers, or flat covers, these results extend and provide much more succinct proofs for various results existing in the literature. Our technique is based on several key observations on the additive unit structure of von Neumann regular rings. (Received May 27, 2015)

1112-16-43 **Alexander Diaz-Lopez*** (adiaz4@nd.edu), 255 Hurley, Department of Mathematics, Notre Dame, IN 46556. *Representations of Hecke algebras on quotients of path algebras.*

Given a Coxeter system (W, S), a W-graph is a graph, together with additional information, that encodes a representation (denoted τ representation) of the Hecke algebra associated to W. We generalize this work by defining W-graphs over non-commutative algebras, which give rise to new representations of Hecke algebras. The main examples to be discussed include several representations of Hecke algebras on quotients of path algebras (over suitable quivers). We discuss the relationship between these representations and the τ representations. The most interesting example comes from a quotient path algebra that is isomorphic to an important ideal of Lusztig's asymptotic Hecke algebra (when defined). (Received July 02, 2015)

1112-16-65 **Uma N Iyer** and **Earl J Taft*** (etaft@math.rutgers.edu), Department of Mathematics, Rutgers University, Piscataway, NJ 08854. *Is there a left quantum group containing $U_q(sl(2))$?*

S. Rodriguez-Romo and E. J. Taft constructed a left quantum group S' (i.e., there is a left antipode which is not a right antipode) modeled after $S = SL_q(2)$ [J. Algebra 285(2005), 154-160]. S is a homomorphic image of S'. Taking continuous duals, S'^o contains S^o, which contains $U_q(sl(2))$. Thus S'^0 appears to be a left quantum group containing $U_q(sl(2))$. However, we show that $S'^o = S^o$, and is thus a (two-sided) quantum group. The title question remains open. (Received July 14, 2015)

1112-16-67 **S K Jain*** (jain@ohio.edu), 76 Anchor Lane, Springboro, OH 45066. *Quasi-Permutation Singular Matrices are Products of Idempotents.*

Initiated by J. Erods the problem of decomposing singular matrices into product of idempotents has been intensively studied by several authors (J. Fountain, J. Hannah, K. O'Meara and others). Recently it has been shown, (Alahmadi-Jain-Leroy-Sathaye, Electronic JLA, to appear), among others, that every nonnegative matrix $A \in M_n(R)$ of rank one, $n > 1$ is a product of at most three nonnegative idempotents.

A matrix $A \in M_n(R)$ over a ring R, is called a quasi-permutation matrix if each row and each column has at most one non-zero entry. We show by using combinatorial techniques that a singular quasi-permutation matrix with coefficients in a domain can be represented as a product of idempotents. As an application it follows that nonnegative matrices having nonnegative von Neumann inverse can be written as product of nonnegatrive idempotents (joint with Alahmadi and Leroy). Indeed, the well-known structures of nonnegative matrices that have nonnegative v.N.i. reveal strong links with rank one matrices and quasi-permutation matrices We would also revisit briefly an open question on group algebras whether continuous von Neumann regular group algebra of a group G over rationals is self-injective, equivalently, semisimple artinian?
(Received July 14, 2015)

1112-16-81 **Jairo Z Goncalves*** (jz.goncalves@usp.br), Rua do Matao 1010, Sao Paulo, SP 05508-090. *My collaboration with Don Passman.*

In this article I highlight some facts from my collaboration with Don Passman, from 1996 to the present time: from our first paper in group rings, till our recent investigations on the existence of free groups in the multiplicative group of division rings.
(Received July 17, 2015)

1112-16-121 **Leo Margolis*** (leo.margolis@mathematik.uni-stuttgart.de), Fachbereich Mathematik, IAZ, Pfaffenwaldring 57, 70569 Stuttgart, Germany. *Zassenhaus Conjecture and Prime Graph Question for Integral Group Rings.*

Let G be a finite group and $V(\mathbb{Z}G)$ the normalized units in the integral group ring of G, i.e. the units whose coefficents sum up to 1. The main open problem concerning torsion units in $V(\mathbb{Z}G)$ is the so called Zassenhaus Conjecture:

For any torsion unit u in $V(\mathbb{Z}G)$ there exists an unit in the rational group algebra of G conjugating u onto an element of G.

At a conference dedicated to the 65th birthday of D. S. Passman W. Kimmerle formulated a much weaker version of the Zassenhaus Conjecture, the so called Prime Graph Question:

If p and q are different primes and $V(\mathbb{Z}G)$ contains an element of order $p*q$, does G also contain an element of order $p*q$?

We will present recent results concerning these questions for non-solvable groups, in particular simple and almost simple groups. Moreover a new method to attack these questions will be presented which involves integral and modular representation theory. (Received July 27, 2015)

1112-16-127 **Allen Herman*** (allen.herman@uregina.ca), Department of Mathematics and Statistics, University of Regina, Regina, SK S4S0A2, Canada. *Torsion units of integral table algebras and RBAs.*

One of the objectives of integral representation theory of finite groups is to understand the structure of the unit group $U(\mathbb{Z}G)$. Hans Zassenhaus formulated three conjectures about torsion units of integral group rings in the mid 1960's, one of which is still open. It states that any torsion unit of $\mathbb{Z}G$ should be conjugate in $\mathbb{Q}G$ (or equivalently in $\mathbb{C}G$) to an element of $\pm G$.

In this talk we will investigate the analogous statement of the Zassenhaus conjecture for unit groups of integral adjacency algebras of association schemes, integral generalized table algebras, and integral reality-based algebras. All of these are $\mathbb{Z}$-algebras of the form $\mathbb{Z}\mathbf{B}$, where $\mathbb{C}\mathbf{B}$ is a C^*-algebra whose basis $\mathbf{B}$ is a $*$-closed set, satisfies a pseudo-inverse condition, and has integer structure constants. We are able to generalize several known results about torsion units from integral group rings to the case of integral RBAs with positive degree map that possess a standard character. In particular these results hold for the integral adjacency algebras of association schemes. This is joint work with Gurmail Singh. (Received July 27, 2015)

1112-16-135 **Apoorva Khare*** (khare@stanford.edu). *Matched pairs of monoids, Hopf algebras, and the BGG Category $\mathcal{O}$.*

The Bernstein-Gelfand-Gelfand Category $\mathcal{O}$ is a fundamental construction in the study of representations of algebras with triangular decomposition. We introduce an axiomatic construction of such algebras, where the "Cartan subalgebra" is a commutative (topological) Hopf algebra. Our framework encompasses symmetrizable Kac-Moody Lie algebras and their quantum groups, the Virasoro Lie algebra and its extensions, a large class of generalized Weyl algebras, and continuous and infinitesimal Hecke algebras, among others.

We term such algebras Regular Triangular Algebras (RTAs); each RTA comes equipped with a matched pair of monoids, consisting of the "positive" and "negative" cones of roots. We characterize the monoid pairs that can arise out of an RTA under reasonably weak assumptions. This enables the first construction of an algebra with a triangular decomposition, which possesses a *non-abelian* root lattice. (Received July 28, 2015)

1112-16-139 **Lauren Grimley***, Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843. *Hochschild cohomology of finite group extensions of some quantum complete intersections.* Preliminary report.

Hochschild cohomology of an associative algebra over a field is a Gerstenhaber algebra, having a cup product and graded Lie bracket which satisfies the Poisson identity. In this talk, we will investigate the Gerstenhaber algebra structure the Hochschild cohomology of group extensions of a class of quantum complete intersections, utilizing the notion of twisted tensor products. (Received July 28, 2015)

1112-16-164 **Vladislav K. Kharchenko*** (vlad@unam.mx), Primero de Mayo s/n, Campo 1, FESC-UNAM, 54768 Cuautitlán Izcalli, México, Mexico. *Noncommutative Galois theory: from subgroups to right coideal subalgebras.*

One-sided comodule subalgebras, but not the Hopf subalgebras, turn out to be the Galois objects in the Galois theory for Hopf algebra actions (A. Milinski, S. Montgomery, D. Passman, T. Yanai, S. Westreich, A. Masuoka). In particular, the Galois correspondence theorem for the actions on a free algebra set up a one-to-one correspondence between all right coideal subalgebras and all intermediate free subalgebras (V.O. Ferreira, L.S.I. Murakami, and A.Paques). In the talk we survey the development of the non-commutative Galois theory and provide recent results on the classification of the right coideal subalgebras of the Drinfel'd-Jimbo quantizations. (Received July 31, 2015)

1112-16-179 **Jason P Bell*** (jpbell@uwaterloo.ca), Department of Pure Mathematics, University of Waterloo, 200 University Ave. W, Waterloo, ON N2L3G1, Canada, and **Jairo Z Goncalves**. *Free groups and free algebras in division rings of Ore extensions.*

We consider division rings of the form $D = K(x; \sigma, \delta)$ where K is a field, σ is an automorphism of K and δ is a σ-derivation of K. We show that if K has characteristic zero then D contains a rank two free algebra over its center. To accomplish this, we use techniques from algebraic geometry and p-adic analysis. We give some applications and consider the question of when D^*, the multiplicative group of D, contains a free non-cyclic subgroup. (Received August 02, 2015)

1112-16-183 **Chia-Hsin Liu*** (chliu@math.ntnu.edu.tw). *SSN groups, NCN groups, and multiplicative Jordan decomposition in group rings.* Preliminary report.

In this talk, I will survey some joint works with Professor Passman about multiplicative Jordan decomposition in group rings. In particular, two classes of groups, SSN groups and NCN groups, are naturally involved. (Received August 02, 2015)

1112-16-189 **Markus Pflaum**, **Hessel Posthuma** and **Xiang Tang*** (xtang@math.wustl.edu), 1 Brookings Drive, St. Louis, MO 63130. *Hochschild homology of a proper Lie groupoid.* Preliminary report.

In this talk, I will present some work in progress on the Hochschild homology of the convolution algebra associated to a proper Lie groupoid. This is joint work with Markus Pflaum and Hessel Posthuma. (Received August 03, 2015)

1112-16-194 **Allan Berele***, DePaul University, Chicago, IL 60614. *GK dimension of p. i. algebras.*

The GK dimension of an algebra generated by k elements and satisfying a polynomial identity of degree d is bounded by $(k-1)\lfloor d/2 \rfloor^2 + 1$.

We can prove this statement in characteristic zero under mild hypotheses on k and d, and we can prove a weaker bound without them. We conjecture that it is always true.

We also mention some related questions. (Received August 03, 2015)

1112-16-209 **Chelsea Walton** and **Sarah Witherspoon*** (sjw@math.tamu.edu). *Hopf actions and PBW deformations.* Preliminary report.

A Hopf algebra acting on another algebra gives rise to a smash product, that is, a larger ring encoding the action. In the special case of a group acting on a polynomial ring, deformations of smash product rings (also known as skew group algebras) include the graded Hecke algebras, symplectic reflection algebras, and rational Cherednik algebras that have arisen independently in many different fields. Replacing the group by a Lie algebra, quantum group, or other Hopf algebra, and polynomials by other Koszul algebras, one obtains analogs of these algebras. In this talk we will introduce these analogs and give some examples. (Received August 04, 2015)

1112-16-211 **Alexander C Garver*** (garv0102@umn.edu), 206 Church Street SE, Minneapolis, MN 55455, and **Thomas McConville**. *Lattice Properties of Oriented Exchange Graphs.*

The exchange graph of a quiver is the graph of mutation-equivalent quivers whose edges correspond to mutations. The exchange graph admits a natural acyclic orientation called the oriented exchange graph. Building on work of Iyama, Reiten, Thomas, and Todorov, we show that this directed graph is a semidistributive lattice by using the isomorphism to the lattice of functorially finite torsion classes of the corresponding cluster-tilted algebra when the exchange graph is finite. Furthermore, if the quiver is mutation-equivalent to a type A Dynkin quiver or is an oriented cycle, then the oriented exchange graph is a lattice quotient of a lattice of biclosed subcategories of modules over the cluster-tilted algebra, generalizing Reading's Cambrian lattices in type A. We also apply our results to address a conjecture of Brustle, Dupont, and Perotin on the lengths of maximal green sequences. (Received August 04, 2015)

1112-16-236 **Van C. Nguyen*** (v.nguyen@neu.edu), Northeastern University, Department of Mathematics, Boston, MA 02115, and **Sarah Witherspoon**, Texas A&M University. *Finite generation of cohomology rings.*

People are interested in the cohomology rings for various reasons. One of the properties they look at is whether the cohomology ring of an algebra is finitely generated. In this talk, we show that some skew group algebras have Noetherian cohomology rings, a property inherited from their component parts. The proof is an adaptation of Evens' proof of finite generation of group cohomology. We apply the result to a series of examples of finite dimensional Hopf algebras in positive characteristic. (Received August 05, 2015)

1112-16-258 **Yorck Sommerhäuser***, Memorial University of Newfoundland, Department of Mathematics and Statistics, St. John's, NL A1C 5S7, Canada. *Yetter-Drinfel'd Hopf Algebras and Their Extensions.* Preliminary report.

Under suitable assumptions on the base field, a commutative and cocommutative semisimple Yetter-Drinfel'd Hopf algebra over a finite abelian group contains a subalgebra that can be described as an extension. We discuss certain aspects of the theory of extensions of Yetter-Drinfel'd Hopf algebras that are relevant in this context. (Received August 06, 2015)

1112-16-263 **Ian M Musson*** (musson@uwm.edu). *The lattice of submodules of a multiplicity free module.*

In this paper we study the lattice of submodules Λ of a module M all of whose composition factors have multiplicity one. Such a lattice is distributive, and hence determined by its poset of down-sets P. We define a directed Ext graph Ext_Λ of Λ and show that Ext_Λ determines P. The result applies to multiplicity free indecomposable modules for finite dimensional algebras with acyclic Ext graph. We also apply our methods to modules in the category $\mathcal{O}$ for a semisimple Lie alsgebra or a classical simple Lie superalgebra. Projective indecomposable modules over the preprojective algebra of type A provide important and interesting examples of modules with distributive lattices of submodules, which are not multiplicity free in general. Many of our results hold in the more general distributive case. (Received August 06, 2015)

1112-16-276 **Susan Montgomery*** (smontgom@usc.edu), **Maria Vega** and **Sarah Witherspoon**. *Hopf automorphisms and twisted extensions.*

We give some applications of a Hopf algebra K constructed from a group acting on another Hopf algebra A as Hopf automorphisms, namely Molnar's smash coproduct Hopf algebra.

We find connections between the exponent and Frobenius-Schur indicators of K and the twisted exponents and twisted Frobenius-Schur indicators of the original Hopf algebra A. (Received August 06, 2015)

1112-16-298 **Mitja Mastnak*** (mmastnak@cs.smu.ca). *Deformations of graded bialgebras.*

I will present some aspect of deformation theory for graded bialgebras and how it relates to the lifting method of Andruskiewitsch and Schneider. Some tools based on joint works with F. Fantino, G. Garcia, L. Grunenfelder, and S. Witherspoon for explicitly computing the relevant cohomology groups and universal defurmation formulas will be presented.

I will also briefly mention a braided version of this theory and how it might be used to define a concept of a quantum Lie algebra. This part is based on joint work with I. Angiono and M. Kochetov. (Received August 07, 2015)

1112-16-305 **Angela Antonou*** (aantonou@stfrancis.edu), 500 Wilcox St., Joliet, IL 60435, and **Harvey I. Blau**. *A Characterization of Standard Table Algebras Based on Conditions on Their Multiplicities.*

This talk contributes to the program of determining the structure of a standard table algebra (in particular, an adjacency algebra) from assumptions on the multiplicities and/or degrees of its irreducible characters. We show that a noncommutative standard table algebra with exactly one character that has nontrivial multiplicity, and also has degree two, must have a closed subset of cardinality two or three with at most four non-singleton cosets. The various configurations lead to several infinite families, in each of which all structure constants and the representation corresponding to the character of degree two are calculated explicitly from the degrees of the elements in these cosets. The sub-families that are integral are also found. (Received August 07, 2015)

1112-16-310 **Iva Halacheva*** (iva.halacheva@utoronto.ca), Department of Mathematics, 40 St George St., Room 6920, Toronto, Ontario M5S 2E4, Canada. *Extensions of the Multivariable Alexander Polynomial.*

In her thesis (arXiv:0710.4885v1), J. Archibald defines an invariant of virtual tangles, valued in a tensor product of exterior algebras, which generalizes the Multivariable Alexander Polynomial (MVA) for links. This invariant can be computed through a straight-forward, albeit exponential-time algorithm from the corresponding Alexander matrix and provides an easy verification of almost all relations satisfied by the MVA and its weight system. On the other hand, D. Bar-Natan also defines a tangle invariant which generalizes the MVA. It is a reduction of an invariant of knotted copies of S^2 and S^1 in four-dimensional space, is matrix-valued and more-easily computable in polynomial time, but is only defined on pure tangles, i.e. no closed components. We will discuss how after some repackaging, Archibald's invariant coincides with that of Bar-Natan on pure tangles, and furthermore gives rise to a partial extension of Bar-Natan's invariant to tangles which can have closed components . (Received August 07, 2015)

1112-16-311 **Lance W Small*** (lwsmall@ucsd.edu), Department of Mathematics C-012, UCSD, La Jolla, CA 92093-0012. *Coherent and Incoherent Enveloping Algebras of Lie Algebras.*

Examples of enveloping algebras that are not coherent will be given as well as criteria for coherence in certain cases. For example, there are finitely presented metabelian Lie algebras whose enveloping algebras are not coherent.

Some of this work is joint with Yuri Bahturin and Efim Zelmanov. (Received August 07, 2015)

1112-16-366 **Xueqing Chen*** (chenx@uww.edu), 800 West Main Street, Whitewater, WI 53190, and **Ming Ding** and **Fan Xu**. *From Hall algebras to cluster algebras.*

In this talk, the constructions of Hall algebras of some orbit triangulated categories via derived Hall algebras for derived categories will be presented and the relations between them will be characterized. As an application, a natural algebra homomorphism from the Ringel-Hall algebra of a hereditary algebra to the corresponding quantum cluster algebra will be provided. This gives alternative proofs of some results recently obtained by Berensein and Rupel. This talk is based on a joint work with Ming Ding and Fan Xu. (Received August 09, 2015)

1112-16-368 **David E Radford*** (radford@uic.edu). *Automorphisms of biproducts.* Preliminary report.

We consider Hopf algebras which are biproducts and explore several notions of automorphism which take into account the additional structure of a biproduct. These notions give rise to subgroups of the full automorphism group. We examine their general structure and discuss the case when both factors of the biproduct are group algebras. Interesting abstract groups arise from our investigation. (Received August 09, 2015)

1112-16-370 **Angel del Rio*** (adelrio@um.es), Departamento de Matematicas, Universidad de Murcia, 30100 Murcia, Murcia, Spain, and **Mariano Serrano** (mariano.serrano@um.es), Departamento de Matematicas, Universidad de Murcia, 30100 Murcia, Murcia, Spain. *How much HeLP can help to describe the torsion units in integral group rings?*

Let G be a finite group and let $V(\mathbb{Z}G)$ denote the group of normalized units in the group ring $\mathbb{Z}G$. Hans Zassenhaus conjectured that every torsion unit of $V(\mathbb{Z}G)$ is conjugate in $\mathbb{Q}G$ to an element of G. This is still an open question which has been verified for nilpotent groups, for cyclic-by-abelian groups and some other families of groups. It has also been verified in a few groups of special type as some symmetric and some projective linear groups of small order.

Marciniak, Ritter, Sehgal and Weiss related Zassenhaus Conjecture with the partial augmentations of the torsion units and Luthar, Passi and Hertweck provided constrains on the partial augmentations of the torsion units. One way to prove Zassenhaus Conjecture consists in showing that the only possible partial augmentations allowed by this constrains are those given in the Marciniak-Ritter-Sehgal-Weiss result. This is the so called the HeLP Method. For example, by results of Hertweck and Margolis one can prove Zassenhaus Conjecture for units of prime power order in $V(\mathbb{Z}G)$, with G a projective special linear group. The aim of this talk is to present the limits of the HeLP Method for projective special linear groups. (Received August 09, 2015)

1112-16-377 **Ellen E. Kirkman*** (kirkman@wfu.edu), Department of Mathematics and Statistics, Wake Forest University, Winston-Salem, NC 27109, and **James J. Kuzmanovich** and **James J. Zhang**. *Dual Reflection Groups.* Preliminary report.

Let k be a field of characteristic zero, and let A be an Artin-Schelter regular k-algebra that is graded by a finite group G. We call G a dual reflection group for A if the identity component A_e of A is also AS regular. We consider necessary conditions on (G, A) for G to be a dual reflection group for A, and we construct some dual reflection groups. We show that the covariant ring, $A^{cov} = A/I$ for $I = ((A_e)_{\geq 1})$, is Frobenius. The Hopf algebra $H = k^G$ associated to a dual reflection group can be regarded as a generalization of a reflection group, since under the action of H on A the invariant subring $A^H = A_e$ is AS regular, providing a generalization of the Shephard-Todd-Chevalley Theorem, where $A = k[x_1, \ldots, x_n]$, G is a reflection group, A^G is a polynomial ring, and $k[x_1, \ldots, x_n]/I$, for $I = (A^G{}_{\geq 1})$, is a complete intersection. (Received August 09, 2015)

1112-16-378 **Daniele Rosso*** (rosso@math.ucr.edu). *Mirabolic quantum* $\mathfrak{sl}_2$.

Beilinson-Lusztig-MacPherson gave a construction of the quantum enveloping algebra $U_q(\mathfrak{sl}_n)$ (and of the q-Schur algebras) as a convolution algebra on the space of pairs of partial n-step flags over a finite field. In this paper we study the associative algebra defined by a convolution product in the mirabolic setting (triples of two partial flags and a vector). In the case $n = 2$ we classify irreducible finite dimensional representations and discuss a mirabolic version of quantum Schur-Weyl duality. (Received August 09, 2015)

1112-16-379 **Zajj B Daugherty*** (zdaugherty@ccny.cuny.edu), Department of Mathematics, The City College of New York, NAC 8/133, New York, NY 10031. *Five occurrences of the affine Hecke algebra of type C.* Preliminary report.

In this talk, we shall endeavor to understand the representation theoretic equivalence between five different algebras: the affine Hecke algebra of type C and its degenerate version, algebras in Schur-Weyl duality with the quantum group and universal enveloping algebra of type $\mathfrak{gl}_n$ on certain tensor spaces, and a graded KLR-like algebra arising geometrically. Likely keywords include braids and diagram algebras, skew shapes and tableaux, intertwiners and weight spaces, and categorification. (Received August 09, 2015)

1112-16-411 **Eric Jespers*** (efjesper@vub.ac.be), Vrije Universiteit Brussel, Department of Mathematics, Pleinlaan 2, 1050 Brussel, Belgium. *Group Ring Groups.*

A survey will be given on the status of the project of describing finitely many generators (of a generic type) of a subgroup of finite index in the unit group of the integral group ring $\mathbb{Z}G$ of a finite group G. This program was initiated by Ritter and Sehgal in 1987 and since then a lot of progress has been made. (Received August 10, 2015)

1112-16-429 **Georgia Benkart*** (benkart@math.wisc.edu), Department of Mathematics, University of Wisconsin-Madison, Madison, WI 53706. *Algebras on the Weyl side.*

This talk will focus on a family of Weyl-like algebras that includes such examples as the Weyl algebra itself, the universal enveloping algebra of the 2-dimensional non-abelian Lie algebra, the Jordan plane that arises in noncommutative geometry, and many others. The aim is to give a uniform approach to the structure, automorphisms, and derivations of these algebras. This is joint work with S. Lopes and M. Ondrus. (Received August 10, 2015)

1112-16-456 **Jonathan D.H. Smith*** (jdhsmith@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011. *Affine triple systems and the Yang-Baxter Equation.* Preliminary report.

The (quantum) Yang-Baxter equation is a condition on automorphisms of tensor squares, corresponding to Type III Reidemeister moves in knot theory and representations of the braid group [1, p.67]. Affine triple systems are perfect matroid designs of rank 4 in which the 3-flats are affine planes of order 3 [2]. This talk will discuss the algebraic methods used to derive solutions of the Yang-Baxter equation from affine triple systems.

[1] V. Chari and A. Pressley, A Guide to Quantum Groups, Cambridge, 1994.

[2] H.P. Young, Affine triple systems and matroid designs, Math. Z. 132 (1973), 343-359. (Received August 10, 2015)

1112-16-488 **Kyu-Hwan Lee*** (khlee@math.uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269-3009, and **Konstantina Christodoulopoulou** (kchristod@ufl.edu), Department of Mathematics, University of Florida, Gainesville, FL 32611-8105. *Representations of spin quiver Hecke algebras for orthosymplectic Lie superalgebras.*

We construct irreducible representations of spin quiver Hecke algebras for orthosymplectic Lie superalgebras $osp(1|2n)$. (Received August 10, 2015)

1112-16-494 **Alex Weekes*** (alex.weekes@gmail.com), Room 6290, 40 St. George Street, Toronto, Ontario M5S 2E4, Canada. *Truncated shifted Yangians.* Preliminary report.

We will give an overview of the on-going study of algebras called "truncated shifted Yangians". These algebras arise as quantizations of slices in the affine Grassmannian, and have strong ties to the representation theory of simple Lie algebras. We will give some results and conjectures about the highest-weight theory of these algebras and links to quiver varieties. (Received August 10, 2015)

1112-16-537 **Leonid Krop*** (leonard.krop@gmail.com). *Recent advances in classification of finite dimensional semisimple Hopf algebras.*

We present a mechanism for classification of isomorphism types of non-trivial (i.e. neither commutative, nor cocommutative) semisimple Hopf algebras H subject to the condition that the group of grouplikes $G(H)$ is abelian of prime index p which is the smallest prime divisor of $|G(H)|$. We apply the theory to classification of Hopf algebras of this kind of dimension p^4 for any prime p. The ground field is algebraically closed of characteristic 0. (Received August 11, 2015)

1112-16-555 **Miodrag C Iovanov*** (miodrag-iovanov@uiowa.edu), IA , and **Gerard D Koffi**, NE.
Deformations of incidence algebras and applications to representation theory.
Cohomology of incidence algebras of posets and singular cohomology of the simplicial realization of the poset have been noticed to be closely related by works of Gerstenhaber, Schack, Cibils, Igusa, Zacharia. Deformations of incidence algebras of more general ordered structures are parametrized by the second cohomology group of the associatef simplicial space. We give intrinsic characterizations of these deformations in algebraic and representation theoretic terms. This approach has applications to algebras of finite representation type: first, given some such finiteness condition for an algebra A, using our results and coalgebra techniques one first proves that that A is such a deformation; then prove the associated space is contractible and obtain that A is an incidence algebra. This recovers, in part, results of Bautista, Gabriel, Router, Salmeron from the 1985 Invent. Math. paper. This is partly joint with G. Koffi. (Received August 11, 2015)

1112-16-558 **Iva Halacheva*** (iva.halacheva@utoronto.ca), **Joel Kamnitzer**, **Leonid Rybnikov** and **Alex Weekes**. *A cactus group action on crystals.* Preliminary report.
Given a complex, finite-dimensional semisimple Lie algebra g, we define a combinatorial action of the cactus group Jg, and in particular the pure cactus group PJg, on any g-crystal corresponding to a highest weight representation V using Schutzenberger involutions. In type A, we show that this action also has a geometric realization in the following way: The moduli space of stable, real, genus zero curves with n marked points indexes a family of maximal commutative (shift of argument) subalgebras in Ug which act on V with simple spectrum. This produces a covering of the moduli space whose monodromy action coincides with that of PJg on the crystal. We conjecture that this is also true in general. Time permitting, I will discuss the connection to another family of algebras, the Gaudin algebras living in the nth tensor product of Ug, using skew-howe duality of crystals. (Received August 11, 2015)

1112-16-565 **Siu-Hung Ng*** (rng@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *On the classification of Hopf algebras of dimension 8p.*
In this talk, we will report the current status of the classification of Hopf algebras of dimension $8p$, where p is an odd prime. In particular, those Hopf algebras with the Chevalley property are completely classified. The talk is based on joint work with M. Beattie, G. Garcìa, and J. Roat. (Received August 11, 2015)

1112-16-610 **Anne V Shepler***, ashepler@unt.edu, and **Sarah Witherspoon**, sjw@math.tamu.edu.
Deformations of group actions in positive characteristic.
Deformations of algebras built from groups acting on polynomial rings include symplectic reflection algebras, Drinfeld orbifold algebras, and graded affine Hecke algebras. A new class of deformation arises in the modular setting, when the characteristic of the underlying field divides the order of the acting group. We use a double complex adapted from Guccione, Guccione, and Valqui to give cohomological conditions for algebraic relations to define graded deformations analogous to those orginially crafted by Lusztig and Drinfeld. (Joint work with Sarah Witherspoon.) (Received August 11, 2015)

1112-16-625 **Christine Uhl*** (christineuhl@my.unt.edu). *Quantum Drinfeld Hecke algebras in low dimension.*
Finite groups act as graded automorphisms on quantum space giving rise to analogs of rational Cherednik algebras and symplectic reflection algebras for quantum/skew polynomial rings. We explore these quantum Drinfeld Hecke algebras in low dimension, including the cases of mystic reflection groups, the infinite family of complex reflection groups, and nonmonomial groups. (Received August 11, 2015)

1112-16-643 **Sarah R. Bockting-Conrad*** (sbocktin@depaul.edu). *Some q-exponential formulas involving the double lowering operator ψ for a tridiagonal pair.* Preliminary report.
Let $\mathbb{K}$ denote an algebraically closed field and let V denote a vector space over $\mathbb{K}$ with finite positive dimension. In this talk, we consider a tridiagonal pair A, A^* on V which has q-Racah type. We will introduce the linear transformations $\psi : V \to V$, $\Delta : V \to V$, and $\mathcal{M} : V \to V$, each of which acts on the split decompositions of V in an attractive way. We will show that Δ can be factored into a q^{-1}-exponential in ψ times a q-exponential in ψ. We view Δ as a transition matrix from the first split decomposition of V to the second. Consequently, we view the q^{-1}-exponential in ψ as a transition matrix from the first split decomposition to a decomposition of V which we interpret as a kind of half-way point. This half-way point turns out to be the eigenspace decomposition of $\mathcal{M}$. We will discuss the eigenspace decomposition of $\mathcal{M}$ and give the actions of various operators on this decomposition. (Received August 11, 2015)

1112-16-646 **David Riley*** (dmriley@uwo.ca), Department of Mathematics, Western University, London, Ontario N6A 5B7, Canada. *Identities of algebras with Hopf algebra actions.*

Let H be a Hopf algebra with a finite basis $\mathcal{B}$, and let A be an algebra with an H-module action. We shall say that the H-action on A is a positive generalized H-algebra action if, for every $h \in H$, there exists $h_{i_1}, h_{i_2} \in H$ such that

$$h \cdot (ab) = \sum (h_{i_1} \cdot a)(h_{i_2} \cdot b),$$

for all $a, b \in A$. Furthermore, we shall say that A is H-rewritable of degree d if, for every $a_1, \ldots, a_d \in A$, there exists scalars $\alpha_{\sigma,b}$ (depending on $a_1, \ldots, a_d$) such that

$$a_1 \cdots a_d = \sum \alpha_{\sigma,b} a_{\sigma(1)}^{b_1} \cdots a_{\sigma(d)}^{b_d},$$

where $1 \neq \sigma \in \mathcal{S}_d$ and $b = (b_1, \ldots, b_d) \in \mathcal{B}^d$. Our goal is to extend various classical PI-theory results by showing that, if an associative algebra A is a positive generalized H-algebra (when viewed as an associative, Lie or Jordan algebra) and A is H-rewritable of degree d, then A satisfies a polynomial identity of $(d, |\mathcal{B}|)$-bounded degree. (Received August 11, 2015)

1112-16-662 **Yevgenia Kashina*** (ykashina@depaul.edu), Department of Mathematical Sciences, DePaul University, Chicago, IL. *On classification of semisimple Hopf algebras of dimension 32.*

In this talk we will first describe up to equivalence all semisimple Hopf algebras of dimension 2^m with a particular group of grouplike elements (the base field is assumed to be algebraically closed of characteristic 0). We will then classify all such Hopf algebras of dimension 32 up to isomorphism. In particular, we will show that all of them have different representation categories. (Received August 11, 2015)

1112-16-678 **Jesse Levitt*** (jlevit3@lsu.edu), 303 Lockett Hall, Baton Rouge, LA 70803, and **Milen Yakimov**. *Connected Hopf Algebras as Deformations of Enveloping Algebras via Drinfeld's Quantization of Triangular R-matrices.*

In 1983 Drinfeld constructed quantizations of all triangular R-matrices. They produce non-cocommutative Hopf algebra structures on completions of universal enveloping algebras. When the quantizations are finite we obtain actual connected Hopf algebras of finite GK-dimension. This has previously unexplored ramifications for the classification problem for Hopf algebras of finite GK-dimension, which has attracted a lot of interest in recent years. Having just advanced to the point where all such Hopf algebras of GK-dimension 4 were able to be classified by Wang, Zhang and Zhuang. We describe necessary and sufficient conditions for deformed universal enveloping algebras such as those arising from this construction to be connected Hopf Algebras and show how previous classifications follow from the Drinfeld construction. (Received August 11, 2015)

17 ► Nonassociative rings and algebras

1112-17-46 **Alper Bulut*** (alper.bulut@aum.edu.kw), Egaila. *K-loops arising as transversal loops from real reductive Lie groups.*

A left Bol loop satisfying the automorphic inverse property is called a K-loop. Many examples and theoretical developments have been accomplished after Ungar's famous example in 1998. He showed that Einstein's velocity addition binary operation over the set of relativistically admissible velocities form a K-loop. Kreuzer and Wefelscheid pioneered an abstract way to construct a K-loop from group transversals. Kiechle used this method to investigate many K-loop structures derived from classical groups over ordered fields. In this talk we follow Kreuzer and Wefeslcheid's method to generalize Kiechle's result to linear reductive connected Lie groups via Cartan decomposition theorem, and carry some of his work from finite dimensional settings to infinite dimensional cases. (Received July 05, 2015)

1112-17-98 **Elena Zizioli*** (elena.zizioli@unibs.it) and **Stefano Pasotti**. *Slid extension of loops.*

Let P be a nonempty set and $\Gamma \subseteq$ Sym P be a regular permutation set acting on P. It is well known that, upon fixing $o \in P$, we can associate to (P, Γ, o) a loop $(P, +)$ and conversely to any loop we can associate a suitable regular permutation set. The detailed study of the relationships between these structures is used here for building a new loop $(L, \oplus)$ starting from the loops $(K, +)$, equipped with a well ordering "$\preceq$", $(P, \widehat{+})$ and assuming that a further loop operation "+" (which may also coincide with "$\widehat{+}$") is defined on P.

We call the loop $(L, \oplus)$ *slid extension* of P by K. We study the dependence of the properties of the new loop $(L, \oplus)$ on the corresponding properties of the initial ones (associativity, automorphic inverse properties, Bol and Moufang conditions) and characterize the nuclei of $(L, \oplus)$. Most of the results presented here appeared in [1].

This procedure can provide examples of proper loops also when the initial loops are groups.

References

[1] Pasotti, S. and E. Zizioli, *Slid product of loops: a generalization*, Res. Math. **65** (2014), pp. 193-212.

(Received July 23, 2015)

1112-17-128 **Gregory G. Simon*** (ggsimon@umich.edu). *Automorphism-invariant integral forms in Griess algebras.* Preliminary report.

Motivated by the existence of monster-invariant integral forms in the moonshine module VOA, I will present a study of automorphism-invariant integral forms in some small-dimensional Griess algebras, which are certain finite-dimensional commutative, nonassociative algebras generated by idempotents. An 'integral form' of a rational algebra is the integer span of a basis of the algebra that is closed under the algebra product. I will present methods that can be used to find and classify the maximal automorphism-invariant integral forms in a rational algebra. Each of the Griess algebras we have analyzed — the eight dihedral Griess algebras and three others — have unique maximal automorphism-invariant integral forms.

This research has been undertaken as a part of the Ph.D. program at the University of Michigan under the guidance of Robert L. Griess, Jr. (Received July 27, 2015)

1112-17-166 **Stefano Pasotti*** (stefano.pasotti@unibs.it) and **Elena Zizioli** (elena.zizioli@unibs.it). *Loops from a graph point of view.*

Over the last years several authors studied the correspondence between geometric structures, loops and regular permutation sets. These relationships were first introduced by H. Karzel and H. Wefelscheid in order to associate to the point-set of a general hyperbolic geometry over a Euclidean field the algebraic structure of a *Bruck loop* (or *K-loop*) and use it for a "coordinatization" of the geometry.

This research is placed in the line of investigations aiming at employing geometric structures and the related insight in order to build up loops and to study their algebraic properties. We present a generalization, introduced in [1], of the idea of describing loops by means of graphs: we show how to relate a loop to suitable *edge-colouring of complete directed graphs*, we find conditions characterizing graphs giving rise to the same loop, to isomorphic and to isotopic loops and we describe loop automorphisms in terms of graph automorphisms permuting the colouring.

References

[1] Stefano Pasotti and Elena Zizioli, *Loops, regular permutation sets and colourings of directed graphs*, J. Geom. **106** (2015), 35–45.

(Received July 31, 2015)

1112-17-190 **Tevian Dray*** (tevian@math.oregonstate.edu), Department of Mathematics, Oregon State Uinversity, Corvallis, OR 97331, **John Huerta** (jhuerta@math.ist.utl.pt), Centro de Análise Matemática, Geometria e Sistemas Dinâmicos, Instituto Superior Técnico, Lisboa, Portugal, and **Joshua Kincaid** (kincajos@onid.orst.edu), Department of Physics, Oregon State University, Corvallis, OR 97331. *The 2×2 magic square of Lie groups.*

The Freudenthal–Tits magic square yields a description of certain real forms of the exceptional Lie algebras in terms of a pair of division algebras. The first two rows are well understood geometrically, with the minimal representations of F_4 and E_6 expressed in terms of the Albert algebra. In the third row, the minimal representation of E_7 consists of "Freudenthal towers", essentially a pair of Albert algebra elements. The fourth row contains E_8, whose minimal representation is the adjoint representation, and whose geometric interpretation remains unclear.

The Lie algebras in the Freudenthal–Tits magic square admit natural representations involving 3×3 matrices. Barton and Sudbery introduced the analogous "2×2" magic square, which contains no exceptional Lie algebras, but nonetheless serves as a useful arena for exploring the full "3×3" magic square.

We present here a unified treatment of the 2×2 magic square at the group level, providing a unified matrix description of the corresponding orthogonal groups, as well as an explicit construction of the corresponding Clifford algebras. We then discuss possible applications of our construction to the Freudenthal–Tits magic square, and thus to the exceptional Lie groups. (Received August 03, 2015)

1112-17-363 **Denis Bashkirov** (bashk003@umn.edu), School of Mathematics, 206 Church St SE, Minneapolis, MN 55455-0488, and **Alexander A. Voronov*** (voronov@umn.edu), School of Mathematics, 206 Church St SE, Minneapolis, MN 55455-0488. *r_∞-Matrices, Triangular L_∞-Bialgebras and Quantum$_\infty$ Groups.*

A homotopy analogue of the notion of a triangular Lie bialgebra is proposed with a goal of extending basic notions of the theory of quantum groups to the context of homotopy algebras and, in particular, introducing a homotopical generalization of the notion of a quantum group, a quantum$_\infty$ group. (Received August 09, 2015)

1112-17-392 **Vincent E. Coll*** (vec208@lehigh.edu), Lehigh University, Department of Mathematics, 14 E. Packer Avenue, Bethlehem, PA 18015, and **Murray Gerstenhaber** (mgersten@math.upenn.edu), University of Pennsylvania, Department of Mathematics, 209 South 33rd Street, Philadelphia, 19184. *Cohomology of Lie Poset Algebras.* Preliminary report.

Classic results of Gerstenhaber and Schack elegantly established that simplicial cohomology is a special case of algebraic cohomology. That is, associated to each triangulable space, there is an associative matrix algebra whose algebraic cohomology is the same as the simplicial cohomology of the original space. These matrix algebras are also Lie algebras and therefore have a Lie algebra cohomology which controls their deformations – as Lie algebras. We find that the latter cohomology is also essentially simplicial and that the deformation theory of these Lie poset algebras is analogous to that of complex analytic manifolds for which it is a small model. (Received August 09, 2015)

1112-17-579 **John Claxton**, **Ben Salisbury**, **Adam Schultze** and **Peter Tingley*** (ptingley@luc.edu). *Crystal combinatorics from PBW bases.*

We re-examine Lusztig's algebraic construction of canonical bases, showing how it gives an alternative way to approach Kashiwara's crystals in finite type. This is in a sense well known, since it is known that canonical bases and global crystal bases coincide, but we feel it has not been fully explored. For instance, we show how, in type A, the familiar Young-tableaux combinatorics can be derived using only Lusztig's piecewise linear functions relating different PBW bases. This same approach works in other types, giving new combinatorics. Those parts of this work which are not due to Lusztig are joint with John Claxton, Ben Salisbury and Adam Schultze. (Received August 11, 2015)

1112-17-593 **Alberto Elduque** and **Mikhail Kochetov*** (mikhail@mun.ca), Department of Mathematics and Statistics, Memorial University, St. John's, NL A1C5S7, Canada. *Graded modules over simple Lie algebras with a group grading.*

In the past two decades there has been a considerable interest in describing all possible gradings by abelian groups on finite-dimensional simple Lie algebras over an algebraically closed field. In characteristic zero, the classification is essentially complete. We will discuss some recent results regarding the classification of G-gradings on finite-dimensional modules over a (semi)simple Lie algebra L equipped with a grading by an abelian group G. (Received August 11, 2015)

18 ► Category theory; homological algebra

1112-18-11 **Adnan H Abdulwahid*** (adnan-al-khafaji@uiowa.edu), Department of Mathematics 14 MacLean Hall, Iowa City, IA 52242, and **Miodrag C Iovanov** (miodrag-iovanov@uiowa.edu), Department of Mathematics 14 MacLean Hall, Iowa City, IA 52242. *Generators for Comonoids and Universal Constructions.*

Let A be an arbitrary ring with 1. Let V be an (A, A)-bimodule. The question is does V have an A-cofree coring? Agore, A. L. mentioned this question in [1] as an open problem. My advisor and I showed that the A-cofree coring exists over an arbitrary (A, A)-bimodule V. More interestingly, we concretely construct that A-cofree coring, and used that construction to get a transparent picture for certain monoidal categories.

Let H be a bialgebra (or a Hopf algebra), and let M^H and ${}_HM$ be the left H-comodules and the right H-comodules categories, respectively. We used the construction of cofree corings that we got in our work to investigate existence and construction of cofree coalgebras in $Coalg(M^H)$ and $Coalg({}_HM)$, the category of coalgebras in M^H and ${}_HM$, respectively..

References

[1] A.L. Agore. *Limits of Coalgebras, Bialgebras and Hopf Algebras*, Proc. Amer. Math. Soc. 139, 855-863, 2011.

(Received April 20, 2015)

1112-18-14 **Vasily A. Dolgushev*** (vald@temple.edu), Department of Mathematics, Temple University, 1805 N. Broad St. Wachman Hall, Rm. 638, Philadelphia, PA 19122, and **Alexander E. Hoffnung** and **Christopher L. Rogers**. *What do homotopy algebras form?*

Homotopy algebras and their generalizations appear in constructions of string topology, in rational homotopy theory, symplectic topology, deformation quantization, and quantum field theory. In this talk, I will show that homotopy algebras of a fixed type form a category enriched over L_∞-algebras. I will also show that this enrichment gives us a higher categorical structure which stands behind the homotopy theory of homotopy algebras. This work is motivated by D. Tamarkin's answer to V. Drinfeld's question "What do dg categories form?" and by papers of A. Berglund, V. Dotsenko, E. Getzler, V. Hinich, A. Lazarev, and N. Poncin. This talk is based on paper arXiv:1406.1751. (Received May 14, 2015)

1112-18-160 **Cris Negron*** (negron@uw.edu). *Twisting Cochains and Hochschild Cohomology.*

Given a Koszul algebra A, there is a canonical dg algebra structure on the tensor product $A^! \otimes A$ so that the Hochschild cohomology ring of A is given as the cohomology $H^\bullet(A^! \otimes A)$, where $A^!$ is the Koszul dual of A. This result is a specific occurrence of a general phenomenon. Namely, given any "acyclic twisting cochain" $\pi : C \to A$ from a dg coalgebra C to a dg algebra A, we get an identification of graded rings between the Hochschild cohomology $HH^\bullet(A)$ and the cohomology of the "twisted hom complex" $\mathrm{Hom}^\pi(C, A)$. Examples of twisting cochains arise in topology (e.g. K.–T. Chen's twisting cochains for loop space homology) and ring theory (e.g. the canonical twisting cochain associated to a Koszul algebra). In this talk I will recall the definition of a twisting cochain and explain a bit about the aforementioned general result and its specific application to Koszul algebras. (Received July 30, 2015)

1112-18-332 **Christopher L Rogers*** (chris.rogers@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, 217 Maxim Doucet Hall P.O. Box 43568, Lafayette, LA 70506. *What do homotopy algebras form?*

In this talk, I will describe joint work with V. Dolgushev in which we use ideas from deformation theory to construct an enriched category whose objects are homotopy algebras of a fixed type, e.g., L_∞, A_∞, or Ger_∞ algebras. The enrichment is over a certain symmetric monoidal category of L_∞-algebras. Roughly, this is a "non-abelian" analogue of the fact that chain complexes are enriched over themselves. From this L_∞-enriched category, we obtain a simplicial category by using a non-abelian analogue of the Dold-Kan functor. We show that the mapping spaces in this simplicial category are, in fact, Kan complexes, and that this construction produces an explicit model for the ∞-category of homotopy algebras. (Received August 07, 2015)

1112-18-391 **Michael Brown**, **Claudia Miller*** (clamille@syr.edu), **Peder Thompson** and **Mark Walker**. *Adams operations for matrix factorizations and a conjecture of H. Dao.*

Using an idea of Atiyah from 1966, we develop Adams operations on the Grothendieck groups of perfect complexes with support and of matrix factorizations using cyclic group actions on tensors powers. In the former setting, Gillet and Soule developed these using the Dold-Kan correspondence and used them to solve Serre's Vanishing Conjecture in mixed characteristic (also proved independently by P. Roberts using localized Chern characters). Their approach cannot be used in the setting of matrix factorizations, so we use Atiyah's approach. In addition, for their p-th operation they require p! to be invertible in the ground ring, whereas the cyclic approach only requires p to be invertible, which is more conducive to proofs in mixed characteristic. Lastly, the cyclic approach gives inherently simpler operations as it avoids the messy simplicialization step.

As an application, we prove a conjecture of H. Dao on the vanishing of Hochster's theta function for pairs of modules over an isolated hypersurface singularity in the remaining open case of mixed characteristic. Our proof is analogous to that of Gillet and Soule for the vanishing of Serre's intersection multiplicity. (Received August 09, 2015)

1112-18-564 **John D. Wiltshire-Gordon*** (johnwg@umich.edu), Department of Mathematics, University of Michigan, 530 Church Street, Ann Arbor, MI 48109. *Representation theory of combinatorial categories.*

Given an interesting sequence of objects X_0, X_1, X_2, ... , it's fun to ponder: is that subscript just a natural number, or is it hiding deeper structure? Maybe these objects ought to be indexed by finite sets, or finite dimensional vector spaces, or finite total orders, or whatever makes sense. The point is, a map relating two of the indexing gadgets should induce a map on the objects themselves. We use this method of argument to give new results on the cohomology of configuration spaces. Next, we give a characterization of indexing categories wherein finitely generated representations are finite length. Finally, we show how computations with these

representations can be made effective. Part of this talk is joint work with Jordan Ellenberg. (Received August 11, 2015)

1112-18-581 **Alexander P. Ellis***, Mathematics Department, University of Oregon, Eugene, OR 97403, and **You Qi**. *The differential graded odd nilHecke algebra.*

We equip the odd nilHecke algebra and its associated thick calculus category with diagrammatically local differentials. The resulting differential graded Grothendieck groups are isomorphic to two different forms of the positive part of quantum sl(2) at a fourth root of unity. (Received August 11, 2015)

19 ► K-theory

1112-19-239 **Ronghui Ji*** (ronji@math.iupui.edu), Department of Mathematical Sciences, IUPUI, 402 N. Blackford Street, Indianapolis, IN 46202-3216, and **Crichton Ogle** and **Bobby Ramsey**. *The ℓ^1-Strong Bass Conjecture for semi-hyperbolic groups.*

Using rapid decay algebras over a discrete group G and cyclic cohomology theory, we prove that the ell^1-strengthened Bass Conjecture for topological K-theory of the $ell^1(G)$ is true for a large class of discrete groups. (Received August 05, 2015)

20 ► Group theory and generalizations

1112-20-40 **Luis Valero-Elizondo*** (lvalero898@gmail.com), Edificio Alfa, Ciudad Universitaria, 58030 Morelia, Mich, Mexico, and **Alberto Gerardo Raggi-Cárdenas**. *Global representation rings.*

In this talk we combine the concepts of Burnside ring and character ring in what we call the global representation ring of a finite group. We compute all ring homomorphisms from this ring to the complex numbers, we compute its spectrum, its connected components, and determine the primitive idempotents. (Received June 30, 2015)

1112-20-119 **Harvey Blau** (hblau@niu.edu), Department of Mathematical Sciences, Northern Illinois University, DeKalb, IL 60115, **Gang Chen*** (chengangmath@mail.ccnu.edu.cn), School of Mathematics and Statistics, Central China Normal University, Wuhan, Hubei 430079, Peoples Rep of China, and **Rulin Shen** (shenrulin@hotmail.com), Department of Mathematics, Hubei University for Nationalities, Enshi, Hubei 445000, Peoples Rep of China. *Two Class of Finite Nilpotent Groups and Related Table Algebras.*

In this talk, we will discuss two classes of finite nilpotent groups,which can be seen as generalizations of finite nilpotent groups of nilpotence length two.Table algebras related to one class of such finite groups will also be considered. (Received July 26, 2015)

1112-20-125 **Alfred W. Hales*** (hales@ccrwest.org), 4320 Westerra Court, San Diego, CA 92121. *Group Rings, Jordan Decomposition and Don Passman.*

Let G be a finite group and x an element of the rational group ring QG. Then x can be written (uniquely) in the form s + n where s is semisimple, n is nilpotent, and s,n commute. Suppose x is integral, i.e. lies in ZG. When can we be sure that these Jordan components s and n must also be integral?

This seemingly innocent question, and its multiplicative counterpart, have spawned a number of papers over several decades. The work has involved three generations of mathematicians from three different countries, and Don's role in all of this has been critical - and in one aspect unexpected even to him. We will outline this fascinating story, and provide background for the later talk by Don's student Chia-Hsin Liu. (Received July 27, 2015)

1112-20-141 **Jane Gilman*** (gilman@rutgers.edu). *Nielsen Transformations and Primitive curve Lengths on Pairs of Pants.*

The fundamental group of a pair of pants is a free group of rank two. A closed geodesic on a pair of pants is a principal primitive if it, together with one other such geodesic, generates the fundamental group. Every such primitive is the image of a simple curve under a series of Nielsen transformations. Its essential self-intersections are those self-intersections that occur along a seam of the pair of pants. The conjugacy class of the primitive is determined by a rational number r with a continued fraction expansion whose entries give a formula for the number of essential self-intersections and are computed using the Non-Euclidean Euclidean algorithm.

A number of length inequalities are obtained including upper and lower bounds on the hyperbolic length of any such primitive in terms of the essential self-intersection numbers, variants on the upper and lower bounds for the translation length of any such primitive using the entries in the continued expansion and the translation length of the shortest curves (which the discreteness algorithm always finds) and the longest seam length is expressed as a limit involving the entries in the continued fraction r and hyperbolic distance.
(Received August 02, 2015)

1112-20-162 **Ewa Tyszkowska*** (ewa.tyszkowska@mat.ug.edu.pl), Gdańsk, Poland. *On (q,n)-gonal pseudo-real Riemann surfaces.*

The moduli space $\mathbb{M}_g$ of complex algebraic curves of genus g is a quasi-projective variety which can be defined in $\mathbb{P}^n(\mathbb{C})$ by polynomials with rational coefficients. There is an antiholomorphic involution $\iota : \mathbb{M}_g \to \mathbb{M}_g$ which maps the class of a complex curve to its conjugate. The fixed points of such a mapping are called *complex algebraic curves with real moduli.* The corresponding to them Riemann surfaces split into symmetric and pseudo-real. Symmetric surfaces admit an antiholomorphic involution (a symmetry) while pseudo-real have an antiholomorphic automorphism but no symmetry. A Riemann surface X is called (q, n)-gonal if it admits a conformal automorphism ρ of prime order n such that the orbit space $X/\langle\rho\rangle$ has genus g. We determine the possible orders of antiholomorphic automorphisms of a pseudo-real Riemann surface of a given genus g. We find the necessary and sufficient conditions for the existence of a (q, n)-gonal automorphism of such a surface. In particular, we determine all possible values of p for which there exists a p-hyperelliptic involution of a pseudo-real Riemann surface of a given genus g. (Received July 31, 2015)

1112-20-203 **Nathaniel Thiem*** (nathaniel.thiem@colorado.edu), Boulder, CO 80304. *Representation theoretic Hopf structures on transportation polytopes.* Preliminary report.

Supercharacter theories have given us new ways to find the representation theory underlying Hopf structures. One of the most striking examples is the Hopf algebra of symmetric functions in noncommuting variables arising from a Hopf monoid in the representation theory of unipotent groups. In this case, we obtain Hopf structures built on set partitions. It turns out that set partitions may be viewed as integer lattice points contained in a family of tranportation polytopes. This talk describes a supercharacter theory for a family of groups that is built on the lattice points of arbitrary transportation polytopes giving rise to a corresponding set of Hopf structures.
(Received August 04, 2015)

1112-20-237 **Christopher P. French*** (frenchc@grinnell.edu), Noyce Science Center, Grinnell College, 1116 8th Ave, Grinnell, IA 50112. *Realizing hypergroups as association schemes.*

A hypergroup is an algebraic structure which arises from an association scheme by considering only the relations and their products. Thus, a hypergroup is to an association scheme what an abstract group is to a thin scheme. However, while all abstract groups can trivially be obtained by forgetting the points of a thin scheme, this is not the case for hypergroups. It is natural to seek a way to characterize those hypergroups which arise from association schemes, finite or infinite. As a case study, we consider noncommutative hypergroups of rank four.
(Received August 05, 2015)

1112-20-252 **Tullia Dymarz** and **Xiangdong Xie***, xiex@bgsu.edu. *Quasiisometric rigidity of some solvable Lie groups.*

We prove the quasiisometric rigidity for some simply connected solvable Lie groups S: if a simply connected solvable Lie group S' is quasiisometric to S, then S and S' are isomorphic. Examples of such solvable Lie groups include $S = F^n \rtimes \mathbb{R}$ with $n \geq 3$, where F^n is the n-th model filiform group and $\mathbb{R}$ acts on F^n by the standard Carnot dilations.

This is a joint work with Tullia Dymarz. (Received August 05, 2015)

1112-20-266 **Jonathan D.H. Smith*** (jdhsmith@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011. *Engel groups and Bruck loops.*

A classical construction associates a Bruck loop with a Moufang or Bol loop on which the squaring map is a permutation. That construction is now extended to a quadratically closed Bol loop or group (where the squaring operation is surjective) that satisfies the 2-Engel condition (for groups: elements commute with their conjugates). The Bruck loop is built on a space of sequences of elements from the original Bol loop.

One application of this work offers a new setting for complex reflections and midpoints on the unit circle, and the Riemann surface of the square root function. (Received August 06, 2015)

1112-20-279 **George Glauberman*** (gg@math.uchicago.edu). *Symmetric groups and fixed points on modules: an application of group theory to topology.*

Let p be a prime. To every finite group is associated a topological space known as the p-completion of its classifying space. The Martino-Priddy conjecture states that for two groups G and H, these spaces are homotopy equivalent if and only if there is a special type of isomorphism between the Sylow p-subgroups of G and H (an isomorphism of fusion systems, e.g., elements conjugate in G are mapped to elements conjugate in H). J. Martino and S. Priddy proved the "only if" part in 1996. B. Oliver proved the converse for odd p in 2004 and $p = 2$ in 2006. In 2013, A. Chermak proved a strong generalization of the conjecture and Oliver proved an extension of Chermak's result. Each of these four proofs relied partly on assuming the classification of finite simple groups. Recently, J. Lynd and I removed this assumption. One key step was to extend an old result about fixed points of a group G of characteristic p for p odd to the case when $p = 2$, except when G is a direct product of symmetric groups. We plan to discuss this step. (Received August 06, 2015)

1112-20-358 **David Carroll** (carroll@math.tamu.edu) and **Andrew Penland*** (adpenland@email.wcu.edu). *Periodic points on shifts of finite type and commensurability invariants of groups.*

We explore the relationship between subgroups and the possible shifts of finite type (SFTs) which can be defined on a group. In particular, we investigate two group invariants, weak periodicity and strong periodicity, defined via symbolic dynamics on the group. We show that these properties are invariants of commensurability. Thus, many known results about periodic points in SFTs defined over groups are actually results about entire commensurability classes. Additionally, we show that the property of being not strongly periodic (i.e. the property of having a weakly aperiodic SFT) is preserved under extensions with finitely generated kernels. We conclude by raising questions and conjectures about the relationship of these invariants to the geometric notions of quasi-isometry and growth. (Received August 08, 2015)

1112-20-376 **Petr Vojtěchovský*** (petr@math.du.edu), University of Denver, Department of Mathematics, 2280 S Vine St, Denver, CO 80208. *Bol loops and Bruck loops of order pq.* Preliminary report.

Bruck loops (also known as K-loops or gyrocommutative gyrogroups) capture algebraic properties of Einstein velocity addition. We present recent results on the classification of Bruck loops of order pq and, more generally, on Bol loops of order pq. Most proofs are based on group-theoretical considerations in transitive groups. This is joint work with M. Kinyon and G. Nagy. (Received August 09, 2015)

1112-20-396 **Peter Plaumann***, peter.plaumann@yahoo.com. *Computational problems in Steiner loops* Preliminary report.

The fact that all elements different from 1 of a Steiner loop have order 2 makes it attractive to apply formal grammars on computational problems in this variety.

In my talk some aspects of this approach will be discussed.
(Received August 09, 2015)

1112-20-403 **Timothy D. Ferdinands*** (ferdinands_t@mercer.edu), Department of Mathematics, Mercer University, 1400 Coleman Ave., Macon, GA 31207. *Groupoids with root systems that resmble Coxeter groups.* Preliminary report.

The study of root systems attached to groupoids that resemble Coxeter groups has seen many recent developments. Brink and Howlett introduce one such notion such groupoids in their study of normalizers of parabolic subgroupoids of Coxeter groups in 1999. We discuss these groupoids and their associated root systems, focusing in particular on instances of these where the root system may be realized in a real vector space.

The strongest results we obtain hold when the Coxeter group is finite. In this case we give an correspondence between a realization of the universal covering of the Brink-Howlett groupoid in a real vector space and a simplicial hyperplane arrangement in that vector space. We discuss these results in the framework of (Received August 09, 2015)

1112-20-413 **Kate Juschenko*** (kate.juschenko@gmail.com), 2033 Sheridan Rd, Evanston, IL 60208. *Techniques and concepts of amenability of discrete groups.*

The subject of amenability essentially begins in 1900's with Lebesgue. He asked whether the properties of his integral are really fundamental and follow from more familiar integral axioms. This led to the study of positive, finitely additive and translation invariant measure on reals as well as on other spaces. In particular the study of isometry-invariant measure led to the Banach-Tarski decomposition theorem in 1924. The class of amenable groups was introduced by von Neumann in 1929, who explained why the paradox appeared only in dimensions

greater or equal to three, and does not happen when we would like to decompose the two-dimensional ball. In 1940's, M. Day defined a class of elementary amenable groups as the largest class of groups amenability of which was known to von Naumann. We will give a current state of the subject of non-elementary amenable groups. (Received August 10, 2015)

1112-20-421 **Jessica Fintzen*** (fintzen@math.harvard.edu). *Stable vectors in the Moy-Prasad filtration.*

Reeder and Yu gave recently a new construction of certain supercuspidal representations of p-adic reductive groups (called epipelagic representations). Their construction relies on the existence of stable vectors in the first Moy-Prasad filtration quotient under the action of a reductive quotient. We will explain these ingredients and present a theorem about the existence of such stable vectors for all primes p. This builds on a result of Reeder and Yu about the existence of stable vectors for large primes.

The above work forms part of a joint research project with Beth Romano. (Received August 10, 2015)

1112-20-434 **Paul-Hermann Zieschang*** (zieschang@utb.edu), West University Dr., Edinburg, TX 78539-299. *Hypergroups of cardinality six.* Preliminary report.

Let S be a set, and let μ be a map from $S \times S$ to the power set of S. For any two elements p and q of S, we write pq instead of $\mu(p, q)$ and assume that pq is not empty.

For any two non-empty subsets P and Q of S, we define the *complex product* PQ to be the union of the sets pq with $p \in P$ and $q \in Q$. If one of the two factors in a complex product consists of a single element s, we write s instead of $\{s\}$ in that product.

Following (and generalizing) Frédéric Marty's terminology we call S a *hypergroup* (with respect to μ) if the following three conditions hold.

1. For any three elements p, q, and r in S, we have $p(qr) = (pq)r$.

2. The set S contains an element e such that $se = \{s\}$ for each element s in S.

3. For each element s in S, there exists an element s^* in S such that $p \in rq^*$ and $q \in p^*r$ for any three elements p, q, and r in S satisfying $r \in pq$.

We give an overview of hypergroups with six elements containing a closed subset with two elements. (Received August 10, 2015)

1112-20-475 **Yair Hartman*** (yairhartman@gmail.com). *Invariant Random Subgroups and the Furstenberg Entropy of stationary actions.*

We will discuss Invariant Random Subgroups (IRS) and introduce a new tool to construct them. This construction is useful to describe the possible values can be realized as the Furstenberg entropies of stationary actions for certain random walks on amenable groups. Joint work with Ariel Yadin (Received August 10, 2015)

1112-20-477 **Harvey I. Blau*** (hblau@niu.edu), Department of Mathematical Sciences, Northern Illinois University, DeKalb, IL 60115. *Control of Fusion in Table Algebras.* Preliminary report.

There is a deep and well-known theory of fusion (conjugation) of subsets of a finite group, with respect to certain subgroups associated with a fixed prime p. We investigate the extent to which some aspects of this theory generalize to p-valenced standard integral table algebras, and in particular to adjacency algebras of p-valenced association schemes. (Received August 10, 2015)

1112-20-492 **David Bruce Cohen***, Dept. of Mathematics, University of Chicago, 5734 S University Avenue, Chicago, IL 60637. *Strongly aperiodic SFTs on surface groups.* Preliminary report.

We describe the construction (joint with Goodman-Strauss) of a strongly aperiodic subshift of finite type on the fundamental group of a higher genus surface. (Received August 10, 2015)

1112-20-496 **Adam M. Jacoby*** (tud55064@temple.edu), 819 North Franklin street, 2F, Philadelphia, PA 19123. *Frobenius divisibility for Hopf algebras.* Preliminary report.

The terminology "Frobenius divisibility", motivated by Frobenius' Theorem on finite complex group representations, is now used in connection with similar divisibility results for the degrees of irreducible representations of other algebraic structures. For semisimple Hopf algebras there are many conjectures and theorems of this type, notably Kaplansky's sixth conjecture and the so-called class equation. Finite dimensional Hopf algebras are known to have the structure of a Frobenius algebra in a way that is deeply intertwined with their Hopf structure. This talk will discuss a unified approach to the majority of known Frobenius divisibility results for Hopf algebras that is based on integrality properties of the Casimir element of the underlying Frobenius structure. (Received August 10, 2015)

1112-20-501 **Silvia Pianta*** (pianta@dmf.unicatt.it), Dipartimento di Matematica e Fisica, Università Cattolica, Via Trieste, 17, 25133 Brescia, Italy, **Stefano Pasotti**, DICATAM-Sez. di Matematica, Università degli Studi di Brescia, Via Branze, 43, 25123 Brescia, Italy, and **Elena Zizioli**, DICATAM-Sez. di Matematica, Università degli Studi di Brescia, Via Branze, 43, 25123 Brescia, Italy. *Geometric construction for loops.* Preliminary report.

We exploit a technique related to *transversals and sections of groups* to build loops and study their properties. Here the group is $\mathrm{PGL}_2(\mathbf{K})$, or its subgroup $\mathrm{PSL}_2(\mathbf{K})$, embedded in the projective space $\mathrm{PG}(3,\mathbf{K})$ without a ruled quadric $\mathcal{Q}$. If $\mathbf{K}$ is a Euclidean field we take a subgroup $\mathcal{D}$ of elliptic projectivities in $\mathrm{PSL}_2(\mathbf{K})$ and characterize loops arising from plane transversals and from the tangent semicone to $\mathcal{Q}$ through the point 1 ([1]). In the finite case we consider, both for $\mathrm{PGL}_2(q)$ and for $\mathrm{PSL}_2(q)$, q odd, different types of subgroups $\mathcal{D}$ and transversals either geometrically or algebraically well characterized.

References

[1] Stefano Pasotti, Silvia Pianta, and Elena Zizioli, *A geometric environment for building up loops*, Results Math. (2015), To appear.

(Received August 10, 2015)

1112-20-516 **Kenneth W Johnson*** (kwj1@psu.edu), Penn State Abington, 1600 Woodland Road, Abington, PA 18901. *Fission of S-rings and association schemes.* Preliminary report.

For a finite group G the class algebra is a basic object, and if a random walk on G is associated to a probability $p : G \to [0, 1]$ the analysis of the walk is easier if p is constant on conjugacy classes. However, some recent work has shown that "fissions" of the class algebra may be produced which remain commutative. An upper bound for the size of such a fission is the degree of the total character of G. If a probability p is constant on the fissioned classes the associated random walk remains easier to handle. A general question in this direction is: Given any (commutative) association scheme, find a maximal fission of the scheme which remains commutative. I will discuss two cases.

(1) G acts on a set and contains a regular subgroup H. This gives rise to an S-ring over H. In the case where (G, H) is a Gelfand pair this S-ring is commutative.

For example G could be the symmetry group of a regular solid (random walk on an n-cube etc).

(2) Consider a loop Q and let G be its mapping group (the group generated by the left and right translations). The centralizer ring of the action of G on Q is necessarily commutative and may be regarded as an S-ring on H. ll be given of commutative fissions in the above cases. (Received August 10, 2015)

1112-20-544 **J. D. Phillips*** (jophilli@nmu.edu), 1401 Presque Isle, Marquette, MI 49855. *Commutant elements in Bol loops.* Preliminary report.

We investigate the commingling of assocaitivity and commutativity (explicitly, the behavior of commutant elements) in Bol loops. (Received August 11, 2015)

1112-20-562 **Clifton E Ealy Jr.*** (clifton.e.ealy@wmich.edu), Department of Mathematics, Western Michigan University, Kalamazoo, MI 49008-4852. *Some examples of profinite loops and K-loops and some remarks on neardomains and nearfields.* Preliminary report.

In this mainly expository talk, I will discuss some examples of profinite loops and K-loops. Also, I will briefly survey nearfields and neardomains following the paper of E. Rips, Y. Segev, and K. Tent: "A sharply 2-transitive group without a non-trivial abelian subgroup". (Received August 11, 2015)

1112-20-614 **Caglar Uyanik***, cuyanik2@illinois.edu. *Dynamics of free group automorphisms.* Preliminary report.

We will discuss various free group analogs of pseudo-Anosov homeomorphisms of hyperbolic surfaces. We will focus mostly on dynamics of their actions and deduce several structural results about subgroups of $Out(F_N)$. Part of this talk is based on joint work with Martin Lustig and Matt Clay. (Received August 11, 2015)

1112-20-623 **Carolyn R. Abbott*** (abbott@math.wisc.edu). *Not all acylindrically hyperbolic groups have universal acylindrical actions.*

The class of acylindrically hyperbolic groups, which are groups that admit a certain type of non-elementary action on a hyperbolic space, contains many interesting groups such as non-exceptional mapping class groups and $\mathrm{Out}(\mathbb{F}_n)$ for $n \geq 2$. In such a group, a generalized loxodromic element is one that is loxodromic for some acylindrical action of the group on a hyperbolic space. Osin asks whether every finitely generated acylindrically hyperbolic group has an acylindrical action on a hyperbolic space for which all generalized loxodromic elements are loxodromic. In this talk, I will answer this question in the negative, using Dunwoody's example of an inaccessible group as a counterexample. (Received August 11, 2015)

1112-20-637 **Jonathan I Hall***, Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48824. *Solvable Moufang loops.*

The general topic is the relationship between the normal structures of a Moufang loop and of its triality and multiplication groups. In particular, a Moufang loop with solvable multiplication group is itself solvable (in the sense of Bruck). For finite Moufang loops, this is a special case of Vesanen's 1996 result. For finite solvable Moufang loops we also have the converse to Vesanan's result: their triality and multiplication groups are always solvable. (Received August 11, 2015)

22 ► Topological groups, Lie groups

1112-22-187 **Kwangho Choiy*** (kchoiy@gmail.com), 1245 Lincoln Drive, Mail Code 4408, Carbondale, IL 62901. *On Multiplicity in Restriction for $SL(m, D)$.*

The multiplicity of an irreducible representation, when restricted to a closed subgroup containing the derived group, extracts arithmetic properties from the given representation. In this talk, we shall focus on the case of discrete series representations of $GL(m, D)$ when restricted to $SL(m, D)$, where D is a central division algebra of dimension d^2 over a p-adic field F of characteristic 0. We will formulate the multiplicity by means of the quotient of the sizes of L-packets of $SL(md, F)$ and $SL(m, D)$. Its bounds and various numerical aspects will be discussed. We will further talk about the multiplicity for other groups. (Received August 06, 2015)

1112-22-254 **Vinoth Nandakumar*** (vinoth.90@gmail.com), Apt 605, The Landing Apartments, 470 S 1300 E, Salt lake city, UT 84112, and **Rina Anno** (bitango@gmail.com). *Modular representations for two-block nilpotents.*

Bezrukavnikov, Mirkovic and Rumynin have shown that the category of modular representations with a fixed nilpotent p-character arises as the heart of a certain t-structure on the (derived) category of coherent sheaves on the corresponding Springer fiber. Inspired by work of Cautis and Kamnitzer, we specialize to the case of a two-block nilpotent in type A, and construct a representation of the affine tangle calculus using these categories. Using this, we describe the coherent sheaves that that corresponds to the irreducible representations, and describe the Ext groups between them. As an application, we give (conjectural) character formulae, and a description of the category as modules over a diagram algebra. (Received August 09, 2015)

1112-22-299 **Dubravka Ban*** (dban@siu.edu), Department of Mathematics, Southern Illinois University, Carbondale, IL 62901, and **Joseph Hundley**. *Principal series representations on p-adic Banach spaces.*

We consider the continuous principal series representations of split p-adic groups over p-adic fields. We show that such representations are irreducible when the inducing character lies in a certain cone. The proof relies on the duality theory developed by Schneider and Teitelbaum. (Received August 07, 2015)

1112-22-337 **Cheng-Chiang Tsai*** (cctsai@math.harvard.edu), Department of Mathematics, 77 Massachusetts Avenue, Cambridge, MA 02139-4307. *Geometry of Orbital Integrals.*

We discuss how orbital integrals for adjoint orbits on the Lie algebra can be expressed in terms of counting points on varieties over the residue field. (Received August 08, 2015)

1112-22-426 **Sean J Rostami*** (srostami@math.wisc.edu). *Fixers of stable functionals.*

The epipelagic representations of Reeder-Yu, a generalization of the "simple supercuspidals" of Gross-Reeder, are certain low-depth supercuspidal representations of reductive algebraic groups G. Given a "stable functional" f, which is a suitably 'generic' linear functional on a vector space coming from a Moy-Prasad filtration for G, one can create such a representation. It is known that the representations created in this way are compactly induced from the fixer in G of f and it is important to identify explicitly all the elements that belong to this fixer. This work is in-progress. (Received August 10, 2015)

1112-22-530 **Kam-Fai Tam*** (geotam@math.mcmaster.ca), HH414, 1280 Main St W, Hamilton, Ontario L8S1A1, Canada. *Endoscopic classification of tame cuspidal representations of quasi-split classical groups.*

We describe the endoscopic classification of certain cuspidal representations, under a tame condition, of quasi-split classical groups over local fields by Arthur and Mok. We use the method of points of reducibility developed by Mœglin, the theory of covers introduced by Bushnell-Kutzko, and the construction of cuspidal representations by Stevens and Blondel. (Received August 10, 2015)

26 ► Real functions

1112-26-113 **Peter A Loeb*** (ploeb@illinois.edu), Department of Mathematics, University of Illinois, 1409 West Green Street, Urbana, IL 61801. *Forming generalized derivatives in analysis and probability theory.*

The talk discusses a powerful technique for showing that a given limit of ratios yields a Radon-Nikodym derivative. This technique, developed by Jürgen Bliedner and the speaker, casts new light on the martingale convergence theorem and significantly simplifies the treatment of fine limit theorems in potential theory and measure differentiation theorems. An important consequence is the existence of simple boundary approach neighborhood systems in probability and potential theory that, after fixing a suitable normalization, are the "best" possible in terms of producing Radon-Nikodym derivatives as limits at the boundary. An analogous construction for the differentiation of measures also exists. Each measurable set acts as a functional on measures: The value of the functional is the measure of the set. The larger the collection of sets one has at any stage of the filtration process associated with a point, the more information one obtains when a limit exists. Given a suitable normalization, there is an "optimal", i.e. coarsest filtration process that can be used to differentiate measures. Ongoing applications include the use of local maximal functions to considerably simplify the material on measure differentiation and absolute continuity in a graduate real variable course. (Received July 24, 2015)

1112-26-145 **Hajrudin Fejzic*** (hfejzic@csusb.edu), Department of Mathematics, CSUSB, San Bernardino, CA 92407. *On Peano derivatives in several variables.*

Let f be a function of several variables that is n times Peano differentiable. A. Fischer proved that if there is a number $M > 0$ such that all Peano partials of order n are less than M or they are all greater than $-M$ then f is n times ordinarily differentiable. Here this result is improved to permit the possibility that some of the Peano partials are bounded from above by M while others are bounded from below by $-M$. Also as a consequence we obtain some new results about the equality of mixed partial derivatives. (Received July 29, 2015)

1112-26-493 **J. Marshall Ash*** (mash@depaul.edu), PO BOX 23, WEST STOCKBRIDGE, MA 01266, **Stefan Catoiu** (scatoiu@math.depaul.edu), Department of Mathematics, DePaul University, Chicago, IL 60614, and **William Chin**, Department of Mathematics, DePaul University, Chicago, IL 60614. *On generalized Riemann derivatives for functions on $\mathbb{R}^n$ and on $\mathbb{C}$.* Preliminary report.

An nth generalized Riemann derivative $D_{\{A_i,b_i\}}f(x)$ is given by specifying $2m$ real constants $\{A_i, b_i\}, i = 1, 2, \ldots, m$, such that for any real valued function f having n derivatives at any real number x, there holds the identity $D_{\{A_i,b_i\}}f(x) := \lim_{h\to 0} h^{-n} \sum_{i=1}^{m} A_i f(x + b_i h) = f^{(n)}(x)$. These derivatives are fairly well understood. Generalized Riemann derivatives can further be defined for real valued functions on higher dimensional Euclidean spaces and also for functions on the complex numbers. I will discuss some results we have obtained in these settings as well as some related open questions. (Received August 10, 2015)

1112-26-622 **Paul M Musial*** (pmusial@csu.edu), 9501 South King Drive, Chicago, IL 60628. *Integrating the L^r-Derivative.*

We formulate a product rule for the L^r-derivative and an integration by parts formula for the L^r Henstock-Kurzweil integral. We then discuss functions of L^r-bounded variation. Joint work with E. Massarwi and F. Tulone. (Received August 11, 2015)

1112-26-668 **J. Marshall Ash** and **Stefan Catoiu*** (scatoiu@condor.depaul.edu), Department of Mathematics, 2320 N. Kenmore Avenue, Chicago, IL 60614. *Generalized Riemann Derivatives with Variable Coefficients.* Preliminary report.

Generalized nth Riemann derivatives of real functions f are defined by limits of the form $D_{\mathcal{A}}f(x) = \lim_{h\to 0} h^{-n} \sum_i A_i f(x + b_i h)$, where the data vector $\mathcal{A}$ of coefficients A_i and b_i is subject to the compatibility condition that $D_{\mathcal{A}}f(x) = f^{(n)}(x)$ whenever f is n times differentiable at x. Allowing the coefficients A_i to be functions of h gives rise to a larger class of generalized Riemann derivatives. I will discuss a few properties, examples, and questions regarding these derivatives. (Received August 11, 2015)

28 ► Measure and integration

1112-28-509 **Marianna Csornyei*** (csornyei@math.uchicago.edu). *Tangents of curves and differentiability of functions.*

One of the classical theorems of Lebesgue tells us that Lipschitz functions on the real line are differentiable almost everywhere. We study possible generalisations of this theorem and some interesting geometric corollaries, in finite and infinite dimensional spaces. The talk is based on joint results with David Bate and Bobby Wilson. (Received August 10, 2015)

30 ► Functions of a complex variable

1112-30-142 **Emilio Bujalance**, **Javier Cirre*** (jcirre@mat.uned.es) and **Peter Turbek**. *Lifting the hyperelliptic involution of a Klein surface.*

We consider unbranched normal coverings $X \to X'$ between compact Klein surfaces of algebraic genus bigger than one where X' is hyperelliptic. Here unbranched means that the fixed point set of the group of covering transformations is either empty or projects onto the boundary of X'. We find a criterion which determines whether the hyperelliptic involution of X' lifts to an automorphism of X. The study splits naturally into five cases, according to the different topological types that X' may have. Similar results in the setting of classical Riemann surfaces (orientable and unbordered) were given by Turbek in 1997.

This is a joint work (in progress) with E. Bujalance and P. Turbek. (Received July 29, 2015)

1112-30-224 **Clifford J. Earle*** (cliff@math.cornell.edu). *Some quasiconformal homeomorphisms of compact Riemann surfaces.*

Let R be a compact Riemann surface of genus at least two. Its universal covering surface is the hyperbolic plane. We use the upper half plane model, so every quasiconformal homeomorphism of R onto itself lifts to a quasiconformal map of the upper half plane onto itself. If the homeomorphism $f\colon R \to R$ is isotopic to the identity, then it has a unique lift $\tilde{f}$ that equalz the identity on the real axis.

In a joint 2002 paper, Nikola Lakic and I gave formulas for maps $\tilde{f}$ that move some points a surprisingly large distance. In this talk, I will illustrate the geometry behind these formulas. (Received August 04, 2015)

1112-30-324 **Thomas W. Tucker*** (ttucker@colgate.edu). *Kulkarni's Theorem and finite groups acting on a surface of genus g with $g-1$ prime.* Preliminary report.

Suppose the finite group G acts, preserving orientation, on an orientable surface of genus $p+1$ where $p > 5$ is prime. Then G is almost Sylow-cyclic (the Sylow p-subgroup G_p is cyclic if p is an odd prime and G_2 has a cyclic subgroup of index at most two) and does not contain $C_2 \times C_4$. In particular, by Kulkarni's Theorem, G acts preserving orientation on all but finitely many orientable surfaces. This also holds for G acting on a non-orientable surface S with $\chi(S) = -p$, where again $p > 5$ is prime. On the other hand, $C_p \times C_p$ acts on the surface of genus $p+1$ for $p = 3, 5$. (Received August 07, 2015)

1112-30-433 **Kyle Kinneberg*** (kk43@rice.edu). *Conformal dimension of boundaries of John domains.*

The conformal dimension of a metric space is a quasisymmetric invariant that has been important in hyperbolic geometry. Motivated by quasiconformal equivalence problems for Kleinian limit sets, Julia sets, and SLE curves, we investigate the conformal dimension of boundaries of certain planar domains. This talk will focus primarily on boundaries of John domains, and we will outline a proof that these have conformal dimension equal to 1. (Received August 10, 2015)

31 ► Potential theory

1112-31-114 **Nageswari Shanmugalingam*** (shanmun@uc.edu), Department of Mathematical Sciences, P.O. Box 210025, University of Cincinnati, Cincinnati, OH 45221-0025, and **Anders Bjorn**, **Jana Bjorn** and **James T. Gill**. *Trees and Cantor sets; Sobolev spaces and Besov spaces; rough quasiisometries and quasisymmetries.*

The talk will focus on the analytic and geometric connections between trees and Cantor sets that arise as boundaries of trees. We will describe connections between Sobolev type spaces of functions on the tree and Besov classes of functions on the boundary of the tree. (Received July 25, 2015)

33 ► Special functions

1112-33-33 **Yaacov Kopeliovich*** (ykopeliovich@yahoo.com), Department of Finance, University of Connecticut Business School, Storrs, CT. *Thomae and Jacobi type formulas for cyclic covers.* Preliminary report.

I will explain how to generalize Jacobi derivative formulas for cyclic covers different from hyperelliptic curves. (Received June 13, 2015)

34 ► Ordinary differential equations

1112-34-36 **Jie Shen** (shen7@purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907-2061, **Yingwei Wang*** (wywshtj@gmail.com), Department of Mathematics, Purdue University, West Lafayette, IN 47907-2061, and **Jianlin Xia** (xiaj@math.purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907-2061. *Fast Structured Spectral Methods.*

Spectral methods have been used extensively in numerical approximation of partial differential equations due to their bigger accuracy when compared to Finite Differences (FD) and Finite Elements (FE) methods. However, FD and FE usually lead to a sparse linear system while spectral methods often suffer from the huge computational complexity caused by dense matrices.

Fortunately, although the matrices arising from spectral methods are dense, they enjoy a hidden nice property, named low-rank structure, i.e. their off-diagonal blocks have small numerical ranks for a given tolerance which is nearly bounded or grows slowly with the sizes of matrices. This property could be exploited to dramatically reduce the computational cost and give birth to direct spectral solvers with nearly optimal complexity and memory, thanks to the hierarchically semiseparable (HSS) representation for structured matrices.

The Fast Structured Spectral Methods presented here include fast structured Jacobi transforms, fast structured spectral Galerkin methods for differential equations with variable coefficients, and fast structured spectral collocation methods. (Received June 19, 2015)

1112-34-673 **Qing Wang*** (qwang@shepherd.edu), **Zhijun Wang** and **David J Klinke**. *Modeling the efficacy of an immunochemotherapy against colorectal cancer.*

A recent study reported that the chemotherapy agent oxaliplatin (OXP) used in combination with interleukin-12 (IL-12) was able to eradicate pre-existing liver metastatic colorectal cancer in mice. A three-compartment mathematical model was developed to describe the interaction between the immune system and tumor in response to the combined immunochemotherapy. The effects of the combined therapy were approximated using impulses due to abrupt changes of IL-12 and OXP concentrations at the administration time. Model parameters were calibrated to published experimental data using a genetic algorithm. The calibrated model was also used to catch the median tumor growth responding to the combined therapy against a tumor rechallenge. The optimal therapeutic dosage and timing in mixed immunochemotherapy were investigated to control tumor growth based on the calibrated model. The study is supported by the NIGMS of the NIH grant as part of the West Virginia INBRE (P20GM103434). (Received August 11, 2015)

35 ► Partial differential equations

1112-35-6 **Eunhee Park*** (parkeh@indiana.edu), 831 East 3rd St, Bloomington, IN 47405, and **Roger Temam** and **Mickael Chekroun**. *The Stampacchia maximum principle for spdes and applications.*

Stochastic partial differential equations are considered, linear and nonlinear, for which we establish comparison theorems for the solutions, or positivity results a.e., and a.s., for suitable data. Comparison theorems for SPDEs are available in the literature and comparisons are made with our results. The originality of our approach is that it is based on the use of truncations, following the Stampacchia approach to maximum principle. We believe that our method, which does not rely too much on probability considerations, is simpler than the existing approaches and more general. As an application we also show how one can prove the existence of positive solutions for SPDEs with a quadratic nonlinearity (and possibly other nonlinearities). (Received March 04, 2015)

1112-35-28 **Grigor Nika*** (gnika@wpi.edu), 100 Institute Rd, Worcester, MA 01609, and **Bogdan Vernescu**. *Effective properties of two phase flows with non uniform surface tension.*

In this study we are interested in a problem of dilute emulsions of two immiscible viscous fluids, in which one is distributed in the other in the form of droplets of arbitrary shape, with non-uniform surface tension due to surfactants. The problem includes an essential kinematic condition on the droplets. In the periodic homogenization framework, it can be shown using Mosco-convergence that, as the size of the droplets converges to zero faster than the distance between the droplets, the emulsion behaves in the limit like the continuous phase. Here we determine the rate of convergence of the velocity field for the emulsion to that of the velocity for the one fluid problem and in addition, we determine the corrector in terms of the bulk and surface polarization tensors. (Received June 03, 2015)

1112-35-30 **Steve Hofmann**, **Phi Le*** (llc33@mail.missouri.edu), **Jose Maria Martell** and **Kaj Nystrom**. *Quasi-linear PDEs and uniform rectifiability.*

Let $E \subset \mathbb{R}^{n+1}$, $n \geq 2$, be an Ahlfors-David regular set of dimension n. If we assume additionally that $\mathbb{R}^{n+1} \setminus E$ has some "nice" properties then whenever the harmonic measure belongs weak-A_∞ with respect to $H^n|E$ we have E is uniformly rectifiable (i.e. E is locally flat). For more details, the reader may check recent works by Steve Hofmann, José María Martell and their collaborators. In this project, we were interested in the similar result for p-harmonic measure. More precisely, let E be as above and let p, $1 < p < \infty$, be given, let u be a non-negative p-harmonic function in $\Omega := \mathbb{R}^{n+1} \setminus E$ which vanishes continuously on E, and let μ be its associated $p-$harmonic measure supported on E. We prove that the weak-A_∞ property of $p-$harmonic measure, weak-A_∞ with respect to $H^n|E$, implies uniform rectifiability of E. This result is new already in the case of harmonic measure ($p = 2$). (Received June 09, 2015)

1112-35-45 **Nam Q. Le*** (nqle@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405, and **Ovidiu Savin** (savin@math.columbia.edu), Department of Mathematics, Columbia University, New York, NY 10027. *Global smoothness of the Monge-Ampere eigenfunctions.*

In this talk, we will discuss global smoothness of the eigenfunctions of the Monge-Ampere operator on smooth, bounded and uniformly convex domains in all dimensions. A key ingredient in our analysis is boundary Schauder estimates for certain degenerate Monge-Ampere equations. This is joint work with Ovidiu Savin. (Received July 03, 2015)

1112-35-74 **Rafael D. Benguria** (rbenguri@fis.puc.cl) and **Soledad Benguria*** (benguria@math.wisc.edu). *The Brezis–Nirenberg Problem on $\mathbb{S}^n$, in spaces of fractional dimension.*

We consider the nonlinear eigenvalue problem,

$$-\Delta_{\mathbb{S}^n} u = \lambda u + |u|^{4/(n-2)} u,$$

with $u \in H_0^1(\Omega)$, where Ω is a geodesic ball of radius θ_1 in $\mathbb{S}^n$. In dimension $n = 3$, Bandle and R. Benguria proved that if $\lambda \geq -n(n-2)/4$ this problem has a unique positive solution if and only if $\lambda \in ((\pi^2 - 4\theta_1^2)/4\theta_1^2, \lambda_1)$, where λ_1 is the first Dirichlet eigenvalue. For positive radial solutions of this problem one is led to an ordinary differential equation that still makes sense when n is a real rather than a natural number. Here we consider precisely that situation with $2 < n < 4$. Our main result is that in this case one has a positive solution if and only if $\lambda \geq -n(n-2)/4$ is such that

$$\frac{1}{4}[(2\ell^* + 1)^2 - (n-1)^2] < \lambda < \lambda_1$$

where ℓ^* is the first positive value of ℓ for which the associated Legendre function $\mathrm{P}_\ell^{(n-2)/2}(\cos\theta_1)$ vanishes. (Received July 15, 2015)

1112-35-84 **Qianyun Miao** (mqy8955@sina.com), Beijing, 100191, Peoples Rep of China, **Changyou Wang*** (wang2482@purdue.edu), 150 N. University Street, West Lafayette, IN 47907, and **Yuan Zhou** (yuanzhou@buaa.edu.cn), Beijing, 100191, Peoples Rep of China. *Uniqueness of absolute minimizeres of L^∞-functional associated with x-dependent Hamiltonians.* Preliminary report.

In this talk, I will show the uniqueness of absolute minimizers to nonnegative Hamiltonian functions $H(x,p)$ in a bounded domain U in R^n, where $H(x,p)$ satisfies: (i) $H(x,p)$ is lower semincontinuous; and $H(x,p)$ is convex in p-variable; (ii) $H(x,0) = 0$ and $\cup_x\{p : H(x,p) = 0\}$ is contained in a hyperplane of R^n; (iii) $H(x,p)$ is coercive in p-variable, uniformly in x.

This is a joint work with Qianyun Miao and Yuan Zhou, Beijing University of Aeronautics and Astronautics. (Received July 18, 2015)

1112-35-92 **Sergey Denisov*** (denissov@math.wisc.edu), 480 Lincoln Drive, Department of Mathematics, UW-Madison, Madison, WI 53706. *The patch dynamics for the two-dimensional active scalar equations: steady states and singularity formation.*

We will consider some two-dimensional active scalar equations and focus on the evolution of the patches. We will first describe the merging mechanism for the central pair of patches. Then, the special curve of regular steady states will be presented. This curve bifurcates from the singular stationary state. (Received July 22, 2015)

1112-35-93 **Luis Silvestre***, luis@math.uchicago.edu, and **Tianling Jin**. *Gradient Holder continuity for the parabolic homogeneous p-Laplacian equation.*

It is well known that p-harmonic functions are $C^{1,\alpha}$ regular, for some $\alpha > 0$. The classical proofs of this fact use variational methods. In a recent work, Peres and Sheffield construct p-Harmonic functions from the value of a stochastic game. This construction also leads to a parabolic versions of the problem. However, the parabolic equation derived from the stochastic game is not the classical parabolic p-Laplace equation, but a homogeneous of degree one version. This equation is not in divergence form and variational methods are inapplicable. We prove that solutions to this equation are also $C^{1,\alpha}$ regular in space. (Received July 22, 2015)

1112-35-140 **Cristian Enache*** (cenache23@yahoo.com), Aleea Malinului #11, Bl. D, App. 20, 900597 Constanta, Romania. *Maximum principles and isoperimetric estimates for a class of Monge-Ampere equations, with applications to surfaces of constant Gauss curvature.*

In this talk we first deal with a general class of Monge-Ampère equations, including the constant Gauss curvature equation. Our first aim is to prove some maximum and minimum principles for suitable P-functions, in the sense of L.E. Payne. Then, these new principles are employed to solve a general class of overdetermined Monge-Ampère problems and to investigate two boundary value problems for the constant Gauss curvature equation. More precisely, when the constant Gauss curvature equation is subject to the homogeneous Dirichlet boundary condition, we prove several isoperimetric inequalities, while when it is subject to the contact angle boundary condition, some necessary conditions of solvability, involving the curvature of the boundary of the underlying domain and the given contact angle, are derived. References:

[1] C. Enache, Maximum and minimum principles for a class of Monge-Ampere equations in the plane, with applications to surfaces of constant Gauss curvature, Communications on Pure and Applied Analysis, 13(3) (2014), 1347-1359.

[2] C. Enache, Maximum principles and isoperimetric inequalities for some Monge-Ampere type problems, Comptes Rendus de l'Académie des Sciences Paris Series I - Mathematics 352 (2014), 37-42. (Received July 29, 2015)

1112-35-153 **Patricia Bauman*** (baumanp@purdue.edu), Purdue University-Dept. of Math, 150 N. University Street, West Lafayette, IN 47907, and **Daniel Phillips**, Purdue University-Dept. of Math, 150 N. University Street, West Lafayette, IN 47907. *Regularity and Properties of Minimizers for Landau-de Gennes Energies defined by Probability Density Functionals.*

We prove regularity and properties of minimizers for Landau-de Gennes energies whose bulk energy term is singular and defined via Maier-Saupe type probability density functionals. In particular, we show that for a general class of these energies describing liquid crystals, minimizers (which are H^1 functions from a two-dimensional domain into a subclass of 3 x 3 symmetric, trace-free matrices) are Holder continuous, and their eigenvalues are strictly within the physically realistic interval (-1/3,2/3), even though the admissible functions have eigenvalues in the closure of this interval. (Received July 30, 2015)

1112-35-159 **Jingrui Cheng**, **Michael J.P. Cullen** and **Mikhail Feldman*** (feldman@math.wisc.edu). *Short-time existence of smooth solutions for semigeostrophic system with variable Coriolis coefficient.*

The semigeostrophic (SG) system is a model of large scale atmosphere/ocean flows. Previous results were obtained for the SG system with constant Coriolis parameter, by rewriting the problem in the "dual variables" and using Monge-Kantorovich mass transport techniques. A more physically realistic SG model has variable Coriolis parameter. Dual space cannot be defined in this case. We work directly in the original "physical" coordinates, and show existence of smooth solutions for short time. (Received July 30, 2015)

1112-35-177 **Songting Luo**, **Hung Tran*** (hung@math.uchicago.edu) and **Yifeng Yu**. *Some Inverse Problems in Periodic Homogenization of Hamilton-Jacobi Equations.*

We look at the effective Hamiltonian $\overline{H}$ associated with the Hamiltonian $H(p,x) = H(p) + V(x)$ in the periodic homogenization theory. Our central goal is to understand the relation between V and $\overline{H}$. We formulate some inverse problems concerning this relation. Such type of inverse problems are in general very challenging. I will discuss some interesting cases in both convex and nonconvex settings. Joint work with Songting Luo and Yifeng Yu. (Received August 02, 2015)

1112-35-193 **Peter Constantin**, **Michele Coti Zelati*** (micotize@umd.edu) and **Vlad Vicol**. *Regularity and longtime behavior of SQG equations.*

We consider the global attractor of the critical SQG semigroup $S(t)$ on the scale-invariant space $H^1(\mathbb{T}^2)$. It is known that this attractor is finite dimensional, and that it attracts uniformly bounded sets in $H^{1+\delta}(\mathbb{T}^2)$ for any $\delta > 0$, leaving open the question of uniform attraction in $H^1(\mathbb{T}^2)$. We answer the question of uniform $H^1(\mathbb{T}^2)$ attraction in the positive, by using ideas from de Giorgi iteration and nonlinear maximum principles. (Received August 03, 2015)

1112-35-195 **Alexey Cheskidov** and **Mimi Dai*** (mdai@uic.edu). *Determining modes for the surface quasi-geostrophic equation.*

We introduce a determining wavenumber for the surface quasi-geostrophic (SQG) equation defined for each individual trajectory and then study its dependence on the force. While in the subcritical and critical cases this wavenumber has a uniform upper bound, it may blow up when the equation is supercritical. A bound on the determining wavenumber provides determining modes, which in some sense measure the number of degrees of freedom of the flow, or resolution needed to describe a solution to the SQG equation. (Received August 03, 2015)

1112-35-202 **Roman Shvydkoy*** (shvydkoy@uic.edu). *Homogeneous solutions to the Euler equation.*

In the talk we present classification results for homogeneous solutions to the 2D and 3D Euler equations. (Received August 04, 2015)

1112-35-204 **Mihai Mihailescu*** (mmihailes@yahoo.com), 010702 Bucharest, Bucharest, Romania. *Classification of isolated singularities for inhomogeneous operators in divergence form.*

Consider the equation $\operatorname{div}\left(\frac{\phi(|\nabla u|)}{|\nabla u|}\nabla u\right) = 0$ on the punctured unit ball from $\mathbb{R}^N$ $(N \geq 2)$, where ϕ is an odd, increasing homeomorphism from $\mathbb{R}$ onto $\mathbb{R}$ of class C^1. Under reasonable assumptions on ϕ we prove that if u is a non-negative solution of the equation, then either 0 is a removable singularity of u or u behaves near 0 as the fundamental solution of the equation. In particular, our result complements to the case on inhomogeneous operators in divergence form Bôcher's Theorem and some classical results by Serrin. (Received August 04, 2015)

1112-35-255 **Sookyung Joo*** (sjoo@odu.edu), Department of Mathematics and Statistics, Old Dominion University, Norfolk, VA 23529, and **Carlos J. Garcia-Cervera** and **Tiziana Giorgi**. *Sawtooth profile of smectic A liquid crystals.*

We study de Gennes free energy for smectic A liquid crystals over $\mathbb{S}^2$ valued vector fields to understand the chevron (zigzag) pattern formed in the presence of an applied magnetic field. Well above the instability threshold, we show via Γ-convergence that a chevron structure where the director connects two minimum states of the sphere is favored. Numerical simulations illustrating the chevron structures for the de Gennes energy will be presented. (Received August 06, 2015)

1112-35-268 **Jennifer Beichman*** (beichman@wisc.edu). *Nonstandard dispersive estimates and linearized water waves.*

In this talk, we focus on understanding the relationship between the decay of a solution to the linearized water wave problem and its initial data. We obtain decay bounds for a class of 1D dispersive equations that includes the linearized water wave. These decay bounds display a surprising growth factor, which we show is sharp. A further exploration leads to a result relating singularities of the initial data at the origin in Fourier frequency to the regularity of the solution. (Received August 06, 2015)

1112-35-275 **Ryan Hynd**, **Charles Smart** and **Yifeng Yu*** (yyu1@math.uci.edu). *Nonuniqueness of infinity ground states.*

Let Ω be a bounded open set in $\mathbb{R}^n$. For $\lambda_\infty = \frac{1}{\max_\Omega d(x,\partial\Omega)}$, the following equation

$$\begin{cases} \max\left\{\lambda_\infty - \frac{|Du|}{u},\ \Delta_\infty u\right\} = 0 & \text{in } \Omega \\ u = 0 & \text{on } \partial\Omega \end{cases}$$

was derived by Juutinen, Lindqvist and Manfredi as the limit of equations satisfied by principal eigenfunctions of p-Laplacian equation when $p \to +\infty$. Its solutions can be viewed as principal eigenfunctions of the infinity Laplacian operator $\Delta_\infty u = u_{x_i} u_{x_j} u_{x_i x_j}$. In this talk, we present a dumbbell domain where solutions to the above equation are not unique up to multiplication by a constant. This is a joint work with Ryan Hynd and Charles Smart. (Received August 06, 2015)

1112-35-304 **Peter Constantin***, Department of Mathematics, Princeton University, Princeton, NJ 08544, and **Mihaela Ignatova**. *Nonlinear maximum principle with boundary.* Preliminary report.

We prove a nonlinear inequality for the fractional Laplacian with Dirichlet boundary conditions and discuss applications to electro-convection. (Received August 07, 2015)

1112-35-343 **Nestor Guillen** and **Russell Schwab*** (rschwab@math.msu.edu), Department of Mathematics, 619 Red Cedar Rd., East Lansing, MI 48824. *Neumann Homogenization Via Integro-Differential Methods.* Preliminary report.

We introduce a nonlinear Dirichlet-to-Neumann mapping to investigate the homogenization of fully nonlinear equations with oscillatory Neumann data. This allows to recast the original second order problem with oscillations at the boundary into a global interior homogenization problem, but this time with an integro-differential equation on the boundary of the original domain. In the case of periodic coefficients in a half-space domain with an irrational normal vector, the problem becomes and almost periodic integro-differential homogenization on the boundary. This is joint work with Nestor Guillen. (Received August 08, 2015)

1112-35-347 **Lidia Mrad*** (lmrad@purdue.edu) and **Daniel Phillips**. *Gradient Flow of Chevron Structures in Liquid Crystal Cells.*

A chiral Smectic C phase develops in liquid crystals as molecules self-organize into layers with a tilt tracing a helix across layers. In a thin cell, these layers deform into V-shaped layers exhibiting a chevron structure. We study the molecular reorientation dynamics of this structure between two stable states caused by an applied electric field. Our model is based on the Chen-Lubensky energy and we use an iterative minimization technique to construct a sequence of discrete-in-time gradient flows. We establish the existence of a continuous gradient flow that describes the switching process. Moreover, we prove the uniqueness of the solution independent of the method by which it was constructed. (Received August 08, 2015)

1112-35-361 **Andrej Zlatos*** (az@math.wisc.edu). *Reactive Processes in Inhomogeneous Media.*

We study fine details of spreading of reactive processes (e.g., combustion) in multi-dimensional inhomogeneous media. In the real world, one often observes a transition from one equilibrium (e.g., unburned fuel) to another (e.g., burned fuel) to happen on short spatial as well as temporal scales. We demonstrate that this phenomenon also occurs in one of the simplest models for reactive processes, reaction-diffusion equations with ignition reaction functions, under very general hypotheses.

Specifically, we show that in up to three spatial dimensions, the width (both in space and time) of the zone where reaction occurs stays uniformly bounded in time for some fairly general classes of initial data, and this bound even becomes independent of the initial datum as well as of the reaction function, after an initial time interval. Such results have recently been obtained in one dimension but are new in higher dimensions. As one indication of the added difficulties, we also show that three dimensions is indeed the borderline case, and the result is false for general inhomogeneous media in four and more dimensions. (Received August 09, 2015)

1112-35-364 **Alexander Kiselev**, **Lenya Ryzhik**, **Yao Yao** and **Andrej Zlatos*** (az@math.wisc.edu). *Finite time blow-up for the α-patch model.*

The global regularity vs finite time blow-up question remains open for many fundamental equations of fluid dynamics. In two dimensions, the solutions to the incompressible Euler equation have been known to be globally regular since the 1930s. On the other hand, this question has not yet been resolved for the less regular (by one derivative) surface quasi-geostrophic (SQG) equation. The latter state of affairs is also true for a natural family of PDE which interpolate between these two equations. They involve a parameter α, which appears as a power

in the kernel of their Biot-Savart laws and describes the degree of regularity of the equation, with the values $\alpha = 0$ and $\alpha = \frac{1}{2}$ corresponding to the Euler and SQG cases, respectively.

In this talk I will present two results about the patch dynamics version of these equations in the half-plane. The first is global-in-time regularity for the Euler patch model, even if the patches initially touch the boundary of the half-plane. The second is local regularity and existence of solutions which blow up in finite time for the α-patch model with any small enough $\alpha > 0$. The latter appears to be the first rigorous proof of finite time blow-up in this type of fluid dynamics models. (Received August 09, 2015)

1112-35-430 **Shuang Miao*** (shmiao@umich.edu). *On shock formations for 3d wave equations.*

In this talk I will present a geometric perspective on shock formations for a class of 3-dimensional quasilinear wave equations which admit global smooth solutions with small data. We exhibit a family of smooth initial data leading to breakdown of smoothness of the solutions. The work combines the ideas from fluid mechanics e.g. shock formation for compressible Euler equation and from general relativity e.g. formation of trapped surfaces. This is a joint work with Pin Yu. (Received August 10, 2015)

1112-35-481 **M. Ignatova*** (ignatova@math.princeton.edu) and **V. Vicol**. *Almost global existence for the Prandtl boundary layer equations with small tangentially analytic initial datum.*

We address the Prandtl boundary layer equations on the half space with real-analytic initial datum with respect to the tangential variable. The boundary traces of the horizontal Euler flow and pressure are taken to be constants. We establish that if the initial datum is of size ϵ, then the time of existence for the solution is $\exp(\epsilon^{-1}/\log(\epsilon^{-1}))$. This is a joint work with V. Vicol. (Received August 10, 2015)

1112-35-483 **Jacob Bedrossian***, jacob@cscamm.umd.edu, Washington, DC, and **Pierre Germain** and **Nader Masmoudi**. *Dynamics near the subcritical transition of the 3D Couette flow.*

We discuss the dynamics of small perturbations of the plane, periodic Couette flow in the 3D incompressible Navier-Stokes equations at high Reynolds number. For sufficiently regular initial data, we determine the stability threshold for small perturbations and characterize the long time dynamics of solutions below this threshold. The primary stability mechanisms are an anisotropic enhanced dissipation effect and an inviscid damping effect of the velocity component normal to the shear, both a result of the mixing caused by the large mean shear. After detailing these linear effects, we will discuss some of the important steps in the proof, such as the analysis of the weakly nonlinear (potential) instabilities connected to the non-normal nature of the linearization. Joint work with Pierre Germain and Nader Masmoudi. (Received August 10, 2015)

1112-35-505 **Farhod Abdullayev*** (fabdullayev@wpi.edu), Department of Mathematical Sciences, Stratton Hall, 100 Institute Road, Worcester, MA 01608. *On quasi-static limits of one-dimensional dynamic cohesive fracture.*

Quasi-static models are based on the assumption that whatever is driving the motion, for example loading or Dirichlet conditions, varies slowly in time compared to the elastic wave speed of the material. We analyze a one-dimensional model of dynamic cohesive fracture with varying Dirichlet condition, and take the limit as the speed with which the condition changes goes to zero. We then study the question of whether the usual model for quasi-static cohesive fracture is the limit of dynamic cohesive fracture. (Received August 10, 2015)

1112-35-511 **Eugene Gartland*** (gartland@math.kent.edu), Department of Mathematical Sciences, Kent State University, P.O. Box 5190, Kent, OH 44242-0001. *Scalings and Limits of the Landau-de Gennes Model for Nematic Liquid Crystals.* Preliminary report.

Stationary points of the Landau-de Gennes free-energy functional give equilibria of the tensor order parameter that characterizes the state of orientational order in a liquid crystal material. This mesoscopic, phenomenological model plays a role in the theory of liquid crystals similar to that of the Ginzburg-Landau model in superconductivity. Some recent analytical papers have explored the behavior of this model in certain extreme ranges of the material parameters. We suggest an interpretation of these limits, based on dimensional analysis and scalings. (Received August 10, 2015)

1112-35-522 **Xinwei Yu*** (xinwei2@ualberta.ca), 632 CAB, University of Alberta, Edmonton, Alberta T6G2G1, Canada, and **Chuong V. Tran**, St. Andrews, KY16 9SS, United Kingdom. *Regularity criteria of 3D Navier-Stokes Equations involving the pressure term.*

In this talk we will present some new regularity criteria for the 3D Navier-Stokes equations. This new criteria explore the relation between the pressure and the velocity. We will also discuss possible depletion of nonlinearity due to the negative correlation between $|u|$ and $|\nabla|u||$. This is joint work with Prof. Chuong V. Tran of University of St. Andrews, Scotland. (Received August 10, 2015)

1112-35-529 **L. Kong***, One University Plaza, MS WUIS 13, University of Illinois Springfield, Springfield, IL, and **N. Rawal** and **W. Shen**. *Spreading Speeds and Linear Determinacy for Two Species Competition Systems with Nonlocal Dispersal in Periodic Habitats.*

The current work is concerned with the existence of spreading speeds and linear determinacy for two species competition systems with nonlocal dispersal in time and space periodic habitats. When the periodic dependence of the habitat is only on the time variable, the existence of a single spreading speed is proved. It also shows that, under certain conditions, the spreading speed interval in any direction is a singleton, and, moreover, the linear determinacy holds. (Received August 10, 2015)

1112-35-542 **Meihua Yang*** (yangmeih@hust.edu.cn), School of Mathematics and Statistics, Huazhong University of Science and Technology, Wuhan, Hubei 430074, Peoples Rep of China. *Attractors for wave equations with nonlinear damping on time-dependent space.*

In this talk, we want to present some results about the attractors on time-dependent spaces.Firstly, we gave a sufficient and necessary condition for the existence of attractors on time-dependent spaces, which is equivalent to that provided by M. Conti et al.[JDE, 2013], and then we provided a technical method for verifying compactness of the process via contractive functions. Finally, we consider the long time behavior of the solution for the nonlinear damped wave equation

$$\varepsilon(t)u_{tt} + g(u_t) - \Delta u + \varphi(u) = f$$

with Dirichlet boundary condition, in which, the coefficient ε depends explicitly on time, the damping g is nonlinear and the nonlinearity φ has a critical growth, and show that the time-dependent attractors for the wave equations with nonlinear damping exists.

This work is joint work with Fengjuan Meng and Chengkui Zhong. (Received August 11, 2015)

1112-35-546 **Jerome Coville*** (jerome.coville@avignon.inra.fr), INRA Centre PACA, Equipe BioSP, 228 route de l'Aérodrome, CS 40509, Domaine Saint Paul - Site Agroparc, 84914cdex9 Avignon, France. *Persistence criteria in some nonlocal model in unbounded domain and application.*

I will report on a recent study made in collaboration with H.Berestycki and H. Vo concerning persistence criteria in some nonlocal models in $\mathbb{R}^N$. I will first present the persistence criteria that we have obtained and then, I will discuss the behavior of this criteria with respect to the dispersal operator when it is conditioned by a cost function. (Received August 11, 2015)

1112-35-551 **Dmitry Golovaty*** (dmitry@uakron.edu), Department of Mathematics, The University of Akron, Akron, OH 44325-4002. *Electroosmosis in nematic liquid crystals.*

I will discuss electroosmosis in thin nematic liquid crystalline films over patterned surfaces. The presence of ions in a nematic matrix, coupled with a director-dependent anisotropic conductivity results in a nematic flow. This is a joint work with Carme Calderer, Noel Walkington, and Oleg Lavrentovich. (Received August 11, 2015)

1112-35-552 **Andres Contreras*** (math@nmsu.edu), NMSU Department of Mathematical Sciences, 1290 Frenger Mall MSC 3MB, Science Hall 236, LasCruces, NM 88003-8001, and **Carlos Garcia-A**, **Carlos Garcia-C.** and **Sookyung Joo**. *Bifurcation in smectic A liquid crystals at the critical magnetic field.*

We consider the Landau-de Gennes model of smectic A liquid crystals in the presence of an applied magnetic field. At the critical field, the uniformly layered state ceases to be stable. At this value, undulation takes place, however the description of the preferred state is not an easy task because the bifurcation at this value is not simple. In this work we overcome this difficulty and are able to find, somewhat surprisingly, two global bifurcation branches starting at the critical field. (Received August 11, 2015)

1112-35-554 **Ibrahim Fatkullin***, 617 N Santa Rita Ave, Tucson, AZ 85721, and **Valeriy Slastikov**. *A model of polydisperse nematics.*

I will present an Onsager-type model of polydisperse nematics in which the nematic rods may have variable sizes. Minimization of the free energy provides the joint distribution of orientations and sizes. The model is derived as a large deviation principle for a scaling limit of specific Gibbs ensembles on Young diagrams. (Received August 11, 2015)

1112-35-578 **Xiaoxa Xie*** (xxie12@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616, **Wenxian Shen** (wenxish@mail.auburn.edu), Department of Mathematics, Auburn University, Auburn, AL 36849, **Jinqiao Duan** (duan@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616, **Xiaofan Li** (lix@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616, and **Guangying Lv** (gylvmaths@126.com), School of Mathematics and Statistics, Henan University, Kaifeng, Henan 475001, Peoples Rep of China. *Two Types of Nonlocal Diffusions and the Convergence to the Random/Normal Diffusion.*

This talk is concerned with the study of different types of diffusions: the random/normal diffusion and two types of nonlocal diffusions. The random/normal diffusion is the classical Laplace operator, while one type of nonlocal diffusions is an integral operator with a smooth kernel, and the other one is called the anomalous diffusion generated by the fractional Laplace operation.

Regarding the nonlocal dispersal operator with a smooth kernel, we first study its principal spectral theory and asymptotic dynamics. Secondly, we consider its convergence to the random dispersal operator from three points of view.

About the anomalous diffusion, we are interested in the Fokker-Plank equation, when the noise in the system is an α-stable Lévy motion. We investigate the existence, uniqueness, and regularity of solutions to the corresponding Fokker-Plank equation in two prototypical stochastic systems. (Received August 11, 2015)

1112-35-591 **Zhiwu Lin*** (zlin@math.gatech.edu), 686 Cherry St., School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332, and **Chongchun Zeng**, 686 Cherry St., Atlanta, GA 30332. *Instability index, exponential trichotomy and invariant manifolds for Hamiltonian PDEs.*

Consider a general linear Hamiltonian system $u_t = JLu$ in a Hilbert space X, called the energy space. We assume that L induces an symmetric bi-linear form $< L., . >$ on X, and the energy functional $< Lu, u >$ has only finitely many negative dimensions $n(L)$. The anti-selfadjoint operator J can be unbounded and even with an infinite dimensional kernel space. First, we proved an index theorem relating $n(L)$ and the dimensions of generalized eigenspaces of eigenvalues of JL, some of which may be embedded in the continuous spectrum. Our second result is the linear exponential trichotomy of the evolution group e^tJL. In particular, we prove the nonexistence of exponential growth in the finite co-dimensional center subspace and the optimal bounds on the algebraic growth rate there. This is applied to construct the local invariant manifolds for nonlinear Hamiltonian PDEs near the orbit of a coherent states (steady state, traveling waves etc.). We will discuss applications to examples including dispersive long wave models such as BBM, KDV and good Boussinesq equations, Gross-Pitaevskii equation for superfluids, 2D Euler equation for ideal fluids, and 3D Vlasov-Maxwell systems for collisionless plasmas. This is a joint work with Chongchun Zeng. (Received August 11, 2015)

1112-35-592 **Jeffrey R Anderson*** (andersjr@ipfw.edu). *Global estimates of solutions of the porous medium equation with boundary flux governed by memory.*

Motivated by a previously introduced model of tumor-induced angiogenesis, we investigate global solvability and blow up in finite time for nonlinear diffusion equations with boundary flux governed by memory. The present study is also in the spirit of extending results for models incorporating local, nonlocal, and delay nonlinearities. Specifically, we establish necessary and sufficient conditions for blow-up in finite time which are identical to those in the parallel result for the case of local flux conditions at the boundary. Key steps for the analysis are obtaining global L^p estimates and converting these to L^∞ estimates. The memory condition, in the form of a time integral at the boundary, and resulting constants which do not permit simply letting $p \to \infty$ complicate the process. We discuss how these can be addressed and extensions to related models under current study. (Received August 11, 2015)

1112-35-598 **Hao Jia*** (jiahao@math.uchicago.edu), 1450 E 55th Pl Apt 325S, Chicago, IL 60637. *Generic and Non-generic behavior of solutions to defocusing energy critical wave equation with potential, in the radial case.*

The long time behavior of dispersive equations containing nontrivial dynamics has been studied for many models, due to its physical relevance as well as intrinsic mathematical interest. The main relaxation mechanism is not energy dissipation, but propagation of energy into large distances, which brings new mathematical challenges. In this talk, we report some results in the context of defocusing energy critical wave equation, with an attractive potential. The potential bounds many steady states (the ground states and many excited states). We note that there could be large stable excited state, although all small excited states are unstable. We show that for generic

potential, the solution scatters to one of the steady states. Moreover, each unstable excited state attracts only a finite co-dimensional manifold of solutions in the energy space, hence scattering to unstable steady state is non-generic. This is based on joint works with B.P. Liu, W. Schlag and G.X. Xu. (Received August 11, 2015)

1112-35-607 **Michael S. Jolly*** (msjolly@indiana.edu), **Vincent R. Martinez**, **Tural Sadigov** and **Edriss S. Titi**. *A determining form for the SQG equation.* Preliminary report.

The dynamics of the surface quasigeostrophic equation is embedded in that of an ordinary differential equation in a Banach space of trajectories. This is done by a mapping generated by a feedback control term involving the lowest Fourier modes. (Received August 11, 2015)

1112-35-636 **Nestor Daniel Guillen*** (nguillen@math.umass.edu) and **Russell Schwab**. *A min-max formula for nonlinear elliptic operators and its applications.*

We show that any operator satisfying a (weak) global comparison principle can be represented by a min-max formula in terms of (possibly nonlocal) linear operators. Besides providing a non-linear analogue of a classical theorem of Courrège, this shows that the general non-local theory can be put within the framework of Bellman-Isaacs equations. Among further applications of this representation formula, we highlight the analysis of questions about (local, nonlinear) boundary problems with integro-differential tools (Received August 11, 2015)

1112-35-653 **Alexey Cheskidov***, Dp. *Determining wavenumber for fluid equations.*

In this talk we review classical results on determining modes for fluid equations and present a slightly different approach where we start with a time-dependent determining wavenumber defined for each individual trajectory and then study its dependence on the force. While in some cases this wavenumber has a uniform upper bound, it may blow up when the equation is supercritical. Nevertheless, the average determining wavenumber is uniformly bounded even for the 3D Navier-Stokes and some supercritical SQG equations. (Received August 11, 2015)

1112-35-656 **Umberto Mosco*** (mosco@wpi.edu), Department of Mathematical Sciences, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609-2280. *On a dynamic interpolation of 1D and 2D attractors.*

We construct a one-parameter family of second order Cauchy initial value problems in the plane with attractors at infinity that interpolate between the boundary of a square and the full square. We describe the dynamic and geometric implications of this result and its generalization to more general domains and interfaces. (Received August 11, 2015)

1112-35-664 **Panagiotis Souganidis*** (souganidis@math.uchicago.edu), Department of Mathematics, 5734 S University Ave, Chicago, IL 60611. *Homogenization for some mean field models.* Preliminary report.

I will discuss some new results about the homogenization of a class of mean field models with nonlocal density dependence. This is joint work with P. L. Lions (Received August 11, 2015)

1112-35-667 **Stan Alama*** (alama@mcmaster.ca), Department of Mathematics & Statistics, McMaster University, Hamilton, ON L8S 4K1, Canada, **Lia Bronsard** (bronsard@mcmaster.ca), Department of Mathematics & Statistics, McMaster University, Hamilton, ON L8S 4K1, Canada, and **Xavier Lamy** (xavierlamy@gmail.com), Institut Camille Jordan, Université Claude Bernard Lyon 1, 69622 Villeurbanne cedex, France. *Minimizers of the Landau-de Gennes energy around a spherical colloid particle.*

We consider energy minimizing configurations of a nematic liquid crystal around a spherical colloid particle, in the context of the Landau-de Gennes model. The nematic is assumed to occupy the exterior of a ball B_{r_0}, and satisfy homeotropic weak anchoring at the surface of the colloid and approach a uniform uniaxial state as $|x| \to \infty$. We study the minimizers in two different limiting regimes: for balls which are small $r_0 \ll L^{\frac{1}{2}}$ compared to the characteristic length scale $L^{\frac{1}{2}}$, and for large balls, $r_0 \gg L^{\frac{1}{2}}$. The relationship between the radius and the anchoring strength W is also relevant. For small balls we obtain a limiting quadrupolar configuration, with a "Saturn ring" defect for relatively strong anchoring, corresponding to an exchange of eigenvalues of the Q-tensor. In the limit of very large balls we obtain an axisymmetric minimizer of the Oseen–Frank energy, and a dipole configuration with exactly one point defect is obtained. (Received August 11, 2015)

1112-35-671 **Stan Alama** (alama@mcmaster.ca), Department of Mathematics & Statistics, McMaster University, Hamilton, ON L8S 4K1, Canada, **Lia Bronsard*** (bronsard@mcmaster.ca), Department of Mathematics & Statistics, McMaster University, Hamilton, ON L8S 4K1, Canada, and **Bernardo Galvão Sousa** (beni@math.toronto.edu), Department of Mathematics, University of Toronto, Toronto, ON M5S 2E4, Canada. *Weak Anchoring for 2D Liquid Crystals.*

We study the weak anchoring condition for nematic liquid crystals in the context of the Landau-De Gennes model. We restrict our attention to two dimensional samples and to nematic director fields lying in the plane, for which the Landau-De Gennes energy reduces to the Ginzburg–Landau functional, and the weak anchoring condition is realized via a penalized boundary term in the energy. We study the singular limit as the length scale parameter $\epsilon \to 0$, assuming the weak anchoring parameter $\lambda = \lambda(\epsilon) \to \infty$ at a prescribed rate. We also consider a specific example of a bulk nematic liquid crystal with an included oil droplet and derive a precise description of the defect locations for this situation, for $\lambda(\epsilon) = K\epsilon^{-\alpha}$ with $\alpha \in (0, 1]$. We show that defects lie on the weak anchoring boundary for $\alpha \in (0, \frac{1}{2})$, or for $\alpha = \frac{1}{2}$ and K small, but they occur inside the bulk domain Ω for $\alpha > \frac{1}{2}$ or $\alpha = \frac{1}{2}$ with K large. (Received August 11, 2015)

37 ► Dynamical systems and ergodic theory

1112-37-106 **Michael Cantrell*** (mcantr2@uic.edu) and **Alex Furman**. *Asymptotic Shapes of Ergodic Random Metrics on Nilpotent Groups.*

In this talk we will present three seemingly different results about randomness in a finitely generated nilpotent group: an asymptotic shape theorem for First Passage Percolation; a generalization to random metrics of Pansu's theorem that the unique asymptotic cone of a nilpotent group is a particularly nice nilpotent Lie group; a Subadditive Ergodic Theorem for nilpotent groups. The results are all related, and the proof involves sub-Riemannian geometry and Ergodic Theory. (Received July 23, 2015)

1112-37-133 **Aimee S.A. Johnson*** (aimee@swarthmore.edu), Department of Mathematics and Statistics, Swarthmore College, Swarthmore, PA 19081. *Speedups of ergodic $\mathbb{Z}^d$-actions.*

Arnoux, Ornstein, and Weiss showed in 1985 that given any two aperiodic measure-preserving transformations $(X, \mathcal{X}, \mu, T)$ and $(Y, \mathcal{Y}, \nu, S)$, one can find a measurable function $p : X \to \mathbb{N}$ such that, by setting $\overline{T}(x) = T^{p(x)}(x)$, $(X, \mathcal{X}, \mu, \overline{T})$ is isomorphic to $(Y, \mathcal{Y}, \nu, S)$. The function $\overline{T}$ is called a "speedup" of T and their result showed that it is always possible to "speed up" one such transformation to "look like" another. Babichev, Burton, and Fieldsteel showed in 2013 that for extensions by a locally compact, second countable group, the function p can be taken to be measurable with respect to the base factor. They also consider n-point extensions and use a conjugacy class of subgroups of the symmetric group on n symbols to characterize which n-point extensions can be sped up to look like another.

The above results concern dynamical systems generated by a single transformation, i.e. $\mathbb{Z}$-actions. Based on joint work with David McClendon (Ferris State University), in this talk we will set up the situation for $\mathbb{Z}^d$-actions and discuss generalizations of the above results. (Received July 28, 2015)

1112-37-134 **Maria Isabel cortez** and **Konstantin Medynets*** (medynets@usna.edu), Annapolis, MD 21402. *A rigidity theorem for generalized odometers.*

We study equicontinuous actions of finitely-generated groups on Cantor sets. These actions are shown to be profinite (conjugate to generalized odometers). We prove that two profinite actions are continuously orbit equivalent (have isomorphic topological full groups) if and only if they are virtually piecewise conjugate, i.e., have finite index subgroups with the same index whose actions are locally conjugate. This result extends M. Boyle's theorem on flip-conjugacy for $\mathbb{Z}$-actions.

We give an example of virtually piecewise conjugate profinite $\mathbb{Z}^2$-actions that are not topologically conjugate. We also show that the full group associated with a profinite action is amenable if and only if the acting group is amenable. This, in particular, implies that the topological full group of a product of $\mathbb{Z}$-odometers is amenable. (Received July 28, 2015)

1112-37-188 **Buddhi Pantha*** (pantha@math.utk.edu), 301 Woodlawn Pike, Apt E9, Knoxville, TN 37920, and **Suzanne Lenhart** and **Judy Day**. *Optimal Control in PDE/DE Model for an Anthrax Epizootic.* Preliminary report.

Anthrax is a rapidly fatal, infectious disease which occurs in many animal species, particularly herbivore mammals and is one of the main causes of population decline in several national parks worldwide. Since the anthrax spores

can survive in soil for a long time and the spores can be found in most parts of the world, clearing anthrax spores from the environment is practically impossible. In this project, we extend an existing mathematical model for anthrax epizootic by introducing two controls, vaccination and carcass disposal. Parameter values are estimated from real data. We investigate the effects of allocating efforts to vaccination and carcasses removal on disease transmission. We formulate the control problem and find the optimal control pair that minimizes density of carcass, environmental contamination and the cost of vaccination and carcass removal. Numerical simulations using the forward-backward sweep method are obtained. (Received August 03, 2015)

1112-37-206 **Jessica Dyer**, **Steven Hurder** and **Olga Lukina*** (lukina@uic.edu), 322 SEO (M/C 249), University of Illinois at Chicago, 851 S. Morgan St, Chicago, IL 60607. *Homogeneity of group actions on Cantor sets.*

An equicontinuous action of a group G on a Cantor set X can be represented by a decreasing chain of finite index subgroups G_i. Such a representation is not unique, depending on a number of factors. In this talk, we study classes of group chains, associated to conjugate actions. Using the properties of group chains, we classify the action by its degree of homogeneity. We introduce an invariant which distinguishes between the actions of different degree of homogeneity, and study the automorphism group for each type of the action. We give examples of the actions of the discrete Heisenberg group with various degrees of homogeneity. (Received August 04, 2015)

1112-37-208 **Bryna Kra*** (kra@math.northwestern.edu), Department of Mathematics, 2033 Sheridan Road, Evanston, IL 60201, and **Van Cyr**. *Shifts of low complexity.*

For shifts with complexity growth at most polynomial, the behavior is quite different than general shifts. Starting with the simplest case of linear complexity, we discuss various properties of the system, such as the automorphism group and the number of invariant measures. We then discuss how these properties change as the growth rate becomes quadratic or a higher order polynomial. (Received August 04, 2015)

1112-37-264 **E Arthur Robinson*** (robinson@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052, and **Joseph Rosenblatt** and **Ayse A Sahin**. *The spectrum of unit suspensions and embeddings for $\mathbb{Z}^d$ actions, and directional ergodic properties.* Preliminary report.

Let $T^{\vec{n}}$ be an ergodic $\mathbb{Z}^d$ action, $d \geq 1$, of a Lebesgue probability space. Let $\mathcal{T}^{\vec{t}}$ be the unit suspension of $T^{\vec{n}}$ (an $\mathbb{R}^d$ action), and let $T^{\vec{t}}$ be an embedding of $T^{\vec{n}}$ into an $\mathbb{R}^d$ action (it may not exist or may not be unique). Let $U_T^{\vec{n}}$, $U_{\mathcal{T}}^{\vec{t}}$ and $U_T^{\vec{t}}$ (respectively) be the corresponding unitary representations of $\mathbb{Z}^d$, $\mathbb{R}^d$ and $\mathbb{R}^d$ on L^2, and let σ_T, $\boldsymbol{\sigma}_{\mathcal{T}}$ and $\boldsymbol{\sigma}_T$ be the corresponding maximal spectral types on $\mathbb{T}^d$, $\mathbb{R}^d$, and $\mathbb{R}^d$ (respectively). If $\pi : \mathbb{R}^d \to \mathbb{T}^d$ is the exponential map, we show that $\sigma_T = \pi^*(\boldsymbol{\sigma}_{\mathcal{T}}) = \pi^*(\boldsymbol{\sigma}_T)$ (π^* is the push forward), and moreover $\boldsymbol{\sigma}_{\mathcal{T}} \sim \sigma_T * \delta_{\mathbb{Z}^d}$, so that $\boldsymbol{\sigma}_T \prec \boldsymbol{\sigma}_{\mathcal{T}}$ for any embedding $T^{\vec{t}}$. The proof uses tempered distributions. We discuss implications for directional ergodic properties. (Received August 06, 2015)

1112-37-307 **Jason Siefken***, siefkenj@math.northwestern.edu. *Explicit Return Times for a Subsystem of the Kari-Culik Tilings.*

A Wang tiling of the plane is a tiling of the plane by square tiles with colored edges satisfying the property that two tiles lie adjacent only if the colors on their shared edge match. In 1966, Berger found a set of 20426 Wang tiles that admit only aperiodic tilings of the plane. In 1995, Kari and Culik introduced a set of 13 Wang tiles that admit only aperiodic tilings of the plane. Unlike previous examples, these 13 Kari-Culik tiles exploit number-theoretic properties to ensure aperiodicity. This talk will give an overview of the Kari-Culik tilings as well as upper bounds on the return time of a minimal subsystem of the Kari-Culik tilings when treated as a $\mathbb{Z}^2$ dynamical system. (Received August 07, 2015)

1112-37-414 **Gheorghe Craciun*** (craciun@math.wisc.edu). *A proof of the Global Attractor Conjecture.*

In a groundbreaking 1972 paper Fritz Horn and Roy Jackson showed that a complex balanced mass-action system must have a unique locally stable equilibrium within any compatibility class. In 1974 Horn conjectured that this equilibrium is a global attractor, i.e., all solutions in the same compatibility class must converge to this equilibrium. Later, this claim was called the Global Attractor Conjecture, and it was shown that it has remarkable implications for the dynamics of large classes of polynomial and power-law dynamical systems, even if they are not derived from mass-action kinetics. Several special cases of this conjecture have been proved during the last decade. We describe a proof of the conjecture in full generality. In particular, it will follow that all detailed balanced mass action systems and all deficiency zero mass-action systems have the global attractor property. We will also discuss a generalization of this conjecture, called the Persistence Conjecture, and some

implications for biochemical mechanisms that implement noise filtering and cellular homeostasis. (Received August 10, 2015)

1112-37-486 **David M McClendon*** (mcclend2@ferris.edu), ASC 2021, Department of Mathematics, Big Rapids, MI 49307. *More on speedups of ergodic $\mathbb{Z}^d$-actions.*

This is a continuation of the talk given by Aimee S.A. Johnson, in which the notion of "speedup" of an action of $\mathbb{Z}^d$ is described. This talk will discuss techniques used in the proofs of the results described in the Johnson lecture, and will describe examples of systems with interesting properties. (Received August 10, 2015)

1112-37-513 **Wenbo Sun*** (math@math.northwestern.edu), 2033 Sheridan Road, Mathematics Department, Evanston, IL 60208. *Face transformations on dynamical cubes and its applications.*

The dynamical cube is a topolocigal structure developed recently in the study of the structure theorem on topological dynamical systems. This structure has various applications including charactering topological systems, computing automorphism groups, and even the convergence problem for multiple averages. In this talk, I will introduce the recent development of this subject and some of its applications. This is joint work with Sebastian Donoso. (Received August 10, 2015)

1112-37-515 **Aijun Zhang*** (zhang0aijun@hotmail.com) and **Yixin Guo**. *Traveling Pulses in a Lateral Inhibition Neural Network.*

We study the spatial propagating dynamics in a neural network of excitatory and inhibitory populations. Our study demonstrates the existence and nonexistence of traveling pulse solutions with a nonsaturating piecewise linear gain function. We prove that traveling pulse solutions do not exist for such neural field models with even(symmetric) couplings. The neural field models only support traveling pulse solutions with asymmetric couplings. We also show that such neural field models with asymmetric couplings will lead to a system of delay differential equations. We further compute 1-bump traveling pulse solutions using the system of delay differential equations. Finally, we develop Evans functions to assess the stability of 1-bump traveling pulse solutions. (Received August 10, 2015)

1112-37-617 **Grace Work*** (work2@illinois.edu), 1409 W. Green Street, Urbana, IL 61801. *Constructing transversals to horocycle flow.*

We will use zippered rectangle coordinates to construct a transversal to horocycle flow in $\mathcal{H}(2)$, the stratum of genus 2 translation surfaces with one singular cone points. We will then show how we can bound the return time of a surface to this stratum. This has applications to computing the gap distributions between slopes of saddle connections. (Received August 11, 2015)

1112-37-618 **Caglar Uyanik** (cuyanik2@illinois.edu), 1409 W. Green Street, Urbana, IL 61801, and **Grace Work*** (work2@illinois.edu), 1409 W. Green Street, Urbana, IL 61801. *Gap distribution for saddle connections on the octagon.*

Following a strategy developed by Athreya and Cheung, we compute the gap distribution of the slopes of saddle connections on the octagon by translating the problem to a question about return times of the horocycle flow to an appropriate Poincaré Section. This same strategy was used by Athreya, Chaika, and Lelièvre to compute the gap distribution on the Golden L. The octagon is the first example of this type of computation where the Veech group has two cusps. (Received August 11, 2015)

1112-37-624 **Michael H. Schraudner*** (mschraudner@dim.uchile.cl), Centro de Modelamiento Matemático, Universidad de Chile, Beaucheff 851, Torre Norte, Of. 709, Santiago, 8370459. *On automorphism groups of "small" subshifts.* Preliminary report.

We study the structure of the automorphism group of certain classes of "small" (i.e. countable, minimal or finite-Cantor-Bendixson-rank) subshifts over finitely presented groups together with the changes these automorphism groups undergo when "extending" the subshifts by introducing new symbols, taking unions, forming products, Cantor-Bendixson derivatives etc. For several interesting examples we can completely describe their automorphism group. The obtained results show drastic differences to the well known results on the structure of the automorphism groups of (mixing) $\mathbb{Z}$-shifts of finite type obtained by Boyle, Lind, Rudolph (1988) and Kim, Roush (1990s).

This is a preliminary report about ongoing joint work with Ville Salo (CMM, U. de Chile). (Received August 11, 2015)

1112-37-626 **Stefan Adams**, **Raimundo Briceno**, **Brian Marcus** and **Ronnie Pavlov*** (rpavlov@du.edu). *Computation of topological entropy for $\mathbb{Z}^d$ shifts of finite type.*

It has been well-known for some time that the topological entropy of a $\mathbb{Z}^d$ shift of finite type may have no closed form, and in fact may even be noncomputable. For this reason, it's worthwhile to find provable approximation schemes for the topological entropy of such systems. I will give a brief survey of hypotheses which allow for approximation schemes for entropy, with varying computation times. The best such results typically leverage uniqueness of the measure of maximal entropy for the system, but I will conclude by outlining recent joint work (with Adams, Briceno, and Marcus) which allows for efficient approximation for some systems where the measure of maximal entropy is not unique. (Received August 11, 2015)

1112-37-652 **Van Cyr*** (van.cyr@bucknell.edu), 361 Olin Science Building, Department of Mathematics, Bucknell University, Lewisburg, PA 17837, and **Bryna Kra** (kra@math.northwestern.edu), 224 Lunt Hall, Department of Mathematics, Northwestern University, Evanston, IL 60208. *Growth in the automorphism group of a minimal subshift.*

The automorphism group of a symbolic dynamical system (X, σ) is the group of homeomorphisms of X that commute with σ. For positive entropy subshifts, this group is often extremely complicated. This can be interpreted as a manifestation of the "high complexity" of these shifts.

In this talk I will discuss joint work with B. Kra in which we study the algebraic properties of the automorphism group of minimal subshifts with "low complexity." As an application of our results, we obtain the amenability of $Aut(X)$ for a broad class of subshifts. (Received August 11, 2015)

40 ► Sequences, series, summability

1112-40-107 **Ranjan Roy*** (royr@beloit.edu). *Newton's Work in Infinite Series.*

In the winter of 1664–65, Newton conjectured the infinite power series expansion of a binomial raised to a fractional power. Within two to three years, he verified a few cases of this formula by multiplication of series. By 1669, he had developed the theory of infinite power series by viewing these series as analogs of real numbers expressed as decimals. This analogy helped him to discover the implicit function theorem. (Received July 23, 2015)

45 ► Integral equations

1112-45-308 **Tadele Mengesha*** (mengesha@utk.edu), University of Tennessee Knoxville. *Multiscale analysis of linear nonlocal evolution equations.*

The method of two scale convergence is implemented to study the homogenization of time-dependent nonlocal continuum models of heterogeneous media. Two integro-differential models are considered: the nonlocal convection-diffusion equation and the state-based peridynamic model in nonlocal continuum mechanics. The asymptotic analysis delivers both homogenized dynamics as well as strong approximations expressed in terms of a suitable corrector theory. The method provides a natural analog to that for the time-dependent local PDE models with highly oscillatory coefficients with the distinction that the driving operators considered in this work are bounded. This is a joint work with Qiang Du of Columbia University and Robert Lipton of Louisiana State University. (Received August 07, 2015)

1112-45-508 **Petronela Radu*** (pradu@math.unl.edu), Lincoln, NE 68588, and **Grozdena Todorova** (todorova@math.utk.edu) and **Boris Yordanov**. *Diffusion phenomenon and decay rates for nonlocal wave equations with damping.*

Nonlocal wave equations with damping have only recently started to be explored in the context of peridynamics and other theories that allow solutions to be discontinuous. In this talk I will focus on results that connect the asymptotic behavior of solutions to dissipative wave equations to solutions of the corresponding diffusion equations, more precisely, show that the abstract diffusion phenomenon takes place. The results hold true in fact for systems that involve two non-commuting self-adjoint operators in a Hilbert space. When the diffusion semigroup has the Markov property and satisfies a Nash-type inequality, we obtain precise estimates for the consecutive diffusion approximations and remainder. Also, I will present some applications including sharp decay estimates for dissipative hyperbolic equations with variable coefficients on an exterior domain. To our knowledge we have obtained the first decay estimates for nonlocal wave equations with damping terms; the decay

rates are sharp. Some of these results have been obtained in collaboration with Grozdena Todorova and Boris Yordanov. (Received August 10, 2015)

46 ► Functional analysis

1112-46-102 **Jiun-Chau Wang*** (jcwang@math.usask.ca), 106 Wiggins Road, Saskatoon, SK S7N5E6, Canada. *Infinite divisibility in bi-free probability theory.* Preliminary report.

We will discuss recent progress in the study of infinitely divisible laws in Voiculescu's bi-free probability. The results are joint with Hao-Wei Huang. (Received July 23, 2015)

1112-46-104 **Paul Skoufranis*** (pskoufra@math.tamu.edu). *Operator-Valued Bi-Freeness and Bi-Matrix Models.*

Since the notion of bi-free pairs of faces was introduced by Voiculescu a couple of years ago, substantial work has been performed surrounding this concept. In this talk, the general framework for operator-valued bi-freeness (joint work with Ian Charlesworth and Brent Nelson) and bi-matrix models will be discussed. (Received July 23, 2015)

1112-46-126 **Michael Anshelevich*** (manshel@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843-3368, and **Octavio Arizmendi** (octavio@cimat.mx), Centro de Investigación en Matemática, Guanajuato, Mexico. *The exponential homomorphism in non-commutative probability.* Preliminary report.

The wrapping transformation is easily seen to intertwine convolutions of probability measures on the real line and the circle. It is also easily seen to *not* transform additive free convolution into the multiplicative one. However, we show that on a large class $\mathcal{L}$ of probability measures on the line, wrapping does transform not only the free but also Boolean and monotone convolutions into their multiplicative counterparts on the circle. This allows us to prove various identities between multiplicative convolutions by simple applications of the additive ones. The restriction of the wrapping to $\mathcal{L}$ has several other unexpected nice properties, for example preserving the number of atoms. (Received July 27, 2015)

1112-46-390 **Ionut Chifan**, **Rolando de Santiago** and **Thomas Sinclair*** (tsincla@purdue.edu). *W^*-rigidity for products of hyperbolic groups.*

We show that if $\Gamma = \Gamma_1 \times \cdots \times \Gamma_n$ is a product of $n \geq 2$ non-elementary ICC hyperbolic groups then any discrete group Λ which is W^*-equivalent to Γ decomposes as a k-fold direct sum exactly when $k = n$. This gives a group-level strengthening of Ozawa and Popa's unique prime decomposition theorem by removing all assumptions on the group Λ. This result in combination with Margulis' normal subgroup theorem allows us to give examples of lattices in the same Lie group which do not generate stably equivalent II_1 factors. (Received August 09, 2015)

1112-46-470 **Brent A Nelson*** (brent@math.berkeley.edu). *An example of full von Neumann algebras under non-tracial finite free Fisher information assumptions.*

Suppose M is a von Neumann algebra equipped with a faithful normal state φ and generated by a finite set $G = G^*$, $|G| \geq 3$. We show that if G consists of eigenvectors of the modular operator Δ_φ and has finite free Fisher information, then the centralizer M^φ is a II_1 factor without property Γ and M is a factor of type depending on the eigenvalues of G. We will also see that M is full when it is a type III_λ factor, $0 < \lambda < 1$. We use methods of Connes and Shlyakhtenko to establish the existence of diffuse elements in M^φ, followed by a contraction resolvent argument of Dabrowski to obtain the factoriality. The lack of property Γ in M^φ is obtained by studying a derivation arising from the free difference quotients of the generators, and applying a lemma of Curran, Dabrowski, and Shlyakhtenko. (Received August 10, 2015)

1112-46-520 **Isaac Goldbring** and **Thomas Sinclair*** (tsincla@purdue.edu). *Model theory and operator systems.*

In essence, operator systems are ordered Banach spaces X whose $n \times n$ matrix spaces $M_n(X)$ are equipped with natural compatible order structure. In this talk I will discuss how continuous model theory connects with and gives new insight into well-studied properties of operator systems as well as several open problems in the field. (Received August 10, 2015)

1112-46-528 **March Boedihardjo** and **Ken Dykema*** (kdykema@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77845. *Some distributions.* Preliminary report.

The talk will most probably be about some interesting new results on distributions arising from asymptotics of certain random matrices. At the time of the deadline for submitting the abstract, the proofs of these results are not yet written out in detail, but we hope to have definitive results in time for the talk. In the unfortunate event that our proofs don't work out, the talk will focus on some preliminary results on Fock spaces that have been finalized. (Received August 10, 2015)

1112-46-533 **Stephen Avsec*** (savsec@math.tamu.edu), Dept. of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843. *Noncommutative Gaussian Functors and Their Symmetries.*

The classical the Gaussian functor affiliates a sequence of orthonormal vectors in a (real) Hilbert space to a sequence of iid standard Gaussian variables. This functor trivially proves one direction of Freedman's Theorem, which states that an infinite sequence of random variables is rotatable (invariant under the action of each orthogonal group) if and only if it is a sequence of iid standard Gaussian variables. In this talk, we will examine noncommutative analogues of the Gaussian functor as well as of Freedman's theorem. Time permitting, we will discuss the quantum rotatable case and half-liberated rotatable case. This talk will include some joint work with M. Junge. (Received August 11, 2015)

1112-46-649 **Buthinah A Bin Dehaish*** (bbendehaish@kau.edu.sa). *Mann iteration presses for a new approach of nonexpansive mappings.*

Abstract Let (X,||.||) be a Banach space. Let C be a nonempty, bounded, closed, and convex subset of X and T:C→C be a monotone nonexpansive mapping. In this talk we will shown that a technique of Mann is fruitful in finding a fixed point of monotone nonexpansive mappings. (Received August 11, 2015)

47 ► Operator theory

1112-47-9 **Kaleem Raza Kazmi**, Aligarh, India, and **Shakeel Ahmad Alvi*** (salvi@kfu.edu.sa), Al-Ahsa, Eastern Pr , Saudi Arabia. *On Parametric Generalized Implicit Quasi Variational-like Inclusion Problem.* Preliminary report.

This paper deals with the behaviour and sensitivity analysis of the solution set of a parametric generalized implicit quasi-variational-like inclusion involving strongly maximal P-η-monotone mapping are studied in real Hilbert space. Further, the Lipschitz continuity of the solution set with respect to the parameter has been discussed under some mild conditions. The technique and results presented in this paper extend the techniques and corresponding results given in [2,7- 10,20,21]. (Received April 12, 2015)

1112-47-122 **John D. Williams*** (williams@math.uni-sb.de), Universität des Saarlandes, Mathematic Postfach 151150, 66041 Saarbrücken, Germany. *B-Valued Free Convolution for Unbounded Operators.*

Consider the $\mathcal{B}$-valued probability space $(\mathcal{A}, E, \mathcal{B})$, where $\mathcal{A}$ is a tracial von Neumann algebra. We extend the theory of operator valued free probability to the algebra of affiliated operators $\tilde{\mathcal{A}}$. For a random variable $X \in \tilde{\mathcal{A}}^{sa}$ we study the Cauchy transform G_X and show that the operator algebra $(\mathcal{B} \cup \{X\})''$ can be recovered from this function. In the case where $\mathcal{B}$ is finite dimensional, we show that, when $X, Y \in \tilde{\mathcal{A}}^{sa}$ are assumed to be $\mathcal{B}$-free, the $\mathcal{R}$-transforms are defined on universal subsets of the resolvent and satisfy

$$\mathcal{R}_X + \mathcal{R}_Y = \mathcal{R}_{X+Y}.$$

Examples indicating a failure of the theory for infinite dimensional $\mathcal{B}$ are provided. Lastly, we show that the class of functions that arise as the Cauchy transform of affiliated operators is, in a natural way, the closure of the set of Cauchy transforms of bounded operators. (Received July 27, 2015)

1112-47-210 **Chunping Xie*** (xie@msoe.edu), Math Department, Milwaukee School of Engineering, 1025 N. Broadway, Milwaukee, WI 53202. *Hardy Type Commutators on Function Spaces.* Preliminary report.

The note deals with commutaors of the Hardy operator, Hardy type operators on Morrey spaces on R^+. We have proved that the commutators generated by Hardy operator and Hardy type operators with a BMO function b are bounded on the Morrey spaces. (Received August 04, 2015)

1112-47-256 **Kazimierz A. Goebel*** (goebel@hektor.umcs.lublin.pl), Institute of Mathematics, UMCS, 20-031 Lublin, Poland. *An example connected to convex functions theory.*

This short presentation, dedicated to Terry Rockafellar, contains an example of a convex function on nonreflexive Banach space with some special properties. Examples of continuous mappings having exotic behavior are constructed with the use of this function. (Received August 06, 2015)

1112-47-272 **Erin Griesenauer** and **Paul S. Muhly*** (paul-muhly@uiowa.edu), Department of Mathematics, University of iowa, Iowa City, IA 52242, and **Baruch Solel**. *Noncommutative Functions and Matrix Bundles.* Preliminary report.

Our objective is to show how noncommutative functions in the sense of "Foundations of Free Noncommutative Function Theory" by D. Kaliuzhnyi-Verbovetskyi and V. Vinnikov, can be studied profitably in terms of holomorphic sections of certain matrix bundles. (Received August 06, 2015)

1112-47-321 **Greg Knese*** (geknese@math.wustl.edu), Washington University in St. Louis, One Brookings Drive, Campus Box 1146, St. Louis, MO 63130. *Regularity of rational functions and extreme points.* Preliminary report.

We discuss non-tangential regularity properties of rational functions on the polydisk and the connection to the problem of characterizing the extreme points of the set of analytic maps from the polydisk to the right half plane normalized to map the origin to 1. (Received August 07, 2015)

49 ► Calculus of variations and optimal control; optimization

1112-49-58 **Francesca Agnese Prinari***, francesca.prinari@unife.it. *On the lower semicontinuity of L^∞-functionals.*

In this talk we discuss the weak* lower semicontinuity of a (supremal) functional of the form

$$F(V,B) = ess\sup_{x\in B} f(x, DV(x))$$

where $V \in W^{1,\infty}(\Omega,\mathbb{R}^d)$, Ω is a fixed open subset of $\mathbb{R}^N$ and $B \subset \Omega$ is open. Barron, Jensen and Wang show that, under suitable assumptions for f, the strong Morrey quasiconvexity is necessary and sufficient for the lower semicontinuity of a supremal functional. Moreover they raise the question if the strong Morrey quasiconvexity is equivalent to a weaker property referred to as weak Morrey quasiconvexity and they conjecture that this is not the case. Here we show that, under a continuity assumption on $f(\cdot,\Sigma)$, if $F(\cdot,B)$ is sequentially weakly* lower semicontinuous for every open set $B \subseteq \Omega$, then $f(x,\cdot)$ is rank-one level convex for every $x \in \Omega$. In particular every strong Morrey quasiconvex function is rank-one level convex. This result is applied to provide an example of a weak Morrey quasiconvex function which is not strong Morrey quasiconvex. Finally we discuss the L^p-approximation of a supremal functional F via Γ-convergence when f is a non negative and coercive Carathéodory function. (Received July 13, 2015)

1112-49-59 **Irene Fonseca*** (fonseca@andrew.cmu.edu), Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213, and **Gianni Dal Maso** and **Giovanni Leoni**. *Second Order Gamma-Convergence for the Modica-Mortola Functional.*

The asymptotic behavior of an anisotropic Cahn-Hilliard functional with prescribed mass and Dirichlet boundary condition is studied when the parameter that determines the width of the transition layers tends to zero. The first order term in the asymptotic development by Gamma-convergence is well-known, and is related to a suitable anisotropic perimeter of the interface. Here it is shown that, under usual assumptions, the second order term is zero, which gives an estimate on the rate of convergence of the minimum value. (Received July 13, 2015)

1112-49-77 **Peter Sternberg*** (sternber@indiana.edu), **Stan Alama**, **Lia Bronsard**, **Andres Contreras** and **Jiri Dadok**. *A degenerate isoperimetric problem and traveling waves to a Hamiltonian bi-stable system.*

We analyze a non-standard isoperimetric problem in the plane associated with a metric having degenerate conformal factor at two points. Under certain assumptions on the conformal factor, we establish the existence of curves of least length under a constraint associated with enclosed Euclidean area. As a motivation for and application of this isoperimetric problem, we identify these isoperimetric curves, appropriately parametrized, as traveling wave solutions to a bi-stable Hamiltonian system of PDE's. (Received July 16, 2015)

1112-49-146 **Bao Q Truong*** (btruong@nmu.edu), 1401 Presque Isle Ave, Marquette, MI 49855. *A blended proof of the vectorial Ekeland variational principle.*

This talk discusses a blended proof of a vectorial Ekeland variational principle. It bases on the nonlinear scalarization functional in Tammer (Gerth) and Weidner's nonconvex separation theorem widely used in the scalarization approach (Gerth (Tammer), C., Weidner, P.: Nonconvex separation theorems and some applications in vector optimization. J. Optim. Theory Appl. 67 (1990) 297–320)) and on an iterative scheme in (Bao T.Q., Mordukhovich B.S.: Relative Pareto minimizers for multiobjective problems: existence and optimality conditions. Math. Progr. 122 (2010) 301–347) developed in the variational approach. It is important to emphasize that this new proof works well even in the case where the ordering cone of the partial ordering image space has an empty interior. Illustrative examples are provided. (Received July 29, 2015)

1112-49-158 **Tan Hoang Cao** (hoangtan2811@gmail.com), 641 Prentis Street, apt 111, Detroit, MI 48201, and **Boris Mordukhovich*** (boris@math.wayne.edu), Wayne State University, Department of Mathematics, 656 W Kirby Rm 1150 Admin Bldg, Detroit, MI 48202. *Optimal control of the perturbed sweeping process over polyhedral controlled set.* Preliminary report.

The paper addresses a new class of optimal control problems governed by the dissipative non-Lipschitzian differential inclusion of the perturbed sweeping/Moreau process over a moving controlled polyhedral set. Besides the highly non-Lipschitzian nature of the unbounded differential inclusion of the controlled perturbed sweeping process, the optimal control problems under consideration contain intrinsic state constraints of the inequality and equality types. All of this creates serious challenges for deriving necessary optimality conditions. We first establish the strong convergence of optimal solutions of discrete approximations to a local minimizer of a continuous-time system and obtain necessary conditions for discrete counterparts of the controlled sweeping process under consideration. And then we derive constructive necessary conditions for the original sweeping process problem expressed entirely in terms of the data and the reference trajectory. Our approach to necessary optimality conditions is based on the method of discrete approximations and generalized differential tools of variational analysis. The established necessary optimality conditions for the perturbed sweeping process are illustrated by some nontrivial examples. (Received July 30, 2015)

1112-49-182 **Dean A. Carlson*** (dac@ams.org), American Mathematical Society, Mathematical Reviews, 416 Fourth Street, Ann Arbor, MI 48103. *Property (D) and the Lavrentiev Phenomenon.*

In 1926 M.Lavrentiev gave an example of a free problem in the calculus of variations for which the infimum over the class of functions in $W^{1,1}[t_1, t_2]$ satisfying prescribed end point conditions was strictly less than the infimum over the dense subset of admissible functions in $W^{1,\infty}[t_1, t_2]$. After Lavrentiev's discovery L.Tonelli and B.Mania gave sufficient conditions under which this phenomenon does not arise. After these results, the study of the Lavrentiev phenomenon lay dormant until the 1980s when a series of papers by Ball and Mizel and by Clarke and Vinter gave a number of new examples for which the Lavrentiev phenomenon occurred. Also in 1979, T.S. Angell showed that the Lavrentiev phenomenon did not occur if the integrands satisfy a certain analytic property known as property (D). Since Angell's result there have been several papers that have discussed the nonoccurence of the Lavrentiev phenomenon for free problems in the calculus of variations. The purpose of this paper is two-fold. First to present a general approach to the proofs of these later papers which unifies the results, and second to show that the extra conditions imposed on the integrands insure property (D) holds with respect to the relevant sequence. (Received August 02, 2015)

1112-49-212 **Boris Mordukhovich** (aa1086@wayne.edu), Department of Mathematics, 1264 Faculty/Administration Building, 656 W. Kirby, Detroit, MI 48202, and **Ebrahim Sarabi*** (ebrahim.sarabi@gmail.com), Department of Mathematics, 1264 Faculty/Administration Building, 656 W. Kirby, Detroit, MI 48202. *Second-order analysis of piecewise linear functions with applications to stability.*

We present relationships between nondegeneracy and second-order qualification for fully amenable compositions involving piecewise linear functions. Moreover, we consider new applications of the developed second-order subdifferentials for convex piecewise linear functions to full stability in composite optimization and constrained minimax problems. (Received August 04, 2015)

1112-49-216 **J. Yunier Bello Cruz** and **Nghia Tran*** (nttran@oakland.edu). *On the convergence of the proximal forward-backward splitting method with linesearches.*

In this talk we focus on the convergence analysis of the proximal forward-backward splitting method for solving nonsmooth optimization problems in Hilbert spaces when the objective function is the sum of two convex

functions. Assuming that one of the functions is Fréchet differentiable and using two new linesearches, the weak convergence is established without any Lipschitz continuity assumption on the gradient. Furthermore, we obtain many complexity results of cost values at the iterates when the stepsizes are bounded below by a positive constant. (Received August 04, 2015)

1112-49-246 **Daniel Phillips*** (phillips@purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47906. *Chevrons in Smectic Liquid Crystals.* Preliminary report.

Smectic liquid crystals self-organize into layers restricted only in that the molecules tilt so as to form a fixed angle with the layer normal. If an electric field is applied to the liquid crystal material the molecules and layer structure reorganizes. This system is characterized by a very nonlinear energy with several small parameters. In earlier work (joint with Lei Cheng) we analyzed the gamma limit for this problem and determined the limit's molecule and layer patterns, and the layer defect structure (the chevrons).

Here we examine the limiting patterns when a more complete electrostatic energy is included. (Received August 05, 2015)

1112-49-253 **Alex Olshevsky*** (aolshev2@illinois.edu), 104 S. Matthews Ave, Urbana, IL 61801, and **Angelia Nedich**, 104 S. Matthews Ave, Chicago, IL 61801. *Optimization over Directed Graphs.*

We consider the problem of optimizing a sum of convex functions in a network where each node knows only one of the functions. Further, we assume that the nodes can only communicate with neighbors in some time-varying sequence of directed graphs. We develop a version of the stochastic gradient method which is fully decentralized and, up to logarithmic factors, achieves the optimal error decay with number of iterations. (Received August 05, 2015)

1112-49-322 **Zhimin Peng**, **Yangyang Xu**, **Ming Yan*** (yanm@math.msu.edu) and **Wotao Yin**. *ARock: an Algorithmic Framework for Asynchronous Parallel Coordinate Updates.*

The problem of finding a fixed point to a nonexpansive operator is an abstraction of many models in numerical linear algebra, optimization, and other areas of scientific computing. To solve this problem, we propose ARock, an asynchronous parallel algorithmic framework, in which a set of agents (machines, processors, or cores) update randomly selected coordinates of the unknown variable in an asynchronous parallel fashion. The resulting algorithms are not affected by load imbalance. When the coordinate updates are atomic, the algorithms are free of memory locks.

We show that if the nonexpansive operator has a fixed point, then with probability one, the sequence of points generated by ARock converges to a fixed point of the operator. Stronger convergence properties such as linear convergence are obtained under stronger conditions. As special cases of ARock, novel algorithms for linear systems, convex optimization, machine learning, distributed and decentralized optimization are introduced with provable convergence. Very promising numerical performance of ARock has been observed. Considering the paper length, we present the numerical results of solving linear equations and sparse logistic regression problems. (Received August 07, 2015)

1112-49-454 **Bingwu Wang*** (bwang@emich.edu), 515 Pray-Harrold Building, Eastern Michigan University, Ypsilanti, MI. *On the Weak Differentiability in Variational Analysis.*

The talk involves the weak differentiability of functions between Banach spaces, which corresponds to the differentiability of the scalarizations of the functions. We will review basic results of this notion and explore its applications to generalized differentiation in variational analysis. In this way we demonstrate that this notion and its variant, in contrast to the usual differentiability, are more suitable for Fréchet and limiting/Mordukhovich constructions. (Received August 10, 2015)

1112-49-510 **Terry Rockafellar*** (rtr@uw.edu), Department of Mathematics Box 354350, University of Washington, Seattle, WA 98195-4350. *Applying Variational Analysis to the Stability of Economic Equilibrium.*

A fundamental topic in economics is the existence of prices which induce the agents who buy and sell goods to act in such a way that supply will equal demand. Along with existence, however, there are important questions of uniqueness, at least in some localized sense, and whether the local equilibrium then responds stably to perturbations of the resources. Economists got some very discuraging news about whether those questions could ever have reasonable answers, but this turns out to be due in part to an inadequate view of what local should mean. Now, with the help of powerful tools in variational analysis, brought to bear on variational inequality models of equilibrium, surprisingly positive results have been achieved. (Received August 10, 2015)

1112-49-641 **Charles K Smart*** (smart@math.uchicago.edu). *Explicit solutions of some degenerate elliptic equations.*

The scaling limit of the Abelian sandpile is a degenerate elliptic partial differential equation with strong algebraic structure. I will discuss a large family of piecewise quadratic solutions and qualitative properties of general solutions. (Received August 11, 2015)

1112-49-669 **Yuri S. Ledyaev*** (ledyaev@wmich.edu), Department of Mathematics, Western Michigan University, 1903 W Michigan Ave, Kalamazoo, MI 49008. *Optimal control under finite set of evolution scenarios.* Preliminary report.

We consider a problem of control under uncertainty. This uncertainty is modeled by a finite set of scenarios of dynamic evolution of some system parameter. We develop mathematical techniques for derivation of optimality condition characterizing optimal control quasi-strategy. We demonstrate how such optimality conditions can be used for designing model predicting feedback control. (Received August 11, 2015)

51 ► Geometry

1112-51-7 **Joel Clarke Gibbons*** (jgibbons@chicagobooth.edu), P.O. Box 63, Saint Joseph, MI 49085, and **Yusheng Luo** (yusheng@nus.edu). *Colorings of the n-sphere and Inversive Geometry.*

This paper shows that in dimensions n > = 2, for any partition of the set of points in the standard unit n-sphere Pn in R(n+1) into (n + 3) or more nonempty sets, there exists a hyperplane in R(n+1) that intersects at least (n+2) of these sets. This result is used to prove a result in inversive geometry. A mapping T : S2 -> Sn, for n>= 2, not assumed continuous or even measurable, is called weakly circle-preserving if the image of any circle is contained in some circle in the range space Sn. If such a map T has a range T(S2) in circular general position, meaning that any circle in Sn misses at least two points of T(S2), then T must be a Möbius transformation of S2. (Received March 24, 2015)

1112-51-101 **Aaron Naber***, 2033 Sheridan Road, Evanston, IL 60208. *Singular Sets of Harmonic Maps and Minimal Surfaces.*

If $f : M \to N$ is a stationary harmonic map, then it is well understood how to stratify M by the singular set of f given by $S^k(f)$. Roughly, $S^k(f)$ is the collection of points in M such that no tangent map of f has $k+1$ degrees of symmetries. It is classical that dim $S^k(f) \leq k$, however little else is known in general. In this talk we discuss recent work which proves S^k is k-rectifiable. If f is minimizing, then we prove uniform $n-3$ measure bounds on $S(f)$. More effectively, we show $|\nabla f|$ has uniform estimates in weak L^3, which is sharp, as there are examples which do not live in L^3. The techniques involve an analysis of the recently introduced quantitative stratification, using a new energy covering argument, combined with a new rectifiable-Reifenberg result, and a new L^2-subspace approximation result for stationary harmonic maps. Similar statements are proved for integral currents with bounded mean curvature. This is joint work with Daniele Valtorta. (Received July 23, 2015)

1112-51-112 **Zahra Sinaei*** (sinaei@math.northwestern.edu). *Riemannian polyhedra and Liouville-type theorems for harmonic maps.*

In this talk we discuss harmonic maps from Riemannian polyhedra to locally non-positively curved geodesic spaces in the sense of Alexandrov. We present Liouville-type theorems for subharmonic functions and harmonic maps under two different assumptions on the source space. First we present the analogue of the Schoen-Yau Theorem on a complete pseudomanifolds with non-negative Ricci curvature. Then we discuss 2-parabolic admissible Riemannian polyhedra and present some vanishing results on them. (Received July 24, 2015)

1112-51-157 **Mariela Carvacho*** (mariela.carvacho@usm.cl), Avenida Espana1680, Valparaiso. *Isogenous decomposition of the Jacobian of generalized Fermat curves.*

A closed Riemann surface S is called a generalized Fermat curve of type (p, n), where $p, n \geq 2$ are integers, if it admits a group $H \cong \mathbb{Z}_p^n$ of conformal automorphisms so that S/H is an orbifold of genus zero with exactly $n+1$ cone points, each one of order p. It is known that S is a fiber product of $(n-1)$ classical Fermat curves of degree p and, for $(p-1)(n-1) > 2$, that it is a non-hyperelliptic Riemann surface. In this talk, assuming p to be a prime integer. We provide a decomposition, up to isogeny, of the Jacobian variety JS as a product of Jacobian varieties of certain cyclic p-gonal curves.

This is a joint work with Ruben Hidalgo and Saul Quispe. (Received July 30, 2015)

1112-51-348 **Joseph A. Vandehey*** (vandehey@uga.edu). *Continued fractions and the Heisenberg group.*

The connections between continued fractions and one-dimensional complex hyperbolic space are both classical and powerful, but both multi-dimensional continued fractions and higher-dimensional complex hyperbolic spaces are still comparatively mysterious. We will discuss some new work studying continued fractions on the Heisenberg group, their surprising strengths compared to other multi-dimensional continued fraction algorithms, and how these relate to complex hyperbolic space. Included in our discussion will be Diophantine approximation on the Heisenberg group and a study on points with periodic continued fraction expansions. (Received August 08, 2015)

1112-51-450 **Colleen Ackermann*** (ackrmnn2@illinois.edu), **Peter Haïssinsky** and **Aimo Hinkkanen**. *Using Equilateral Triangles to Show Mappings are Quasiconformal.*

Since quasiconformal mappings were first studied nearly a century ago, they have been applied in a wide variety of fields including complex dynamics, elliptic PDE's and Teichmüller theory. This may be due in part to the many diverse definitions of quasiconformal mappings, all of which are equivalent in the plane. In this talk, we will give a new sufficient condition for planar quasiconformality which relies only on the relative distances between the images of vertices of equilateral triangles. (Received August 10, 2015)

1112-51-452 **Kasra Rafi***, rafi@math.toronto.edu, and **David Dumas**, **Anna Lenzhen** and **Jing Tao**. *Thurston's Lipschitz metric on the Teichmüller space of the punctured torus.* Preliminary report.

Teichmüller space can be equipped with a metric using the hyperbolic structure of a Riemann surface, as opposed to the conformal structure that is used to define the Teichmüller metric. This metric, which is asymmetric, was introduced by Thurston and has not been studied extensively. However, it equips Teichmüller space with a distinctive and rich structure. We examine various aspects of the coarse and fine geometries of this metric. In the case of the punctured torus, we come close to reaching a detailed understanding of the space. (Received August 10, 2015)

1112-51-489 **Alex D Austin*** (alexander.austin@gmail.com). *Logarithmic Potentials and Quasiconformal Flows on the Heisenberg Group.* Preliminary report.

The Heisenberg group, $\mathbb{H}$, arises in several geometric settings, with descriptions suited to each. In this talk it is $\mathbb{R}^3$, with group product $uq = (u_1 + q_1, u_2 + q_2, u_3 + q_3 + 2(q_1u_2 - u_1q_2))$, homogeneous norm $\|(u_1, u_2, u_3)\| = ((u_1^2 + u_2^2)^2 + u_3^2)^{1/4}$, and metric $d(u, q) = \|q^{-1}u\|$.

We display a family of metrics on $\mathbb{R}^3$, which can be thought of as the Heisenberg metric d weighted with (the exponential of) a logarithmic potential. Given one of these metrics, we show it to be bilipschitz equivalent to d by constructing a quasiconformal mapping of $\mathbb{H}$ with Jacobian comparable to the weighting.

Construction of the quasiconformal mapping, following analogous work of Bonk, Heinonen, and Saksman in the Euclidean setting, uses quasiconformal flows. Along the way we extend the quasiconformal flow theory of Korányi and Reimann, establish a new variational equation, confront the limitations of conformal mappings on $\mathbb{H}$, and discover links to the radial stretch maps of Balogh, Fässler and Platis. (Received August 10, 2015)

1112-51-498 **David Fisher** and **Thang Nguyen*** (nguyentq@indiana.edu). *Quasi-isometry embeddings of non-uniform lattices.* Preliminary report.

Let G and G' be simple higher rank Lie groups of equal real rank. Let $\Gamma < G$ and $\Lambda < G'$ be non-uniform lattices. We prove that that with an appropriate condition on the Lie groups, any quasi-isometric embedding of Γ into Λ is at bounded distance from a homomorphism. For example, any quasi-isometric embedding of $SL(n, \mathbb{Z})$ into $SL(n, \mathbb{Z}[i])$ is at bounded distance from a homomorphism. We also discuss the cases when the condition is not satisfied which there exist counter examples of the result. (Received August 10, 2015)

52 ► Convex and discrete geometry

1112-52-165 **Hyun Jin Kim*** (hyunjin.sun.kim@gmail.com), Hofstra University, Hempstead, NY 11549-1000, and **Hyun Sun Kim**. *Special Configurations of Triangle Centers.*

For a given triangle, the circumcenter is the unique point in the plane of the triangle at equal distance from all three vertices. Similarly, the orthocenter is the point of intersection of the altitudes of the triangle. Euler proved that for any triangle, the midpoints of the sides, the feet of the altitudes and the midpoints of the segments joining the vertices of the triangle to the orthocenter lie on a circle. The center of this circle is the 9-point center of the triangle. We prove the following: Let A_1, A_2, A_3, A_4 be four points in the plane, no three on a

line, all four not on a circle. For all $1 \leq i \leq 4$, let O_i and ω_i be the circumcenters and the 9-point centers of triangle $A_{i+1}A_{i+2}A_{i+3}$, respectively. Then the four-point configurations (O_1, O_2, O_3, O_4) and $(\omega_1, \omega_2, \omega_3, \omega_4)$ are similar. Moreover, the similarity ratio is not constant but depends on the initial points A_i in a way that is made explicit.) There are many triangle centers: these special points can be defined either as the result of some geometric construction (as it is the case with the circumcenter, the orthocenter, and the 9-point center) or may just have a pure algebraic description as explained in the paper. (Received July 31, 2015)

1112-52-346 **Ivan Soprunov** (i.soprunov@csuohio.edu), 2121 Euclid Ave, Cleveland, OH 44115, and **Jenya Soprunova*** (soprunova@math.kent.edu), E Summit st, Kent, OH 44242. *Lattice geometry of toric codes.*

Fix a convex lattice polytope P in R^m, and define $\mathcal{L}(P)$ to be the $\mathbb{F}_q$-vector space spanned by the monomials whose exponent vectors lie in P. The codewords of a toric code are obtained by evaluating polynomials in $\mathcal{L}(P)$ at the points of the torus $(\mathbb{F}_q^*)^m$, taken in some fixed order. The question of computing or giving bounds on the minimum distance of toric codes has been studied by Hansen, Joyner, Little and Schenck, and others. In this talk, I will explain our results that demonstrate a strong connection between the minimum distance of a toric code and the geometry of its lattice polytope P.

The geometric invariant $L(P)$ that appears in our bounds on the parameters of toric codes is called the Minkowski length of a polytope P. It's defined to be the smallest number of primitive lattice segments whose Minkowski sum is in P. I will explain why $L(tP)$ is an eventually quasi-linear function in t. (Received August 08, 2015)

53 ► Differential geometry

1112-53-13 **Ovidiu Munteanu*** (ovidiu.munteanu@uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06268. *Ricci solitons.*

I will survey some recent development in the study of Ricci solitons. These are some generalizations of Einstein manifolds, and have proved to be very important for the study of the Ricci flow. They are classified in dimension two and three, but much less is understood in higher dimension. We will present some new results in dimension four, which show that the behavior of scalar curvature controls the geometry of the manifold. For example, we show that if the scalar curvature is bounded, then so is the Riemann curvature operator, and furthermore the curvature must be asymptotically non-negative, with an explicit decay rate at infinity. Furthermore, if the scalar curvature converges to zero at infinity, then the soliton must be asymptotically conical. Some extensions to arbitrary dimension can be obtained as well. This is joint with Jiaping Wang. (Received May 03, 2015)

1112-53-49 **Matthew J Gursky*** (mgursky@nd.edu), Department of Mathematics, 262 Hurley Hall, Notre Dame, IN 46530. *A Riemannian structure on space of conformal metrics.*

I will describe a Riemannanian structure on the space of conformal metrics satisfying a certain positivity condition. This metric is inspired by the Riemannian of the space of Kahler metrics, and shares many of the same properties. After defining the metric and deriving the geodesic equation, I will specialize to the case of two dimensions and prove some of the basic properties of the space. This is joint work with J. Streets (UC-Irvine). (Received July 06, 2015)

1112-53-168 **Bin Guo***, 2990 Broadway, New York City, NY 10027. *On the Kahler Ricci flow on projective manifolds of general type.*

We consider the Kähler Ricci flow on a smooth minimal model of general type, and we show that if the Ricci curvature is uniformly bounded below along the Kähler-Ricci flow, then the diameter is uniformly bounded. As a corollary we show that under the Ricci curvature lower bound assumption, the Gromov-Hausdorff limit of the flow is homeomorphic to the canonical model. (Received July 31, 2015)

1112-53-169 **Lu Wang***, 480 Lincoln Drive, Madison, WI 53706. *Geometry of Two-dimensional Self-shrinkers.*

In this talk, we will give an attempt to classify the asymptotic behaviors of two-dimensional complete non-compact properly embedded self-shrinkers with finite genus. (Received July 31, 2015)

1112-53-319 **Gregory R. Chambers*** (chambers@math.uchicago.edu). *Existence of homotopies with prescribed Lipschitz constants.*

Given Riemannian manifolds M and N, consider maps $f : M \to N$ and $g : M \to N$ which are homotopic and L-Lipschitz. Gromov asked the following question: Does there exist a homotopy from f to g which is itself

L-Lipschitz? In this talk, I will describe recent work with D. Dotterrer, F. Manin, and S. Weinberger which partially answers this question. I will also outline some interesting applications of our results. (Received August 07, 2015)

1112-53-320 **M T Mustafa*** (tahir.mustafa@qu.edu.qa), Mathematics, Statistics and Physics, Qatar University, Doha, 2713, Qatar. *Exact solutions and symmetry classification of wave equation on surfaces of revolution.*

A classification of surfaces of revolution according to their isometries was carried out by Eisenhart in 1925. We investigate the corresponding classification question for symmetries of wave equation, and obtain a complete classification of surfaces of revolution according to the symmetries of wave equation. The minimal symmetry algebras are utilized in a unified manner to obtain the solutions, in general integral form, for the wave equation on any surface of revolution. In particular, we compute examples of exact solutions of wave equation on surfaces in different classes of classification including surfaces admitting only minimal symmetry algebra as well as surfaces admitting extra symmetries. (Received August 07, 2015)

1112-53-583 **Andrew Zimmer*** (aazimmer@uchicago.edu). *Negative curvature in several complex variables.*

Any complex manifold has several intrinsic (but possibly degenerate) metrics: for instance the Kobayashi, Carathéodory, and Bergman metrics. In this talk we will describe when these metrics have negative curvature like behavior and give some applications to understanding the biholomorphism group of domains in $\mathbb{C}^n$. (Received August 11, 2015)

54 ► General topology

1112-54-218 **Jonathan Schneider*** (jschne9@uic.edu), Chicago, IL. *Welded surface-knots.* Preliminary report.

I will define and compare "welded 2-knot theory", which is a direct analog of the diagrammatic theory of welded 1-knots, and "virtually-regular welded 2-knot theory", which is an analog of Rourke's interpretation of welded 1-knots as fibered ribbon-torus knots. (Received August 04, 2015)

1112-54-601 **Alissa S. Crans*** (acrans@lmu.edu), Department of Mathematics, Loyola Marymount University, One LMU Drive, Suite 2700, Los Angeles, CA 90045. *Unital Shelves.* Preliminary report.

A shelf is a generalization of a rack whose single axiom,

$$(a \lhd b) \lhd c = (a \lhd c) \lhd (b \lhd c)$$

algebraically encodes the Third Reidmeister move. A unital shelf has the additional structure of an element "1" that satisfies:

$$a \lhd 1 = a \quad \text{and} \quad 1 \lhd a = a$$

It turns out that the shelf operation for unital shelves is associative! We will explore properties of unital shelves and their homology in this preliminary work with Mukherjee and Przytycki. (Received August 11, 2015)

1112-54-631 **Forrest Gordon*** (fgordo2@lsu.edu) and **Peter Lambert-Cole**. *Knot Floer homology of pretzel knots.*

A null-homologous knot K in a closed 3-manifold Y induces a filtration on the Heegaard Floer homology of Y, and the filtered homotopy type is a powerful knot invariant referred to as the knot Floer homology of K. In this talk, we consider the family of all pretzel knots $K = P(t_1, \ldots, t_n)$ in S^3. We describe the computation of the knot Floer homology groups and the accompanying concordance invariants of these knots. (Received August 11, 2015)

1112-54-657 **Matthew T Hogancamp*** (mhoganca@indiana.edu), Department of Mathematics, Rawles Hall, 831 E. Third st, Bloomington, IN 47405, and **Michael Abel**. *Stable homology of torus links, and a conjecture of Gorsky-Rasmussen.*

I will discuss recent work with Michael Abel in which we show that, for all integers n, m, the triply graded homology of the $(n, nk + m)$ torus link stabilizes as $k \to \infty$. We are able to compute the stable limit for all n, m, and we show that the result is isomorphic to a certain ring associated to a Hilbert scheme on $\mathbb{C}^2$, thereby proving a conjecture of Gorsky-Rasmussen. (Received August 11, 2015)

55 ► Algebraic topology

1112-55-60 **KaiHo Tommy Wong*** (wong@math.wisc.edu). *Alexander Invariant and Application to Milnor Fiber of Hyperplane Arrangements.*

The study of Milnor Fiber of Hyperplane Arrangement is very active. In particular, it is still remained unknown that the topology of the Milnor Fiber of a central arrangement in $\mathbb{C}^3$ is combinatorially determined by the intersection lattice.

By the means of Alexander Invariants, I will provide combinatorial upper bounds on the Betti numbers of the Milnor fiber of a central plane arrangement in $\mathbb{C}^3$. The obtained upper bounds are sharp in many cases. Comparisons to previously known results and examples will be provided. (Received July 13, 2015)

1112-55-61 **Yun Su*** (ysu@math.wisc.edu). *Higher-Order Degrees of Complex Hypersurface Complements.*

In this talk, I will define higher-order Alexander modules and higher-order degrees, which are invariants of the complement of a complex hypersurface. These invariants come from the module structure of the homology of certain solvable covers of the complements. Such invariants were originally developed by Cochran and Harvey, and were used to study knots and 3-manifolds. I will generalize the result proved by Maxim and Leidy for plane curves to higher-dimensional hypersurfaces. (Received July 13, 2015)

1112-55-83 **Bruce R Corrigan-Salter*** (brcs@wayne.edu). *Coefficients for higher order Hochschild cohomology.*

When studying deformations of an A-module M, Laudal and Yau showed that one can consider 1-cocycles in the Hochschild cohomology of A with coefficients in the bi-module $End_k(M)$. With this in mind, the use of higher order Hochschild (co)homology, presented by Pirashvili and Anderson, to study deformations seems only natural though the current definition allows only symmetric bi-module coefficients. In this talk we present an extended definition for higher order Hochschild cohomology which allows multi-module coefficients (when the simplicial sets $\mathbf{X}_\bullet$ are accommodating) which agrees with the current definition. Furthermore we determine the types of modules that can be used as coefficients for the Hochschild cochain complexes based on the simplicial sets they are associated to and give an example of deformations that can be described via higher order Hochschild cohomology. (Received July 18, 2015)

1112-55-91 **Sam Nelson*** (sam.nelson@cmc.edu). *Quantum Enhancements of Biquandle Counting Invariants.* Preliminary report.

Biquandles are algebraic structures related to knots. For every finite biquandle X there is an integer-valued knot and link invariant called the biquandle counting invariant. An enhancement is a stronger invariant which determines but is not determined by the counting invariant. In this talk we will discuss current work on enhancements defined analogously to quantum invariants. (Received July 21, 2015)

1112-55-99 **Mauro Spera*** (mauro.spera@unicatt.it), Dipartimento di Matematica e Fisica, Universita' Cattolica del Sacro Cuore, Via dei Musei 41, 25121 Brescia, Italy. *Geometry of some unitary Riemann surface braid group representations and Laughlin-type wave functions.*

In this talk a construction of the simplest unitary Riemann surface braid group representations is outlined via stable holomorphic vector bundles over complex tori and the prime form on Riemann surfaces. Generalised Laughlin wave functions are then introduced. The genus one case is discussed in more detail also with the help of noncommutative geometric and of Fourier-Mukai-Nahm techniques, in view of elucidating the emergence of an intriguing Riemann surface braid group duality. The talk is based on the paper "On the geometry of some unitary Riemann surface braid group representations and Laughlin-type wave functions" J.Geom.Phys. 94 (2015),120-140. (Received July 23, 2015)

1112-55-151 **Anthony Weaver*** (anthony.weaver@bcc.cuny.edu). *A coarse classification of elementary abelian p-group actions.*

Topological equivalence is the natural equivalence relation for groups acting on surfaces. However, the complexity of the topological classification problem grows rapidly with the group order. We construct a coarser classification which respects topological equivalence, but yields just finitely many types. Coarsely equivalent actions can occur in (infintely many) distinct genera.

Here we consider actions of Z_p^k, the elementary abelian p-group of rank $k > 1$, on compact surfaces of genus $g > 1$. For simplicity, we take $p = 2$, and assume the action has quotient genus 0 (neither assumption is essential). The coarse topological types are given by certain additive partitions of $R \geq 3$, the number of branch points;

the type is determined not by the partition itself, but by the numbers of odd and even parts of the partition. We give necessary and sufficient conditions for a partition type to determine a coarse Z_2^k action; this yields a count, depending only on the rank k, of the number of coarse classes. Examination of coarse classes with fixed R organizes and simplifies the classification of (ordinary) topological equivalence classes of Z_2^k actions.

This talk is based on joint work with Mariela Carvacho Bustamante. (Received July 30, 2015)

1112-55-232 **Huan T Vo***, University of Toronto, Canada. *On the $\mathfrak{sl}_2$ Weight System and Intersection Graphs.*

Given a chord diagram D, the value of the $\mathfrak{sl}_2$ weight system on the primitive part of D is a polynomial in c, the Casimir element of $\mathfrak{sl}_2$. It turns out that the coefficient of the highest power of c can be computed in terms of the intersection graph of D. This formula was first conjectured in a paper by Lando et al. In this talk, I will sketch a proof of this fact, which is a simple consequence of the Melvin-Morton-Rozansky conjecture. (Received August 05, 2015)

1112-55-416 **Mahmoud Zeinalian*** (mzeinalian@liu.edu), Dept of Mathematics, LIU Post, 720 Northern Blvd, Brookville, NY 11548. *Poisson geometry and Fricke-Klein coordinates on the moduli of local systems.* Preliminary report.

Length of the hyperbolic geodesic in a given free homotopy class of closed curves on a surface defines a function on the deformation space of hyperbolic structures. Poisson bracket of two such functions is intimately related to the hyperbolic geometry of the surface in several ways, for example through Wolpert's cosine formula. This line of thinking has been extended to the study of the deformation space of local systems in increasing levels of generality. I will describe how this fits into the study of the (2-d)-shifted symplectic structure on the moduli of infinity local systems of perfect complexes on a d-dimensional closed and oriented manifold. (Received August 10, 2015)

1112-55-420 **Seung Yeop Yang*** (syyang@gwu.edu) and **Jozef H. Przytycki**. *The torsion of rack and quandle homology groups of some finite quandles.*

It is a classical result in reduced homology of finite groups that the order of a group annihilates its homology. Similarly, we have proved that the torsion subgroup of rack and quandle homology of a finite quasigroup quandle is annihilated by its order. But it does not hold for connected quandles in general.

We prove that for some connected quandles, the order of their quandle inner automorphism groups annihilate the torsion parts of rack and quandle homology. We study as well annihilation of rack and quandle homology of some non-connected quandles. As a result, we partially solve the conjecture [M. Niebrzydowski, J. H. Przytycki, Homology operations on homology of quandles, Journal of Algebra, 324, 2010, 1529-1548, Conjecture 14] that the number k annihilates $\mathrm{tor}H_n(R_{2k})$, unless $k = 2^t, t > 1$. (Received August 10, 2015)

1112-55-431 **Manuel Gonzalez Villa*** (villa@math.wisc.edu), **Anatoly Libgober** and **Laurentiu Maxim**. *Motivic zeta functions and infinite cyclic covers.* Preliminary report.

We associate with an infinite cyclic cover of a punctured neighborhood of a simple normal crossing divisor on a complex quasi-projective manifold (assuming certain finiteness conditions are satisfied) a rational function with coefficients in the localized Grothendieck ring of algebraic varieties over the complex numbers and a motive in Grothendieck ring. We show the birational invariance of both objects and discuss, among other aspects, their relations with the motivic zeta functions and motivic Milnor fibers of and Denef and Loeser. (Received August 10, 2015)

1112-55-487 **Micah Chrisman** and **Robert G. Todd*** (rtodd@mtmercy.edu). *Milnor's triple linking and Index.* Preliminary report.

A. Henrich, in constructing a Vassiliev invariant for virtual knots, defined the index of a classical crossing in a virtual knot diagram. The definition is combinatorial and has been used or modified to define several other invariants. Using the theory of virtual covers initiated by M. Chrisman we relate the index of a classical crossing to Milnor's triple linking number of a suitably defined 3 component link. (Received August 10, 2015)

57 ► Manifolds and cell complexes

1112-57-56 **Mustafa Hajij*** (mhajij1@lsu.edu), Louisiana State University, Baton Rouge, 70802. *q-Series Identities From Pretzel Links.* Preliminary report.

The tail of the colored Jones polynomial is a q-power series alternating knot invariant. It has been shown that the tail of the colored Jones polynomial of (2,p) torus knots give the Andrews Gordon identities for the two

variable Ramanujan theta function as well as corresponding identities for the false theta function. In this talk we show some q-series identities that one can obtain from pretzel links. (Received July 11, 2015)

1112-57-90 **Louis H Kauffman*** (kauffman@uic.edu), Math UIC, 851 South Morgan Street, Chicago, IL 60607-7045, and **Christopher Gomes** (cgomes2@uic.edu), Math UIC, 851 South Morgan Street, Chicago, IL. *An Application of the Dold-Kan Theorem to the Homotopy Theory of Link Homology.* Preliminary report.

We point out that the well-known Dold-Kan constructon in simplicial homotopy theory can be fruitfully applied to convert link homology theories into homotopy theories. We construct a mapping taking link diagrams to a category of simplicial objects such that up to looping or delooping, link diagrams related by Reidemeister moves will give rise to homotopy equivalent simplicial objects, and the homotopy groups of these objects will be equal to the link homolgy groups of the original link homology theory. The construction is independent of the particular link homology theory, applying equally well to Khovanov Homology and to Knot Floer Homology and other theories of these types. For Khovanov Homology, the associated simplical object is constructed directly via the cube category associated with a given knot or link. (Received July 21, 2015)

1112-57-120 **Charles D Frohman*** (charles-frohman@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242. *Positivity of the Kauffman Bracket Skein Algebra of the Torus.*

The Kauffman bracket skein algebra $S^{-1}K_N(T^2)$ of the torus at a $2N$th root of unity, localized to be an algebra over the function field of the character variety of the fundamental group of the torus is Frobenius. This gives rise to a pairing

$$\beta : K_N(T^2) \otimes K_N(T^2) \to \chi(T^2),$$

where $\chi(T^2)$ denotes the ring of $SL_2\mathbb{C}$-characters of the fundamental group of T^2.

Since $SU(2) \to Sl_2\mathbb{C}$ we can restrict $SL_2\mathbb{C}$-characters of $\pi_1(T^2)$ to be $SU(2)$ characters. We say that $f \in \chi(T^2)$ is positive if for every $\rho : \pi_1(T^2) \to SU(2)$, $f(\rho)$ is real and positive.

We prove that for all nonzero skeins $s \in K_N(T^2)$ that are real linear combinations of simple diagrams on the torus,

$$\beta(s, s) > 0$$

. (Received July 27, 2015)

1112-57-124 **Carmen L Caprau***, Department of Mathematics, California State University, Fresno, 5245 North Backer Avenue M/S PB 108, Fresno, CA 93740. *A Khovanov-type homology theory for singular knots and singular tangles.* Preliminary report.

We extend the Khovanov homology to singular tangles and singular knots or links. In doing so, we employ Bar-Natan's geometric approach to local Khovanov homology, but instead of classical 2-cobordisms modulo local relations we use 'disoriented' 2-cobordisms regarded modulo a finite set of local relations. (Received July 27, 2015)

1112-57-149 **Eugene Gorsky***, Department of Mathematics, UC Davis, One Shields Avenue, Davis, CA 95616, and **Jennifer Hom**. *Cable links and L-space surgeries.*

An L-space link is a link in S^3 on which all sufficiently large integral surgeries are L-spaces. We prove that a cable link is an L-space link if and if only each component is an L-space knot. We also compute HFL-minus and HFL-hat of an L-space cable link in terms of its Alexander polynomial. As an application, we confirm a conjecture of Licata regarding the structure of HFL-hat for (n, n) torus links. (Received July 30, 2015)

1112-57-163 **Christine Ruey Shan Lee*** (rueyshan.lee@icloud.com) and **Roland van der Veen**. *The Slope Conjecture and 3-string pretzel knots.*

For $2 \leq n < \infty$, let $d(n)$ be the degree of the nth-colored Jones polynomial $J^n_K(q)$ of a knot K. Garoufalidis' Slope Conjecture predicts that the limit points of the set $\{\frac{4d(n)}{n^2} : n \geq 2\}$ correspond to boundary slopes of a knot. So far, the Conjecture has been verified for several classes of knots including adequate knots and points to interesting relationships between the quantum invariant and incompressible surfaces in a knot complement. We discuss the proof of the Slope Conjecture for a new class of 3-string pretzel knots using the Hatcher-Oertel algorithm. (Received July 31, 2015)

1112-57-174 **Jozef H. Przytycki*** (przytyck@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *Curtain homology: 2-(co)cycle invariants from Yang-Baxter operators.*

Soon after discovery of his link polynomial in 1984, V.F.R.Jones gave an interpretation of his invariant (and the Homflypt polynomial) using statistical mechanics language involving Yang-Baxter operator $R : V \times V \to V \times V$ (R is invertible and satisfies $(R \otimes Id)(Id \otimes R)(R \otimes Id) = (Id \otimes R)(R \otimes Id)(Id \otimes R)$). The general approach to quantum link invariants via Yang-Baxter operators was developed by Jones and Turaev in 1987. We define homology of any Yang-Baxter operator and show how to obtain a 2-cocycle invariant of links, at least in the case of column probabilistic Yang-Baxter operator. These generalize the 2-cocycle constructed by Carter at al. for set theoretic Yang-Baxter operators (and for quandles). The key in our approach is that our homology, comes from precubic module with good visualization and that the third Reidemeister move can be interpreted as the third boundary operation written in the form $\partial_3 = d_1^0 + d_2^1 + d_3^0 - (d_1^1 + d_2^0 + d_3^1)$. In particular for two proportional Yang-Baxter operators, R and R' with $R_{c,d}^{a,b} = f(a,b)(R')_{c,d}^{a,b}$ we discuss the meaning of the 2 chain $f : V \otimes V \to k$. (Received August 01, 2015)

1112-57-186 **Dror Bar-Natan*** (drorbn@math.toronto.edu), Department of Mathematics, University of Toronto, 40 St. George St., Toronto, Ontario M5S2K3, Canada. *Polynomial Time Knot Polynomials.*

Abstrant: The value of things is inversely correlated with their computational complexity. "Real time" machines, such as our brains, only run linear time algorithms, and there's still a lot we don't know. Anything we learn about things doable in linear time is truly valuable. Polynomial time we can in-practice run, even if we have to wait; these things are still valuable. Exponential time we can play with, but just a little, and exponential things must be beautiful or philosophically compelling to deserve attention. Values further diminish and the aesthetic-or-philosophical bar further rises as we go further slower, or un-computable, or ZFC-style intrinsically infinite, or large-cardinalish, or beyond.

I will explain some things I know about polynomial time knot polynomials and explain where there's more, within reach.

Also see http://www.math.toronto.edu/drorbn/Talks/Loyola-1510/ (Received August 03, 2015)

1112-57-223 **Peter Feller*** (peter.feller.2@bc.edu). *The slice genus and the Alexander polynomial.*

We discuss differences between the smooth and the topological slice genus for knots. In particular, we compare the two notions for torus knots and two-bridge knots and present the following result: For all knots, the topological slice genus is bounded above by the degree of the Alexander polynomial. (Received August 04, 2015)

1112-57-241 **J Scott Carter*** (carter@southalabama.edu), Department of Mathematics and Statistics, ILB 325, Mobile, AL 36688. *Geometric, homological, and categorical considerations of local crossings of n-foams.*

An n-foam is a space that is locally modeled on a dual structure to an $(n+1)$-simplex. Their crossings are parametrized by means of binary sequences. Colorings of the crossings can be given in terms of so-called endomorphic quasigroups: sets that have two binary operations which satisfy certain associativity, distributivity, and self-distributivity conditions. From such colorings and from the local pictures, a homology theory is formed. These ideas will be sketched and a plethora of pictures will be presented. (Received August 05, 2015)

1112-57-261 **JungHwan Park*** (jp35@rice.edu). *A construction of slice knots via annulus modification.*

In this talk I will present a method of constructing slice knots from a fixed slice knot by doing surgeries on two curves which bound a standard annulus in the exterior of the slice disk. I will also talk about few applications. (Received August 06, 2015)

1112-57-267 **J. Scott Carter**, **Atsushi Ishii**, **Masahico Saito*** (saito@usf.edu) and **Kokoro Tanaka**. *Homology for quandles with partial group operations.*

A quandle is a set that has a binary operation satisfying three conditions corresponding to the Reidemeister moves. A multiple conjugation quandle is a union of groups with the quandle operation restricting to conjugation on each group component, satisfying certain compatibilities between the group and quandle operations. The definition is motivated for coloring handlebody-link diagrams. In this talk, a homology theory for multiple conjugation quandles is presented, that unifies group and quandle homology theories. Algebraic aspects, such as extensions, are discussed, and degenerate subcomplexes are defined. Cocycle invariants are defined for handlebody-links using this homology theory. (Received August 06, 2015)

1112-57-344 **Heather A Dye*** (heatheranndye@gmail.com). *Red-Black Khovanov Homology for Virtuals.*

This is a preliminary report on red-black Khovanov homology for virtuals. (Received August 08, 2015)

1112-57-373 **Radmila Sazdanovic*** (rsazdanovic@math.ncsu.edu), Department of Mathematics, North Carolina State University, Box 8205, Raleigh, NC 27695-8295, and **Adam M Lowrance**. *Khovanov homology, chromatic homology, and torsion.* Preliminary report.

We show that a suitable version of the chromatic polynomial categorification has no odd torsion. Then we use a partial isomorphism between the categorification of the chromatic polynomial of a graph and Khovanov homology of a related link in order to show that the Khovanov homology of a semi-adequate link has no odd torsion in prescribed gradings. (Received August 09, 2015)

1112-57-375 **Shida Wang*** (wang217@indiana.edu). *The genus filtration in the concordance group.*

We define a filtration of the smooth concordance group based on the genus of representative knots. We will explore some examples and give an obstruction using the invariants of epsilon equivalence classes defined by J. Hom. As a consequence, we will prove that the quotient groups with respect to this filtration contain an infinitely generated free summand of topologically slice knots. (Received August 09, 2015)

1112-57-382 **Allison N. Miller***, University of Texas, Austin, Department of Mathematics, RLM 8.100, 2515 Speedway Stop C1200, Austin, TX 78712. *Distinguishing mutant pretzel knots in concordance.*

The metabelian twisted Alexander polynomials developed by Kirk and Livingston provide powerful and computationally accessible obstructions to the topological sliceness of knots. In particular, they are among the few invariants known to be capable of distinguishing mutant knots in concordance. Lecuona and Long independently classified the smoothly slice 4-strand pretzel knots up to mutation. They showed that if $K = P(a, b, c, d)$ is smoothly slice then $\{a, b, c, d\} = \{2n, -2n \pm 1, m, -m\}$; that is, K is a mutant of a ribbon knot. However, there is no reason to believe that $K_{n,m} = P(2n, m, -2n \pm 1, -m)$ should be smoothly slice. We show via explicit computation of twisted Alexander polynomials that a large infinite family of these $K_{m,n}$ are not even topologically slice, providing further evidence for the slice-ribbon conjecture for 4-strand pretzel knots. (Received August 09, 2015)

1112-57-394 **Nicolas Petit*** (nicolas.petit.gr@dartmouth.edu), Dartmouth College, Dept of Mathematics, Hanover, NH 03755. *Vassiliev invariants of order one for framed virtual knots.*

A. Henrich discovered three Vassiliev invariants of order one for virtual knots, including a universal invariant, taking values in the free abelian group generated by homotopy classes of virtual strings with a singular point. In this talk we extend the construction of all three invariants to framed virtual knots; this will bring us to develop the notion of a framed virtual string and its associated based matrix. (Received August 09, 2015)

1112-57-419 **Moshe Cohen*** (mcohen@tx.technion.ac.il) and **Sunder Ram Krishnan**. *The probability of choosing the unknot among 2-bridge knots using random Chebyshev billiard table diagrams.*

Koseleff and Pecker showed that every knot can be parametrized as a generalized harmonic curve using Chebyshev polynomials and a single phase shift. These have diagrams that appear as nice trajectories on billiard tables. We present a truncated model for random knotting using these diagrams giving all 2-bridge knots together with the unknot. We determine the probability of choosing any of these knots.

This is joint work with Sundar Ram Krishnan.

Supported in part by the funding from the European Research Council under Understanding Random Systems via Algebraic Topology (URSAT), ERC-2012-ADG-20120216. (Received August 10, 2015)

1112-57-446 **Christopher K Atkinson*** (catkinso@morris.umn.edu), Division of Science and Mathematics, Science Building, 600 E. 4th St., Morris, MN 56267, and **David Futer** (dfuter@temple.edu), Department of Mathematics, 1805 N. Broad St., Philadelphia, PA 19122. *The lowest volume 3-orbifolds with high torsion.*

For each natural number $n \geq 4$, we determine the unique lowest volume hyperbolic 3–orbifold whose torsion orders are bounded below by n. This lowest volume orbifold has base space the 3–sphere and singular locus the figure–8 knot, marked n. We apply this result to give sharp lower bounds on the volume of a hyperbolic manifold or hyperbolic knot complement in terms of the order of elements in its symmetry group. (Received August 10, 2015)

1112-57-479 **Katherine Vance*** (kvance@rice.edu), Houston, TX. *A Tau invariant for links.*

In 2003, Ozsváth and Szabó defined the concordance invariant τ for knots in S^3 as part of the Heegaard Floer homology package. In 2011, Sarkar gave a combinatorial definition of τ and proof that τ gives a lower bound on the slice genus of a knot. We define a τ invariant for links. Using techniques similar to those of Sarkar, we show that the τ invariant can be an obstruction to a link being slice. (Received August 10, 2015)

1112-57-482 **Peter Feller** and **Arunima Ray*** (aruray@brandeis.edu), Brandeis University, Mathematics Department MS050, 415 South St, Waltham, MA 02453. *Independence of satellite knots in smooth concordance.* Preliminary report.

It was recently shown that 'strong winding number one' satellite operators give injective functions on the smooth knot concordance group, modulo the smooth 4–dimensional Poincaré Conjecture. Here we address the related question of whether such satellite operators preserve independence in the concordance group; in particular we confirm this for certain families of torus knots. This is of interest since A. Levine has recently shown that strong winding number one satellite operators may be non-surjective on the concordance group. We also give several related applications of our techniques. (Received August 10, 2015)

1112-57-484 **Daniel S Silver** and **Susan G Williams*** (swilliam@southalabama.edu). *Periodic plane graphs and medial link components.*

Let G be a connected, locally finite plane graph with a free $\mathbb{Z}^2$-action by automorphisms. Applying the medial link construction to G, we obtain a (generalized) link of infinitely many components, which may be unbounded. We associate to G a finitely generated module $C(G)$ over the ring of Laurent polynomials in two variables with mod 2 coefficients. The orbit structure of the components of the link under $\mathbb{Z}^2$ can be determined from the sequence of elementary divisors of $C(G)$. A presentation matrix for $C(G)$ is easily obtained from graph data. (Received August 10, 2015)

1112-57-485 **Daniel S Silver*** (silver@southalabama.edu), Department of Mathematics and Statistics, ILB 325, Mobile, AL 36608, and **Susan G Williams**. *Periodic graphs, spanning trees and Mahler measure.*

Motivated by techniques of knot theory and algebraic dynamical systems, we prove several results about connected, locally finite graphs G with free Z^d-action by automorphisms. For any such graph, a *Laplacian polynomial* $\Delta(G)$ in d variables is defined. Its logarithmic Mahler measure $m(\Delta(G))$ is a growth rate of spanning trees. When G is a lattice graph, this rate determines the so-called *thermodynamic limit* of G, usually computed by analytic methods rather than the algebraic ones used here.

We prove that $m(\Delta(G))$ is minimized by the standard d-dimensional grid graph G_d. We prove also that $m(\Delta(G_d))$ is asymptotic to $\log 2d$ as d goes to infinity. (Received August 10, 2015)

1112-57-499 **Tye Lidman** and **Steven Sivek***, Fine Hall, Washington Road, Princeton, NJ 08544. *Quasi-alternating links with small determinant.*

Quasi-alternating links of determinant 1, 2, 3, and 5 were previously classified by Greene and Teragaito, who showed that the only such links are two-bridge. We extend this result by showing that all quasi-alternating links of determinant at most 7 are connected sums of two-bridge links, which is optimal since there are quasi-alternating links not of this form for all larger determinants. We achieve this by studying their branched double covers and characterizing distance-one surgeries between lens spaces of small order, leading to a classification of formal L-spaces with order at most 7. (Received August 10, 2015)

1112-57-536 **Abhijit Champanerkar*** (abhijit@math.csi.cuny.edu), Department of Mathematics, College of Staten Island, CUNY, 2800 Victory Boulevard, Staten Island, NY 10314, **Ilya Kofman** (ikofman@math.csi.cuny.edu), Department of Mathematics, College of Staten Island, CUNY, 2800 Victory Boulevard, Staten Island, NY 10314, and **Jessica Purcell**, School of Mathematics, 1 Einstein Dr, Princeton, NJ 08540. *Density spectra for knots.*

In this talk we will explore the interactions between knot theory, hyperbolic geometry and graph theory. We study two natural quantities: the volume density defined as the hyperbolic volume of a knot complement per crossing number, a geometric invariant, and the determinant density defined similarly, a diagrammatic invariant. We will talk about recently discovered interesting relationships between the spectra of volume and determinant densities, and explore natural questions and conjectures motivated by this study. The techniques used in answering some of these questions involve an interesting blend of graph theory, dimer models and circle packings, in addition to geometric techniques such as polyhedral decomposition and volume bounds. This is joint work with Ilya Kofman and Jessica Purcell. (Received August 11, 2015)

1112-57-541 **Ina Petkova** (ina@math.columbia.edu) and **C.-M. Michael Wong*** (cmmwong@math.columbia.edu). *An unoriented skein exact triangle for tangle Floer homology.* Preliminary report.

Knot Floer homology, a link invariant with rich applications defined by Ozsváth–Szabó and Rasmussen, has been shown by Manolescu to satisfy an unoriented skein exact triangle. A combinatorial proof has later been provided by the second author. More recently, inspired by the work of Lipshitz–Ozsváth–Thurston on bordered Floer homology, Vera Vértesi and the first author have defined tangle Floer homology, a tangle invariant that satisfies a pairing theorem, recovering the knot Floer homology of a link obtained by gluing tangles. In this talk, we prove that an analogous skein exact triangle is satisfied by combinatorial tangle Floer homology, indicating concretely how this skein relation can be viewed as a local property of links. The proof is reminiscent of the combinatorial proof for knot Floer homology mentioned above. No prior knowledge is necessary for the talk, as a brief introduction to tangle Floer homology will be given. (Received August 11, 2015)

1112-57-560 **David Futer*** (dfuter@temple.edu) and **Christian Millichap**. *Geometrically similar knots.* Preliminary report.

This talk is motivated by the following question: how well do geometric invariants (such as hyperbolic volume and the length of geodesics) distinguish knot complements, or more general 3-manifolds?

There are several known ways to produce hyperbolic 3-manifolds that isospectral (i.e. have exactly the same spectrum of geodesic lengths) but not isometric. All known constructions of of this sort involve finite covers of the same base manifold, leading Reid to ask whether this is a necessary feature. That is, are isospectral manifolds necessarily commensurable? I will describe a way to build pairs of knot complements that are incommensurable but have the same closed geodesics up to length L, where L is as large as one likes. (Received August 11, 2015)

1112-57-604 **Heaher M Russell*** (hrussell@richmond.edu), **Alexander Madaus** and **Maisie Newman**. *Dehn coloring and the dimer model for knots.* Preliminary report.

Fox coloring provides a combinatorial framework for studying dihedral representations of the knot group. Dehn coloring captures the same data from the perspective of the Dehn rather than Wirtinger presentation. A recent paper of Carter-Silver-Williams discusses the relationship between the two coloring schemes focusing on how one transitions between them. In this talk, we review Dehn coloring and relate it to the dimer model for knots showing that Dehn coloring data is encoded by a certain weighting of the balanced overlaid Tait graph. Using Kasteleyn theory, one can compute coloring data using partition functions. These constructions are closely related to Kauffman's work on a state sum model for the Alexander polynomial. (Received August 11, 2015)

1112-57-639 **Andrew Donald** and **Faramarz Vafaee*** (vafaee@caltech.edu), 1200 East California Blvd., Pasadena, CA 91125. *A Slicing Obstruction From The 10/8 Theorem.*

A smooth slicing obstruction for knots in S^3 can be derived from Furuta's 10/8 theorem using spin 4-manifold whose boundary is 0-surgery on a knot. We show that this obstruction is able to detect torsion elements in the smooth concordance group and find topologically slice knots which are not smoothly slice. (Received August 11, 2015)

1112-57-676 **Krzysztof K. Putyra** and **Alexander N. Shumakovitch*** (shurik@gwu.edu), Monroe Hall, 2115 G St. NW, room 240, Department of Mathematics, The George Washington University, Washington, DC 20850. *Homological operations on reduced Khovanov homology.* Preliminary report.

There are several homological operations that can be defined between even and odd reduced Khovanov homology theories using the unified even/odd Khovanov homology theory developed by Putyra. We discuss these homological operations, compare them to those between underduced versions of Khovanov homology, and show how they can give rise to new knot invariants with interesting properties. (Received August 11, 2015)

58 ► Global analysis, analysis on manifolds

1112-58-78 **Guillaume Roy-Fortin*** (gui@math.northwestern.edu), 2033 Sheridan Rd, Evanston, IL 60208. *Growth and nodal sets of Laplace eigenfunctions on manifolds.*

We will discuss a recent result that exhibits a relation between the average local growth of a Laplace eigenfunction on a smooth, compact, boundaryless Riemannian surface and the global size of its nodal set. More precisely, we provide a lower and an upper bound for the Hausdorff measure of the nodal set in terms of the expected value of the growth exponents of an eigenfunction on disks of radius comparable to the wavelength. Combined with Yau's conjecture, the result implies that the average local growth of an eigenfunction on such disks is bounded

by constants in the semi-classical limit. We also will discuss results that link the size of the nodal set to the growth of solutions of planar Schrodinger equations with small potential. (Received July 16, 2015)

1112-58-117 **Sean Li*** (seanli@math.uchicago.edu). *BiLipschitz decomposition for Carnot groups.*
Let $f : X \to Y$ be a Lipschitz function between metric measure spaces. A natural question one can ask is if X can be decomposed into Borel pieces $\{A_i\}$ and a junk set Z so that $f|_{A_i}$ are biLipschitz and $f(Z)$ has small (or null) measure. This has been extensively studied when X is Euclidean and a positive result holds even when Y is a general metric measure space. We present two results of this type in the nonabelian setting of Carnot groups. When X and Y are both Carnot groups, we show that this is possible to do quantitatively. On the other hand, we construct a metric space Y of positive Hausdorff 4-measure for which there is a Lipschitz surjection f from the Heisenberg group with no biLipschitz decomposition.

The second result is joint work with E. Le Donne and T. Rajala. (Received July 25, 2015)

1112-58-467 **David Bate***, Dept. of Mathematics, University of Chicago, 5734 S. University Avenue, Chicago, IL 60637. *The geometry of Radon Nikodym Lipschitz differentiability spaces.*
We give a purely geometric characterisation of those metric measure spaces that satisfy the differentiability theory of Cheeger for Lipschitz maps into Banach spaces with the Radon-Nikodym property. We will then see that this is also equivalent to satisfying an asymptotic non-homogeneous Poincaré inequality. This is joint work with Sean Li. (Received August 10, 2015)

1112-58-576 **Ralf J Spatzier*** (spatzier@umich.edu), 530 Church St., University of Michigan, Department of Mathematics, Ann Arbor, MI 48103. *Exponential Mixing and Rigidity Theorems.*
I will report on various exponential mixing results and their relations to proving rigidity theorems in smooth dynamics. (Received August 11, 2015)

60 ► Probability theory and stochastic processes

1112-60-38 **Andrew Papanicolaou***, NYU Polytechnic School of Engineering, 6 Metrotech Center, Brooklyn, NY 11201. *Forward-Backward SDEs for Control with Partial Information.*
This talk considers the non-Markov control problem that arises when a hidden state must be filtered before an action is taken. The problem involves nonlinear filtering, which means the control problem is infinite dimensional and cannot be solved using Hamilton-Jacobi-Bellman (HJB) equations. Instead, the problem is analyzed and solved using a system of forward-backward SDEs. A numerical methods is proposed using a particle filter, and accuracy of the method is proven. In applications, this problem is relevant in finance for management portfolios of commodities ETFs. (Received June 28, 2015)

1112-60-55 **Asaf Cohen*** (asafc@umich.edu), 517 Little Lake Dr., Ann Arbor, MI 48103, and **Erhan Bayraktar**. *Risk Sensitive Control of the Lifetime Ruin Problem.* Preliminary report.
We study a risk sensitive control version of the lifetime ruin probability problem. We consider a sequence of investments problems in Black-Scholes market that includes a risky asset and a riskless asset. We present a differential game that governs the limit behavior. We solve it explicitly and use it in order to find an asymptotically optimal policy. (Received July 10, 2015)

1112-60-100 **Panki Kim** and **Renming Song*** (rsong@math.uiuc.edu), Department of Mathematics, University of Illinois, 1409 W Green St, Urbana, IL 61801, and **Zoran Vondracek**. *Martin boundary for subordinate Brownian motions.*
In this talk, I will present a survey on recent results in identifying the Martin boundary of general open sets with respect to general subordinate Brownian motions. (Received July 23, 2015)

1112-60-105 **Luay Nakhleh*** (nakhleh@rice.edu), 6100 Main Street, Houston, TX 77005. *Gene trees in phylogenetic networks.*
Phylogenetic networks model reticulate evolutionary histories arising due to processes such as horizontal gene transfer in prokaryotes and hybridization in eukaryotes. The topology of a phylogenetic network (the "evolutionary" version of networks) is a rooted, directed, acyclic graph, whose leaves are bijectively labeled by a set of taxa and in which each node (except for the root) has in-degree 1 or 2. Each edge in the network has parameters that include the population size and length in generations along that edge. Furthermore, given a gene, or genomic region of interest, we associate with each edge in the network a function to capture the probability that the gene

has evolved inside that edge. This model constitutes a generative model of gene trees under the multi-species coalescent model with reticulation. In this talk, I will describe the model, the distribution of genes under it, and a maximum likelihood framework for inferring phylogenetic networks from genome-wide data. This is joint work with James Degnan, Jianrong Dong, Kevin Liu, and Yun Yu. (Received July 23, 2015)

1112-60-118 **Kiseop Lee*** (kiseop.lee@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Sang-Hyeon Park**. *Insiders' hedging in a stochastic volatility model.* Preliminary report.

We study a market where there are traders with different levels of information. Insiders observe exclusive, non-public information that affects the volatility of the price process, and the information levels are different even among insiders. By the nature of information, some information processes are continuous, while others are discrete. We study the local risk minimization hedging strategies of the insiders under stochastic volatility models, and compare them with an honest trader's strategy. A numerical example is provided. (Received July 25, 2015)

1112-60-130 **Jinho Baik***, 530 Church Street, Ann Arbor, MI 48103. *Fluctuations of the free energy of spherical spin glass.*

We consider the spherical spin glass model, also known as the spherical Sherrington-Kirkpatrick (SSK) model. We show that the limit of the law of the fluctuations of the free energy is given by the GOE Tracy-Widom distribution in the low temperature regime and by the Gaussian distribution in the high temperature regime. Non-Gaussian interactions are also discussed. This is a joint work with Ji Oon Li. (Received July 28, 2015)

1112-60-161 **Alexander Drewitz*** (drewitz@math.uni-koeln.de), Köln, Germany. *The maximal particle of branching random walk in random environment.*

We consider one-dimensional branching random walk in a random branching environment. Amongst others we show that after recentering and scaling certain quantities related to the maximal particle exhibit normal fluctuations. (Received July 30, 2015)

1112-60-171 **Wei-Kuo Chen*** (wkchen@math.uchicago.edu), Department of Mathematics, 5734S, University Avenue, Chicago, IL 60637, and **Dmitry Panchenko** (panchenk@math.toronto.edu). *Self-averaging in spin glasses with Gaussian disorder.*

In this talk we will consider an natural generalization of the mean-field and short range spin glass models with Gaussian disorder. We will present quantitative results on the self-avergaging properties of some physical observables including the magnetization, the Hamiltonian and the cross overlap in the disorder chaos problem. These will cover particularly the Edwards-Anderson model, the random field Ising model and the Sherrington-Kirkpatrick model. Based on joint work with D. Panchenko. (Received August 01, 2015)

1112-60-197 **Wojbor A Woyczynski*** (waw@case.edu), Case Western Reserve University, Cleveland, OH 44106. *Multiscale conservation laws driven by Lévy stable and Linnik diffusions: asymptotics, explicit representations, shock creation, preservation and dissolution.*

Asymptotic behavior of subcritical multifractal fractal conservation laws with integrable initial conditions corresponds to that of the linearized case. Thus obtaining explicit solutions of the latter is of interest. Some fractal conservation laws driven by Lévy α-stable diffusions exhibit shocks for bounded, odd, and convex on the positive half-line, initial data when the parameter $\alpha < 1$. For the Lévy α-Linnik diffusions the local behavior is strikingly different, although we are able to establish analytically that the large time behavior of the two types of conservation laws are similar. But the main new insights obtained via large-scale numerical experiments is that, for any $0 < \alpha \leq 2$, the conservation laws driven by α-Linnik diffusions display shocks that do not dissipate over time while those for α-stable diffusion ($0 < \alpha \leq 1$) do. (Joint work with B. Gunaratnam and K. Gorska) (Received August 03, 2015)

1112-60-207 **Tandy Warnow*** (warnow@illinois.edu), University of Illinois at Urbana-Champaign, Department of Computer Science, Urbana, IL 61801, and **Siavash Mirarab**, **Shamsuzzoha Bayzid** and **Bastien Boussau**. *Species Tree Estimation in the presence of Incomplete Lineage Sorting.*

Estimating the Tree of Life will likely involve a two-step procedure, where in the first step trees are estimated on many genes, and then the gene trees are combined into a tree on all the taxa. However, the true gene trees may not agree with with the species tree due to biological processes such as deep coalescence, gene duplication and loss, and horizontal gene transfer. Statistically consistent methods based on the multi-species coalescent model have been developed to estimate species trees in the presence of incomplete lineage sorting; however, the

relative accuracy of these methods compared to the usual "concatenation" approach is a matter of substantial debate within the research community.

I will present results showing that coalescent-based estimation methods are impacted by gene tree estimation error, so that they can be less accurate than concatenation in many cases. I will also present weighted and unweighted statistical binning (see Mirarab et al., Science 2014, and Bayzid et al., PLOS One 2015), methods for improving gene tree estimation, and that enable more accurate estimations of species trees in the presence of gene tree conflict due to ILS. (Received August 04, 2015)

1112-60-213 **Partha Sarathi Dey*** (psdey@illinois.edu), 1409 W Green St, Urbana, IL 61801, and **Matthew Joseph** and **Ron Peled**. *Longest increasing path within the critical strip.*

Consider a Poisson Point Process of intensity one in the two-dimensional square of length n. In Baik-Deift-Johansson (1999), it was shown that the length of a longest increasing path (an increasing path that contains the most number of points) when properly centered and scaled converges to the Tracy-Widom distribution. Later Johansson (2000) showed that all maximal paths lie within the strip of width $n^{2/3+\epsilon}$ around the diagonal with probability tending to 1 as n increases to infinity. We consider the length of maximal increasing paths restricted to lie within a strip of width n^{γ} when $\gamma < 2/3$ around the diagonal and show that when properly centered and scaled it converges to a Gaussian distribution. We also obtain tight bounds on the expectation and variance which plays a crucial role on the distributional convergence. (Received August 04, 2015)

1112-60-251 **Mei Yin*** (mei.yin@du.edu), 2280 S Vine St, Denver, CO 80208. *Asymptotic properties of the (generalized) edge-triangle exponential random graph model.*

The edge-triangle exponential random graph model has been a topic of continued research interest. Chatterjee and Diaconis showed that when the triangle parameter β_2 is non-negative, the model always looks like an Erdős-Rényi random graph in the limit. In further works (see for example, Radin and Yin, Aristoff and Zhu, Yin, Rinaldo and Fadnavis), it was shown that the line $\beta_2 = -\beta_1$, where β_1 is the edge parameter, is of particular importance. The model transitions from being a very sparse graph to a very dense graph as the natural parameters (β_1, β_2) cross this line, completely skipping all intermediate structures. I will present recent extensions of this result, including: When a typical graph is sparse, how sparse is it? When a typical graph is dense, how dense is it? The relevant asymptotic properties of the generalized edge-triangle model considered by Lubetzky and Zhao will also be discussed. (Received August 05, 2015)

1112-60-283 **Vadim Linetsky** (linetsky@iems.northwestern.edu), 2145 Sheridan Rd, Evanston, IL 60208, and **Yutian Nie*** (ynie@u.northwestern.edu), 2145 Sheridan Rd, Evanston, IL 60208. *Modeling interest rates with the zero lower bound: applications of diffusions with sticky boundaries.*

Since the financial crisis of 2008 short-term interest rates in developed economies, including the US, Eurozone, and Japan, have been at or near zero. Conventional interest rate models essentially break down in this zero lower bound (ZLB) regime. We propose to apply diffusions with sticky boundaries, as originally developed by Feller, Wentzell, Sato and Ueno, and Ikeda and Watanabe, to this problem of modeling interest rates with the ZLB. (Received August 06, 2015)

1112-60-291 **Elchanan Mossel***, 3730 Walnut Street #400, Philadelphia, PA 19104. *Shotgun Assembly of Graphs.*

In a recent work with Nathan Ross we introduced the problem of Shotgun Assembly of Graphs. We will explain the problem and its connection to DNA shotgun assembly as well as some initial results and open problems. (Received August 07, 2015)

1112-60-297 **Zachary Feinstein*** (zfeinstein@ese.wustl.edu) and **Birgit Rudloff**. *Multiportfolio Time Consistency of Multivariate Dynamic Risk Measures and Equivalent Formulations.*

In markets with transaction costs, when capital requirements can be made in a basket of currencies or assets, risk measures are naturally set-valued functions. In the dynamic and multivariate setting, the appropriate time consistency property appears to be multiportfolio time consistency. This is equivalent to the recursive formulation, an additive property for the acceptance sets, the cocycle condition for penalty functions (for convex risk measures), a version of m-stability (for coherent risk measures), and a supermartingale property (for convex or coherent risk measures). We can additionally use these properties to define multiportfolio time consistent versions of well-known risk measures. (Received August 07, 2015)

1112-60-353 **James E Johndrow*** (james.johndrow@duke.edu), 211 Old Chemistry Building, Durham, NC 27713, and **Jonathan C Mattingly**, **Sayan Mukherjee** and **David B Dunson**. *Approximations of Markov Chains and High-Dimensional Bayesian Inference.*

The Markov Chain Monte Carlo method is the dominant paradigm for posterior computation in Bayesian analysis. It has long been common to control computation time by making approximations to the Markov transition kernel. Comparatively little attention has been paid to convergence and estimation error in these approximating Markov Chains. We propose several frameworks for assessing when to use approximations in MCMC algorithms, and how much error in the transition kernel should be tolerated to obtain optimal estimation performance with respect to a specified loss function and computational budget. The results require only ergodicity of the exact kernel and control of the kernel approximation accuracy. The theoretical framework is applied to approximations based on random subsets of data, low-rank approximations of Gaussian processes, and a novel approximating Markov chain for discrete mixture models. (Received August 08, 2015)

1112-60-367 **Sveinn Ólafsson*** (sveinno@purdue.edu). *Short-term asymptotic properties of option prices and implied volatility under financial models with jumps.*

We provide asymptotic expansions for option prices and implied volatility when time-to-maturity and log-moneyness become small, which for liquidity reasons is of particular importance in practice. We also consider the implied volatility skew (i.e. the strike derivative), which has received relatively little attention in the literature, but is actively monitored in practice by traders and analysts. As auxiliary results we obtain short-term expansions for the prices of digital call options and the delta of European call options. These results are markedly different from those obtained for vanilla options and shed further light on the relationship between important model parameters and the implied volatility smile near expiry. Simulation results indicate that the approximations give good fits for options with maturities up to one month, underpinning their relevance in e.g. FX markets where there are actively traded options with short maturities, and where the volatility skew plays a critical role in option pricing. (Received August 09, 2015)

1112-60-384 **Sergey Nadtochiy*** (sergeyn@umich.edu), 530 Church St, Ann Arbor, MI 48109, and **Roman Gayduk**, 530 Church St, Ann Arbor, MI 48109. *Endogenous Formation of Limit Order Books: The Effects of Trading Frequency.*

In this talk, I will present a modeling framework in which the shape and dynamics of a Limit Order Book (LOB) arise endogenously from an equilibrium between multiple market participants (agents). This new framework, on the one hand, captures closely the true, micro-level, mechanics of an auction-style exchange. On the other hand, it uses the standard abstractions of games with continuum of players (in particular, the Mean Field Game theory) to obtain a tractable macro-level description of the LOB. Finally, I will use the proposed modeling framework to analyze the effects of trading frequency on the market microstructure. In particular, I will present a general result that connects the market efficiency and stability of LOB to the martingale properties of agents' beliefs. The theoretical results will be illustrated with numerical simulations. (Received August 09, 2015)

1112-60-387 **Grzegorz A Rempala*** (rempala.3@osu.edu), Columbus, OH 43210. *Stochastic Dynamics on Large Contact Networks.* Preliminary report.

We develop a general framework for analyzing dynamics of certain classes of contact processes on random (configuration model) graphs with given degree distributions. We show that for a certain class of degree distributions the counting process which describes the dynamics may be approximated by a simpler (Markov) process which may be studied in the large volume limit. We expand the traditional model of an SIR stochastic epidemic on a graph by including heterogenous contact and infectivity structure to account for the disease-specific features. The work was originally motivated by building a model of the recent Ebola epidemic. (Received August 09, 2015)

1112-60-405 **Ruoting Gong*** (rgong2@iit.edu), Room 116-B, Engineering 1 Building, 10 West 32nd Street, Chicago, IL 60616, and **Christian Houdre** and **Juri Lember**. *Lower Bounds on the Generalized Central Moments of the Optimal Alignments Score of Random Sequences.*

We present a general approach to the problem of determining tight asymptotic lower bounds for generalized central moments of the optimal alignment score of two independent sequences of i.i.d. random variables. At first these are obtained under a main assumption for which sufficient conditions are provided. When the main assumption fails, we nevertheless develop a "uniform approximation" method leading to asymptotic lower bounds. Our general results are then applied to the length of the longest common subsequence of binary strings, in which case asymptotic lower bounds are obtained for the moments and the exponential moments of the optimal score. This is the joint work with Christian Houdré and Jüri Lember. (Received August 10, 2015)

1112-60-417 **Fabrice Baudoin** and **Cheng Ouyang*** (couyang@math.uic.edu), Dept of Math, Statistics and Computer Science, University of Illinois at Chicago, 851 S. Morgan Street, Chicago, IL 60607. *On small time asymptotics for rough differential equations driven by fractional Brownian motions.*

We survey existing results concerning the study in small times of the density of the solution to a rough differential equation driven by fractional Brownian motions. We then discuss some possible applications to mathematical finance. (Received August 10, 2015)

1112-60-418 **François Guay** (fguay@bu.edu), Department of Economics, Boston University, Boston, MA 02215, and **Gustavo Schwenkler*** (gas@bu.edu), Questrom School of Business, Boston University, 595 Commonwealth Ave, Boston, MA 02215. *Uncovering the Transition Density of Multivariate Markovian Diffusions.* Preliminary report.

We develop novel representations of the transition density of a multivariate diffusive stochastic process. The representations are based on a randomization technique introduced by Glynn & Rhee (2013), and they facilitate the unbiased estimation of the transition density across the state and parameter spaces via Monte Carlo simulation. We use our density estimators for parameter inference in settings with latent factors that are common in financial engineering. The obtained parameter estimators are shown to be consistent and asymptotically normal under certain conditions. Numerical examples illustrate our results. (Received August 10, 2015)

1112-60-425 **Daniele Cappelletti***, d.cappelletti@math.ku.dk, and **Carsten Wiuf**. *Complex Balanced Reaction Systems and Product-form Poisson Distribution.*

Stochastic reaction networks are dynamical models of biochemical reaction systems and form a particular class of continuous-time Markov chains on $\mathbb{N}^n$. We define the notion of 'stochastically complex balanced systems' in terms of the network's stationary distribution and provide a characterization of stochastically complex balanced systems, parallel to that established in the 70-80ies for deterministic reaction networks by Horn, Jackson and Feinberg. Additionally, we establish that a network is stochastically complex balanced if and only if an associated deterministic network is complex balanced (in the deterministic sense), thereby proving a strong link between the theory of stochastic and deterministic networks. Further, we prove a stochastic version of the 'deficiency zero theorem' and show that any (not only complex balanced) deficiency zero reaction network has a product-form Poisson-like stationary distribution on all irreducible components. Finally, we provide sufficient conditions for when a product-form Poisson-like distribution on a single (or all) component(s) implies the network is complex balanced, and explore the possibility to characterize complex balanced systems in terms of product-form Poisson-like stationary distributions. (Received August 10, 2015)

1112-60-448 **Shankar Bhamidi*** (bhamidi@email.unc.edu), 304 Hanes Hall, Dept of Statistics and OR, University of North Carolina, Chapel Hill, NC 27599. *Continuum scaling limits of critical inhomogeneous random graph models.*

Over the last few years a wide array of random graph models have been postulated to understand properties of empirically observed networks. Most of these models come with a parameter t (usually related to edge density) and a (model dependent) critical time t_c which specifies when a giant component emerges. There is evidence to support that for a wide class of models, under moment conditions, the nature of this emergence is universal and looks like the classical Erdos-Renyi random graph, in the sense that (a) the sizes of the maximal components in the critical scaling window scale like $n^{2/3}$, and (b) the structure of components in this window (rescaled by $n^{-1/3}$) converge to random fractals related to the continuum random tree. We will describe a general program for proving such results. The program requires three main ingredients: (i) in the critical scaling window, components merge approximately like the multiplicative coalescent (ii) scaling exponents of susceptibility functions (including distance based susceptibility) are the same as the Erdos-Renyi random graph and (iii) macroscopic averaging of expected distances between random points in the same component in the barely subcritical regime. (Received August 10, 2015)

1112-60-451 **David Renfrew*** (dtrenfrew@math.ucla.edu). *Structured Non-Hermitian Random Matrices.*

We will discuss several ensembles of non-Hermitian random matrices with given variance profiles, motivated from math and physics. We give a characterization of the limiting spectral measure and compute their spectral radius. (Received August 10, 2015)

1112-60-495 **Nicos Georgiou** and **Firas Rassoul-Agha*** (firas@math.utah.edu), 155 S 1400 E, Salt Lake City, UT 84109, and **Timo Seppalainen**. *Busemann functions and geodesics for the corner growth model.*

We consider the directed last-passage percolation model on the planar integer lattice with nearest-neighbor steps and general i.i.d. weights on the vertices, outside the class of exactly solvable models. Stationary cocycles are constructed for this percolation model from queueing fixed points. These cocycles define solutions to variational formulas that characterize limit shapes and yield new results for Busemann functions, geodesics and the competition interface. This is joint work with Nicos Georgiou and Timo Seppalainen. (Received August 10, 2015)

1112-60-502 **Steven P Lalley*** (lalley@galton.uchicago.edu), Department of Statistics, University of Chicago, 5734 University Ave, Chicago, IL 60637, and **Bowei Zheng**. *Critical Branching Brownian Motion with Killing at 0.* Preliminary report.

We obtain sharp asymptotic estimates for hitting probabilities of a critical branching Brownian motion in one dimension with killing at 0. We also obtain sharp asymptotic formulas for the tail probabilities of the number of particles killed at 0. In the special case of double-or-nothing branching, we give exact formulas for both the hitting probabilities, in terms of elliptic functions, and the distribution of the number of killed particles. (Received August 10, 2015)

1112-60-507 **Ramon Van Handel*** (rvan@princeton.edu), Sherrerd Hall 227, Princeton University, Princeton, NJ 08544. *Chaining and convexity.*

Classical estimates on the suprema of random processes in terms of entropy numbers have found widespread use in probability theory, statistics, computer science, and other areas. Such estimates are powerful and relatively easy to use, but often fail to be sharp. To obtain sharp bounds, it is necessary to replace these methods by a multiscale analogue known as the generic chaining that was developed in depth by Talagrand. Unfortunately, the latter is notoriously difficult to use in any given situation. In this talk, I will exhibit a completely elementary construction that is almost as easy to use as classical entropy estimates, but produces sharp results in many geometric situations. In particular, I will show that when applied to a convex set, one can obtain a bound in terms of the entropy numbers of certain "thin" subsets that are often much smaller than the original convex set. Prior knowledge of these ideas will not be assumed in the talk. (Received August 10, 2015)

1112-60-517 **Jinqiao Duan*** (duan@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616, **Rui Cai** (mathcenter@hust.edu.cn), Center for Mathematical Sciences, Huazhong University of Science and Technolog, 1037 Luoyu Road, Wuhan, Hubei 430074, Peoples Rep of China, and **Hui Wang** (mathcenter@hust.edu.cn), Center for Mathematical Sciences, Huazhong University of Science and Technology, 1037 Luoyu Road, Wuhan, Hubei 430074, Peoples Rep of China. *Non-local PDEs and Non-Gaussian Stochastic Dynamics.*

Dynamical systems arising in engineering and science are often subject to random fluctuations. The noisy fluctuations may be Gaussian or non-Gaussian, which are modeled by Brownian motion or α-stable Levy motion, respectively. Non-Gaussianity of the noise manifests as nonlocality at a "macroscopic" level. Stochastic dynamical systems with non-Gaussian noise (modeled by α-stable Levy motion) have attracted a lot of attention recently. The non-Gaussianity index α is a significant indicator for various dynamical behaviors. The speaker will present a few aspects of non-Gaussian stochastic dynamical systems, highlighting how PDEs help quantify stochastic dynamical behaviors, including escape probability (which quantifies likelihood for a complex system changes from one regime to another, when uncertainty is taken into account). Some materials are taken from new books "An Introduction to Stochastic Dynamics" (by Jinqiao Duan, Cambridge University Press, and Science Press, 2015) and "Effective Dynamics of Stochastic Partial Differential Equations" (by Jinqiao Duan and Wei Wang, Elsevier, 2014). (Received August 10, 2015)

1112-60-518 **Prasad Tetali*** (tetali@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30030. *Some open problems inspired by discrete curvature.*

Inspired by a fruitful development and recent mature understanding of the notion of lower-boundedness of Ricci curvature in continuous settings, several independent groups of researchers have introduced intriguing analogs of such a (Ricci) curvature in discrete settings. The approaches vary based on whether the perspective is probabilistic, analytical or combinatorial. In this talk, I will mention at least two such approaches and state some open problems. This is based on my recent joint works with Erbar-Maas, and Klartag-Kozma-Ralli. (Received August 10, 2015)

1112-60-534 **Jose E. Figueroa-Lopez*** (figueroa@math.wustl.edu), One Brookings Drive, St. Louis, MO 63130-4899, and **Yankeng Luo**, 150 N. University Street, West Lafayette, IN 47907-2067. *Small-time expansions for state-dependent local jump-diffusion models with infinite jump activity.* Preliminary report.

In this article, we consider a Markov process X, solving a stochastic differential equation which is driven by a Brownian motion and an independent pure jump component exhibiting state-dependent jump intensity and infinite jump activity. A second order expansion is derived for the tail probability of the process in small time. As an application of this expansion and a suitable change of the underlying probability measure, a second order expansion, near expiration, for out-of-the-money European call option prices is obtained when the underlying stock price is modeled as the exponential of the jump-diffusion process X under the risk-neutral probability measure. (Received August 11, 2015)

1112-60-540 **Archil Gulisashvili**, **Frederi Viens** and **Xin Zhang*** (zhang407@purdue.edu), 150 N. University Street, West Lafayette, IN 47906. *Extreme-strike asymptotics for general Gaussian stochastic volatility models.*

We consider a stochastic volatility stock price model in which the volatility is a non-centered continuous Gaussian process with arbitrary prescribed mean and covariance. By exhibiting a Karhunen-Loève expansion for the integrated variance, and using sharp estimates of the density of a general second-chaos variable, we derive asymptotics for the stock price density and implied volatility in these models in the limit of large or small strikes. Our main result provides explicit expressions for the first three terms in the expansion of the implied volatility, based on three basic spectral-type statistics of the Gaussian process: the top eigenvalue of its covariance operator, the multiplicity of this eigenvalue, and the L^2 norm of the projection of the mean function on the top eigenspace. Strategies for using this expansion for calibration purposes are discussed. (Received August 11, 2015)

1112-60-548 **Nayantara Bhatnagar*** (naya@math.udel.edu). *Limit Theorems for Monotone Subsequences in Mallows Permutations.*

I will present some results on the limiting distribution of longest increasing subsequences of random Mallows permutations in the regime where q is constant. We make use of the regenerative structure of the permutations in this regime. This is joint work with Riddhi Basu. (Received August 11, 2015)

1112-60-567 **Paul Bourgade*** (bourgade@cims.nyu.edu), 251 Mercer Street, New York, NY 10012. *Quantum Unique Ergodicity as a tool for Universality for random matrices.*

Eugene Wigner has envisioned that the distributions of the eigenvalues of large Gaussian random matrices are new paradigms for universal statistics of large correlated quantum systems.

I will explain recent developments proving this paradigm for eigenvalues of some geometry-dependent random matrices of band type. Some random walks in dynamic random environments play a key role. (Received August 11, 2015)

1112-60-568 **Xiang Yu*** (xymath@umich.edu). *Optimal Consumption under Habit Formation In Markets with Transaction Costs and Random Endowments.*

This paper studies the optimal consumption under addictive habit formation preferences in markets with transaction costs and unbounded random endowments. To model the proportional transaction costs, we adopt the Kabanov's multi-asset framework with a cash account. At the terminal time T, the investor can receive unbounded random endowments for which we propose a new definition of acceptable portfolios based on the strictly consistent price system (SCPS). We prove a type of super-hedging theorem using the acceptable portfolios which enables us to obtain the consumption budget constraint inequality under the market frictions. By path dependence reduction and the embedding approach, the existence and uniqueness of the optimal consumption are obtained using some auxiliary processes and the convex duality analysis. (Received August 11, 2015)

1112-60-599 **Ohad Feldheim**, **Ron Peled** and **Arnab Sen***, arnab@umn.edu, and **Ofer Zeitouni**. *Double Roots of Random Integer Polynomials.*

We consider random polynomials whose coefficients are i.i.d. integer-valued random variables. We will show that the probability that such a polynomial of degree n has a double root is at most $O(n^{-2})$. The proof exploits the algebraic nature of the roots of the polynomials with integer coefficients.

This is joint work with Ohad Feldheim, Ron Peled and Ofer Zeitouni. (Received August 11, 2015)

1112-60-602 **Scott P Robertson*** (scottrob@andrew.cmu.edu), Carnegie Mellon University, Department of Mathematical Sciences, Wean Hall 6113, Pittsburgh, PA 15213. *Optimal Investment for Large Positions in Contingent Claims, A Gartner-Ellis Approach.*

Motivated by the large notional amounts outstanding in over-the-counter derivatives markets, we consider the optimal investment problem, for an investor holding a large position in a non-traded asset, in a general incomplete semi-martingale market. In particular we are interested in identifying limiting indifference prices, optimal position sizes and hedging strategies in a sequence of incomplete markets which is asymptotically complete in that hedging errors vanish. Drawing connections with the classical Gartner-Ellis theorem from Large Deviations, we show that if indifference prices converge when positions are taken at a certain "large deviations" rate, then optimal position sizes become large at precisely this rate as well. Furthermore, that prices converge along a given rate is the typical situation in asymptotically complete markets: this is shown via numerous examples, including those with vanishing transactions costs, trading constraints, and unhedgeable shock correlations. Lastly we show that when taking position size into account, it is in general not true that limiting indifference prices coincide with the unique arbitrage free price in the limiting model. This is joint work with Constantinos Spiliopoulos and Michalis Anthropelos. (Received August 11, 2015)

1112-60-605 **Michael Raghib*** (mraghib@br.ibm.com), IBM Research, 138 Avenida Pasteur, Botafogo, Rio de Janeiro, RJ 22290-240, Brazil. *Nonlocal in time diffusions as effective models of collective motion in animal groups.*

We propose a (time) multiscale method for the coarse-grained analysis of collective motion and decision-making in self-propelled particle models of swarms comprising a mixture of 'naïve' and 'informed' individuals. The method is based on projecting the particle configuration onto a single 'meta-particle' that consists of the elongation of the flock together with the mean group velocity and position. We find that the collective states can be associated with the transient and asymptotic transport properties of the random walk followed by the meta-particle, which we assume follows a continuous time random walk (CTRW). These properties can be accurately predicted at the macroscopic level by an advection–diffusion equation with memory (ADEM) whose parameters are obtained from a mean group velocity time series obtained from a single simulation run of the individual-based model. (Received August 11, 2015)

1112-60-616 **Lee Gibson** and **Melanie Pivarski*** (mpivarski@roosevelt.edu), Chicago, IL 60605. *The Rate of Decay of the Wiener Sausage in Local Dirichlet Space.*

In the context of a heat kernel diffusion which admits a Gaussian type estimate with parameter β on a local Dirichlet space, we consider the log asymptotic behavior of the negative exponential moments of the Wiener sausage. We show that the log asymptotic behavior up to time $t^\beta V(x,t)$ is $-V(x,t)$, which is analogous to the Euclidean result. Here $V(x,t)$ represents the mass of the ball of radius t about a point x of the local Dirichlet space. The proof of the upper asymptotic uses a known coarse graining technique which must be adapted to the non-transitive setting. This result provides the first such asymptotics for several other contexts, including diffusions on complete Riemannian manifolds with non-negative Ricci curvature. (Received August 11, 2015)

1112-60-647 **Andrey Sarantsev*** (ansa1989@gmail.com), Seattle, WA 98105. *Infinite Systems of Competing Brownian Particles.*

Consider an infinite system of Brownian particles on the real line. Each particle moves as a Brownian motion with drift and diffusion coefficients depending on its current rank relative to other particles. We find a stationary distribution for the spacings between particles. This continues the work by Pal, Pitman (2008) and by Ichiba, Karatzas, Shkolnikov (2013). (Received August 11, 2015)

1112-60-663 **Roger Lee*** (rogerlee@math.uchicago.edu) and **Ruming Wang**. *How Leverage Shifts and Scales a Volatility Skew: Asymptotics for Continuous and Jump Dynamics.*

To model leveraged investments such as leveraged ETFs, define the *β-leveraged product* on a positive semi-martingale S to be the stochastic exponential of β times the stochastic logarithm of S.

In various asymptotic regimes, we relate rigorously the implied volatility surfaces of the β-leveraged product and the underlying S, via explicit shifting/scaling transformations. In particular, a family of regimes with *jump* risk admit a shift coefficient of $-3/2$, unlike the previously conjectured $+1/2$ shift. The $+1/2$, we prove, holds in a family of continuous stochastic volatility regimes at short expiry and at small volatility-of-volatility. In another regime, which does not admit a simple spatial shifting/scaling rule, we find an *expiry* scaling together with a spatial transformation. (Received August 11, 2015)

1112-60-675 **Panagiotis Souganidis*** (souganidis@math.uchicago.edu), Department of Mathematics, The University of Chicago, Chicago, IL 60637. *Pathwise entropy solutions for conservation laws with nonlinear rough path dependence.*

I will present the theory of pathwise solutions ro scalar conservation laws with fluxes that depend on rough signals. I will discuss the wellposedness of the solurions as well as their large time behavior in the brownian case. The results are joined in several combinatios with lions, perthame and Gess. (Received August 11, 2015)

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1112-62-22 **Seth Sullivant***, smsulli2@ncsu.edu. *Algebraic geometry of Gaussian graphical models.*

The parameter space of a Gaussian graphical model is a semialgebraic subset of the cone of positive definite matrices. This talk will describe some results on the vanishing ideals of these Gaussian graphical models. For general graphs, it is an open problem to give generators or a Grobner basis of the vanishing ideal. Special instances include well-studied ideals of combinatorial commutative algebra including determinantal ideals, secant ideals, and the vanishing ideals of matrix Schubert varieties. (Received May 31, 2015)

1112-62-116 **Alessandro Rinaldo*** (arinaldo@cmu.edu), Department of Statistics - 132 Baker Hall, Carnegie Mellon University, Pittsburgh, PA 15213. *Random Networks, Graphical Models, and Exchangeability.*

We describe several connections between exchangeable random networks and graphical models. We show that exchangeable finite networks extendable to larger networks can be approximated by mixtures of curved exponential families. In turn, these models correspond to a distinguished class of graphical models of marginal independence for binary data. We further consider extendability to infinite exchangeable networks. We obtain a simple derivation of de-Finetti theorem for exchangeable arrays, and we link it to the theory of graphons. Unlike previous results, our analysis yields a canonical parametric model for finite exchangeable arrays. Using this characterization, we discuss the challenges and intrinsic difficulties of fitting exchangeable network models. Joint work with Steffen Lauritzen and Kayvan Sadeghi. (Received July 25, 2015)

1112-62-233 **Alberto Caimo*** (alberto.caimo@usi.ch), Via Buffi 13, 6904 Lugano, Switzerland. *Approximate Monte Carlo algorithms for social network models.* Preliminary report.

Recent advances in statistical computation has demonstrated the advantages and effectiveness of Bayesian approaches to social network data. Exponential random graph models (ERGMs) represent one of the most important families of statistical models. The ERGM likelihood $f(y|\theta)$ states that the probability of observing a given network graph y is equal to the exponent of the observed network statistics $s(y)$ multiplied by a parameter vector θ divided by a normalising constant term $z(\theta)$ which is computationally intractable for all but trivially small networks. Following the Bayesian paradigm, prior distribution is assigned to the parameter θ. Direct evaluation of the posterior distribution $p(\theta|y)$ requires the calculation of both the likelihood $p(y|\theta)$ and the model evidence $p(y)$ which are both intractable. We present some approximate Monte Carlo strategies based on the exchange algorithm for doubly intractable distributions which improve the efficiency of Bayesian methods for exponential random graph models and increase their scalability to large social networks. (Received August 05, 2015)

1112-62-296 **Laura Kubatko*** (lkubatko@stat.osu.edu), 404 Cockins Hall, 1958 Neil Avenue, Columbus, OH 43210, and **Julia Chifman**. *Parameter Identifiability and Inference for Species Phylogenies Under the Coalescent.*

The rapid increase in availability of DNA sequence data coupled with gains in computational power have led to the use of increasingly complex models for inferring the evolutionary relationships among collections of species. These models have largely made use of the coalescent to capture the within-population dynamics of the speciation process along a phylogenetic tree. Though at least a dozen inference methods/software packages have been developed in this setting in the last 10 years, there has been little attention given to identifiability of model parameters. We have previously established identifiability of the species tree topology using techniques from algebraic statistics. We now extend our methodology to consider the estimation of parameters along that tree. In particular, we consider identifiability of the times of the speciation events along a fixed phylogeny. We apply our methods to both simulated and empirical data sets. (Received August 07, 2015)

1112-62-412 **Dane Wilburne*** (dwilburn@hawk.iit.edu) and **Hisayuki Hara** (hara@econ.niigata-u.ac.jp). *Markov Bases for Poisson and Multinomial Logistic Regression Models.* Preliminary report.

The complexity of Markov bases for a large class of Poisson and multinomial logistic regression models is in general not well understood. The configuration matrices of many such models can be viewed as generalizations of primitive partition identities (ppi). In this talk, we will explore the connection between these models and generalizations of ppi and see how it can be exploited to provide new complexity bounds in some cases. (Received August 10, 2015)

1112-62-445 **David Haws*** (dchaws@gmail.com), **James Cussens** and **Milan Studeny**. *Score Equivalence and Polyhedral Approaches to Learning Bayesian Networks.*

Bayesian networks (BN) are graphical models represented by directed acyclic graphs (DAGs). Two DAGs may define the same probabilistic model, and are called Markov equivalent. Learning BN structure is the NP-hard task of finding the BN structure that best fits real data, typically via a scoring function such as Schwartz's BIC. Integer linear programming approaches to learning BN structure have recently seen success in finding exact solutions. One IP approach to learning Bayesian network structure models DAGs with zero-one vector encodings where their convex hull is called the family-variable polytope. The other integer linear programming approach to learning BN structure models the Markov equivalence classes with zero-one vector encodings where their convex hull is called the characteristic-imset polytope.

A common form of linear objectives to be maximized leads to the concept of score equivalence, both for linear objectives and faces of the family-variable polytope. We show deep connections between the score-equivalent faces of the family-variable and characteristic-imset polytopes via a one-to-one correspondence in terms of extremality of supermodular functions. As a consequence, many faces of the family-variable polytope can be eliminated. (Received August 10, 2015)

1112-62-469 **Jing Xi** (jxi2@ncsu.edu), Department of Mathematics, North Carolina State University, 3250 SAS Hall, Raleigh, NC 27695, **Jin Xie*** (jin.xie@uky.edu), Department of Statistics, University of Kentucky, 725 Rose St MDS Room 338, Lexington, KY 40506, and **Ruriko Yoshida** (ruriko.yoshida@uky.edu), Department of Statistic, University of Kentucky, 725 Rose St MDS Room 325D, Lexington, KY 40506. *Distributions of topological tree metrics between a species tree and a gene tree.*

In order to conduct a statistical analysis on a given set of phylogenetic gene trees, we often use a distance measure between two trees. In a statistical distance-based method to analyze discordance between gene trees, it is a key to decide "biological meaningful" and "statistically well-distributed" distance between trees. Thus, in this paper, we study the distributions of the three tree distance metrics: the edge difference, the path difference, and the precise K interval cospeciation distance, between two trees: First, we focus on distributions of the three tree distances between two random unrooted trees with n leaves ($n \geq 4$); and then we focus on the distributions the three tree distances between a fixed rooted species tree with n leaves and a random gene tree with n leaves generated under the coalescent process with given the species tree. We show some theoretical results as well as simulation study on these distributions. (Received August 10, 2015)

1112-62-504 **Somak Dutta***, somakd@iastate.edu, and **Debashis Mondal**. *Variogram calculations for random fields on regular lattices using quadrature methods.*

We discuss a numerical algorithm for calculating a large class of analytically intractable theoretical variogram functions that arise in studies of random fields on regular lattices. Examples of these random fields include conditional and intrinsic autoregressions, fractional Laplacian differenced random fields, and regular block averages of continuum random fields. Typically, the variogram functions for these random fields appear in the form of multi-dimensional integrals with singularities at the origin, and, the algorithm laid out to evaluate these integrals invoke certain quadrature rules and regression formulas based on the asymptotic expansions of these integrals. This is so that singularities at the origin can be accounted for in a straightforward manner. This numerical algorithm opens new avenues to advancing geostatistical data analysis and solving krigging and estimation problems for various lattice-based random fields. The usefulness of this numerical method is illustrated by fitting certain theoretical variogram functions to ocean color and the Waker lake data. (Received August 10, 2015)

1112-62-549 **Hisayuki Hara*** (hara@econ.niigata-u.ac.jp), 8050 Ikarashi 2-no-cho Nishi-ku, Niigata, 950-2181, Japan. *Identifiability of Gaussian DAG models with one latent source.*

Linear structural equations are used to model linear functional relationships between random variables of interest and additional independent Gaussian noise terms. The relationship between different variables within such a

model can be represented by a directed graph. In this talk, in relation to the graphical structures, we study generic parametric identifiability of these models when the corresponding graphical representation is acyclic and one of the variables is a latent factor. We extend the results of previous work by exploiting the structure of Jacobian matrix for the parametrization map. We also give a condition under which generic parameter identifiability can be determined from identifiability of a model associated with a subgraph. (Received August 11, 2015)

1112-62-569 **Vishesh Karwa*** (vishesh.karwa@gmail.com), 165 Pleasant Street, Cambridge, MA 02139, and **Michael J Pelsmajer**, **Sonja Petrovic**, **Despina Stasi** and **Dane Wilburne**. *What is the core distribution of a graph telling us?*

The k-core of a graph is its largest subgraph such that all nodes have degree at least k in the subgraph. The shell index of a node, the largest core it belongs to, can be used a measure of importance of a node. We propose to model networks by their shell structures and discuss network models based on the core decomposition of a graph. (Received August 11, 2015)

1112-62-611 **Johannes Rauh*** (jarauh@yorku.ca), Department of Mathematics and Statistics, York University, 4700 Keele Street, Toronto, ON M3J1P3. *Exponential random graphs and their polytopes.* Preliminary report.

Exponential random graph models (ERGMs) are statistical random graph models of exponential family type. While they inherit many of the nice theoretical properties of exponential families, in practice they also exhibit many degeneracies that makes it difficult to use them in applications. First, in applications, the sample size is usually small, and very often there is just a single observed network from which the parameters have to be estimated. Second, many ERGMs behave like the Erdős-Rényi model, even if they have a lot more parameters.

As usual for exponential families, a lot of information can be obtained by studying the convex support polytope. In my talk, I will review some examples in which these polytopes (or some of their properties) are known. (Received August 11, 2015)

1112-62-620 **Elizabeth Gross*** (elizabeth.gross@sjsu.edu) and **Seth Sullivant** (smsulli2@ncsu.edu). *The maximum likelihood threshold of a graph.*

The maximum likelihood threshold of a graph is the smallest number of data points that guarantees that maximum likelihood estimates exist almost surely in the Gaussian graphical model associated to the graph. In this talk, we will show that this graph parameter is connected to the theory of combinatorial rigidity. In particular, if the edge set of a graph G is an independent set in the $(n-1)$-dimensional generic rigidity matroid, then the maximum likelihood threshold of G is less than or equal to n. This connection allows us to make several new statements regarding the existence of the maximum likelihood estimator in situations of limited data. (Received August 11, 2015)

65 ► Numerical analysis

1112-65-24 **Alexey Sukhinin*** (asukhinin@smu.edu), Southern Methodist University, Dallas, TX 75243. *Multi-resolution method for co-propagating high intensity pulses.* Preliminary report.

In this talk I will describe the (3+1)D model of co-propagating nanosecond and femtosecond pulses in air and present the resolution technique that allows to capture all important effects on different time scales. (Received May 31, 2015)

1112-65-47 **Fatih Celiker*** (celiker@wayne.edu), 656 W. Kirby 1150 FAB, Detroit, MI 48202, and **Burak Aksoylu** and **Horst R. Beyer**. *Local boundary conditions in nonlocal problems.*

We study nonlocal wave equations on bounded domains related to peridynamics. We display a methodology for enforcing boundary conditions(periodic, Dirichlet, or Neumann) through an integral convolution. We present a numerical study of the approximate solution, study convergence order with respect to the polynomial order of approximation, and observe optimal convergence. We depict solutions for each boundary condition to ascertain the behavior of waves under the nonlocal theory. (Received July 05, 2015)

1112-65-238 **Jie Shen*** (shen7@purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47906. *Decoupled energy stable schemes for phase-field models of two-phase complex fluids.*

We consider in this paper numerical approximations of phase-field models for twophase complex fluids. We first reformulate the phase-field models derived from an energetic variational formulation into a form which is suitable for numerical approximation and establish their energy laws. Then, we construct two classes, stabilized and convex-splitting, of decoupled time discretization schemes for the coupled nonlinear systems. These schemes are unconditionally energy stable and lead to decoupled elliptic equations to solve at each time step. Furthermore, these elliptic equations are linear for the stabilized version. Stability analysis and ample numerical simulations are presented. (Received August 05, 2015)

1112-65-331 **Guannan Zhang*** (zhangg@ornl.gov), One Bethel Valley Road, P.O. box 2008 MS-6211, Oak Ridge, TN 37831, and **Weidong Zhao**, **Clayton Webster** and **Max Gunzburger**. *Numerical Methods for a Class of Nonlocal Diffusion Problems with the Use of Backward SDEs.*

We propose a novel numerical approach for a class of nonlocal diffusion equations with integrable kernels, based on the relationship between the nonlinear backward Kolmogorov equation and backward stochastic differential equations (BSDEs) driven by Levy processes with jumps. The nonlocal diffusion problem under consideration is converted to a BSDE, for which numerical schemes are developed and applied directly. As a stochastic approach, the proposed method does not require the solution of linear systems, which allows for embarrassingly parallel implementations and also enables adaptive approximation techniques to be incorporated in a straightforward fashion. Moreover, our method is more accurate than classic stochastic approaches due to the use of high- order temporal and spatial discretization schemes. In addition, our approach can handle a broad class of problems with general nonlinear forcing terms as long as they are globally Lipchitz continuous. Rigorous error analysis of the new method is provided as several numerical examples that illustrate the effectiveness and efficiency of the proposed approach. (Received August 07, 2015)

1112-65-444 **Jianlin Xia*** (xiaj@math.purdue.edu). *Multi-layer Structures for the Direct Solution of Multi-Dimensional Discretized Problems.*

We propose multi-layer hierarchically semiseparable (MHS) structures for the efficient factorizations of dense matrices arising from high dimensional discretized problems. The problems include discretized integral equations and dense Schur complements in the factorizations of discretized PDEs. Unlike existing work on hierarchically semiseparable (HSS) structures which is essentially 1D, the MHS framework integrates multiple layers of rank and tree structures. We lay theoretical foundations for MHS structures and justify the feasibility of MHS approximations for these dense matrices. Rigorous rank bounds for the low-rank structures are given. Representative subsets of mesh points are used to illustrate the multi-layer structures as well as the structured factorization. Systematic fast and stable MHS algorithms are proposed, particularly convenient direct factorizations. The new structures and algorithms can yield direct solvers with nearly linear complexity and linear storage for solving some practical 2D and 3D problems. (Received August 10, 2015)

1112-65-459 **Lluis Antoni Jimenez Rugama*** (ljimene1@hawk.iit.edu), 10 W 32st, E1 - Room 120, Chicago, IL 60616. *Efficient resource allocation based on error and cost analysis: Guaranteed Automatic Integration Library.*

Computing power has been growing exponentially over the past decades. However, such powerful tools require more advanced mathematical techniques for a better resource allocation. Some questions such as "How much of these resources are needed?" or "Will it make an improvement taking more resources?" can be answered with a rigorous error and cost analysis of the numerical problem. Thus, this talk presents the GAIL MATLAB Toolbox (http://gailgithub.github.io/GAIL_Dev/, free software), a set of Adaptive Guaranteed Automatic algorithms for function integration and approximation. In particular, some details about the quasi-Monte Carlo algorithms will be provided, which are high-dimensional numerical integration methods with applications in finance, particle physics, or imaging. (Received August 10, 2015)

1112-65-491 **Youngjoon Hong*** (hongy@uic.edu). *Numerical simulations of the humid atmosphere above a mountain.*

New avenues are explored for the numerical study of the two dimensional inviscid primitive equations of the atmosphere with humidity and saturation, in presence of topography and subject to physically plausible boundary conditions for the system of equations. A compatibility condition similar to that related to the condition of incompressibility for the Navier-Stokes equations, is introduced. In that respect, a version of the projection

method is considered to enforce the compatibility condition on the horizontal velocity field, which comes from the boundary conditions. This is joint work with A. Bousquet, M. Chekroun, R. Temam, and J. Tribbia. (Received August 10, 2015)

1112-65-608 **Xiaofan Li*** (lix@iit.edu), 10 W 32nd St, E1-117C, Chicago, IL 60616, and **Ting Gao** and **Jinqiao Duan** (duan@iit.edu), Chicago, IL 60616, and **Renming Song**. *Numerical methods for nonlocal equations due to Lévy processes.*

The mean first exit time, escape probability and transitional probability density are utilized to quantify dynamical behaviors of stochastic differential equations with non-Gaussian α-stable type Lévy motions. Taking advantage of the Toeplitz matrix structure of the time-space discretization, a fast and accurate numerical algorithm is proposed to simulate the nonlocal Fokker-Planck equations on either a bounded or infinite domain. Under a specified condition, the scheme is shown to satisfy a discrete maximum principle and to be convergent. The numerical results for two prototypical stochastic systems, the Ornstein-Uhlenbeck system and the double-well system are shown (Received August 11, 2015)

1112-65-628 **Karl Liechty*** (kliechty@depaul.edu), Department of Mathematical Sciences, DePaul University, 2320 N Kenmore Ave, Chicago, IL 60614-3210, and **Jeff Geronimo**. *The Fourier continuation method, and discrete orthogonal polynomials on an arc.* Preliminary report.

The Fourier continuation method is a numerical method used to estimate a function from a discrete sample using Fourier techniques. It turns out that the error estimates in this method are closely connected with polynomials orthogonal with respect to a discrete weight on an arc of the unit circle. I will discuss the asymptotic properties of these polynomials, and their implications for the Fourier continuation method. (Received August 11, 2015)

1112-65-666 **Xiaofeng Yang*** (xfyang@math.sc.edu), 1523 Greene St, Columbia, SC 29208. *Some techniques to decouple the computations of phase field model of complex fluids.*

Abstract: We consider the numerical approximations of phase-field modelsfor two-phase complex fluids. We first reformulate the phase-field models derived from an energetic variational formulation into a form which is suitable for numerical approximation and establish their energy laws. Then, we construct two classes, stabilized and convex-splitting, of decoupled time discretization schemes for the coupled nonlinear systems. These schemes are unconditionally energy stable and lead to decoupled, elliptic equations to solve at each time step. Furthermore, these elliptic equations are linear for the stabilized version. Stability analysis and ample numerical simulations are presented. (Received August 11, 2015)

1112-65-670 **Siwei Duo** and **Yanzhi Zhang*** (zhangyanz@mst.edu), 400 W 12th Street, Department of Mathematics and Statistics, Missouri University of Science and Technology, Rolla, MO 65401. *Numerical approximation to the Reisz fractional Laplacian.*

Recently, one debate in the literature is whether the fractional Schroedinger equation in an infinite potential well has the same eigenfunctions as those of its standard (non-fractional) counterpart. Due to the nonlocality of the fractional Laplacian, it is challenging to find the eigenvalues and eigenfunctions of the fractional Schroedinger equation analytically. In this talk, we present a novel numerical method for discretizing the Riesz fractional Laplacian and numerically study the eigenfuctions of the fractional Schroedinger equation. (Received August 11, 2015)

68 ► Computer science

1112-68-284 **Bing Liu*** (liub@cs.uic.edu), 1050 Willow Road, None, Winnetka, IL 60093. *Sentiment Analysis and Lifelong Machine Learning.* Preliminary report.

Sentiment analysis (SA) or opinion mining is the computational study of people's opinions, sentiments, attitudes, and emotions. Due to almost unlimited applications and numerous research challenges, SA has been a very active research area in natural language processing (NLP) and data mining. SA is regarded as a semantic analysis problem, but is also highly targeted and bounded because a SA system does not need to fully "understand" a sentence or document. It only needs to comprehend some aspects of its meaning, e.g., positive/negative opinions and their targets. Due to this targeted nature, it allows us to perform deeper language analyses to gain better insights into NLP than in the general setting because the complexity of the general setting of NLP is too overwhelming. Thus, although general NL understanding is still far from us, we may be able to solve the SA problem satisfactorily. In this talk, I will first introduce SA and the existing research, and then go into detail to

discuss a recent study that aims to solve a SA problem but also contributes to machine learning in the areas of lifelong machine learning and topic modeling. (Received August 06, 2015)

1112-68-574 **Qingming Tang** (tqm2004@gmail.com), 6045 S. Kenwood Ave., Chicago, IL 60637-2803, and **Jinbo Xu*** (jinboxu@gmail.com), 6045 S. Kendwoood Ave, Chicago, IL 60637. *New machine learning methods for network inference.*

Learning network structure underlying data is an important problem in machine learning. This paper presents a novel degree prior to study the inference of scale-free and hub networks, which are widely used to model social and biological networks. In particular, this paper formulates scale-free and hub network inference using Gaussian Graphical model (GGM) regularized by a node degree prior. Our degree prior not only promotes a desirable global degree distribution, but also exploits the estimated degree of an individual node and the relative strength of all the edges of a single node. To fulfill this, this paper proposes a ranking-based method to dynamically estimate the degree of a node, which makes the resultant optimization problem challenging to solve. To deal with this, this paper presents a novel ADMM (alternating direction method of multipliers) procedure. Our experimental results on both synthetic and real data show that our prior not only yields a scale-free or hub network, but also produces many more correctly predicted edges than existing scale-free-inducing priors, hub-inducing prior and the l_1 norm. (Received August 11, 2015)

1112-68-575 **Steven B Damelin*** (damelin@umich.edu), 416 Fourth Street, Ann Arbor, MI 48103, and **Charles Fefferman** (cf@math.princeton.edu), Fine Hall, Washington Road, Princeton, NJ 0854. *Extensions, interpolation and matching in R^D.* Preliminary report.

A classical problem in geometry goes as follows. Suppose we are given two sets of D dimensional data, that is, sets of points in Euclidean D-space, where $D \geq 2$. The data sets are indexed by the same set, and we know that pairwise distances between corresponding points are equal in the two data sets. In other words, the sets are isometric. Can this correspondence be extended to an isometry of the ambient Euclidean space?

In this form the question is not terribly interesting; the answer has long known to be yes. But a related question is actually fundamental in data analysis: here the known points are samples from larger, unknown sets—say, manifolds in R^D—and we seek to know what can be said about the manifolds themselves. A typical example might be a face recognition problem, where all we have is multiple finite images of people's faces from various views.

An added complication is that in general we are not given exact distances. We have noise and so we need to demand that instead of the pairwise distances being equal, they should be close in some reasonable metric.

We will discuss ongoing work on this problem. This is joint with Charles Fefferman (Princeton). (Received August 11, 2015)

70 ► Mechanics of particles and systems

1112-70-265 **Mark Wilkinson*** (mwilkins@cims.nyu.edu), Courant Institute of Mathematical Sciences, 251 Mercer Street, New York, NY 10012. *On Collisions of Hard Nematic Particles.*

It is an interesting challenge to understand how observable phenomena in nematic liquid crystals arise from properties of their constituent molecules. Commonly, nematic liquid crystals are modelled at the molecular level by long, rod-like rigid bodies such as hard ellipsoids. Notably, a densely-packed domain of such hard nematic particles will experience many collisions as the particles evolve under Euler's equations of rigid body mechanics. In this talk, we present some surprising mathematical results on the collisions of such hard particles, and discuss some of the analytical challenges one faces when trying to construct solutions to Euler's equations of motion for these particles. (Received August 06, 2015)

74 ► Mechanics of deformable solids

1112-74-110 **Peter Sternberg*** (sternber@indiana.edu), **Dmitry Golovaty** (dmitry@uakron.edu) and **Alberto Montero** (amontero@mat.puc.cl). *Dimension reduction for the Landau-de Gennes model in planar nematic thin films.*

We use the method of Γ-convergence to study the behavior of the Landau-de Gennes model for a nematic liquid crystalline film in the limit of vanishing thickness. In this asymptotic regime, surface energy plays a greater role and we take particular care in understanding its influence on the structure of the minimizers of the derived two-dimensional energy. We assume general weak anchoring conditions on the top and the bottom surfaces of

the film and the strong Dirichlet boundary conditions on the lateral boundary of the film. The constants in the weak anchoring conditions are chosen so as to enforce that a surface-energy-minimizing nematic Q-tensor has the normal to the film as one of its eigenvectors. We establish a general convergence result and then discuss the limiting problem in several parameter regimes. (Received July 24, 2015)

76 ► Fluid mechanics

1112-76-323 **Zachary Bradshaw** (zbradshaw@math.ubc.ca), Department of Mathematics, #121-1984 Mathematics Road, Vancouver, B.C. V6T 1Z2, Canada, and **Zoran Grujic*** (zg7c@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22904. *Diffusion of low modes in the 3D NSE.*

A regularity criterion based on the diffusion of low Littlewood-Paley modes of solutions to the 3D NSE will be presented. An interesting feature is that the window of relevant frequencies (the frequencies involved in the criterion) is vanishing as the solution in view approaches the possible singular time. (Received August 07, 2015)

1112-76-468 **Robert Hardt*** (hardt@rice.edu), Mathematics Department-MS 136, Rice University, PO Box 1892, Houston, TX 77251-1892. *Line Defects in a Modified Ericksen Model.* Preliminary report.

In 1985, J. Ericksen proposed a model for uniaxial liquid crystals to explain disclinations (i.e. line defects or curve singularities). It involved not only a unit orientation vectorfield on a region of $\mathbb{R}^3$ but also a scalar function giving a local probability of orientation order. FH. Lin, in several papers, related this model to harmonic maps to a metric cone over $\mathbb{S}^2$ and studied the regularity of minimizers. The optimal partial regularity result of R.Hardt-FH.Lin in 1993 unfortunately excluded line singularities. This paper accordingly introduced a modified model involving a metric cone over $\mathbb{RP}^2$, the real projective plane. Here the nontrivial homotopy leads to the optimal estimate of the singular set being 1 dimensional. In 2010, J. Ball and A.Zarnescu discussed a derivation from the de Gennes Q tensor and interesting orientability questions using $\mathbb{RP}^2$. In recent ongoing work with FH.Lin and T. Huang, we see that the disinclination set necessarily consists of Hölder continuous curves. (Received August 10, 2015)

1112-76-503 **Nicholas O Cox-Steib*** (noc3md@mail.missouri.edu), 800 South Tucker Drive, Tulsa, OK 74104, and **Kevin O'Neil**. *Identities Satisfied by Roots of Vortex Polynomials.*

The Adler-Moser polynomials were originally introduced in the study of rational solutions to the Korteweg-de Vries equation. Later it was discovered that the zeros of these polynomials are related to equilibrium configurations of point vorticies with strength ratio -1. Recently Loutsenko introduced a similar sequence of polynomials that are related to systems of vortices with strength ratio -2. In our previous work, doubly-indexed families of polynomials were introduced that generalize the Adler-Moser and Loutsenko sequences by including an additional vortex of integer or half-integer strength.

The zeros of the Adler-Moser polynomials correspond to poles of rational solutions to the Korteweg-de Vries equation and are known to satisfy highly non-trivial identities. The present work discusses the similar identities satisfied by the zeros of Loutsenko's polynomials and a technique for generalizing these results to the doubly-indexed families of polynomials introduced in our earlier work. (Received August 10, 2015)

1112-76-547 **Jia Zhao***, Department of Mathematics, Columbia, SC 29208, and **Qi Wang**, Dept of Math, Columbia, SC 29208. *A Multiphasic Complex Fluids Model for Cytokinesis of Eukaryotes.*

Cell Mitosis is a fundamental process in eukaryotic cell reproduction, during which parent cell's nucleus first dissembles leading to DNA and chromosome replication, then chromosomes migrate to new locations within the parent cell to form offspring nuclei which triggers cytokinesis leading to the formation of two offspring cells eventually. In this presentation, we develop a full 3D multiphase hydrodynamic model to study the fundamental mitotic mechanism in cytokinesis, the final stage of mitosis. The model describes the cortical layer, a cytoplasmic layer next to the cell membrane rich in F-actins and myosins, as an active liquid crystal system and integrate the extra cellular matrix material and the nucleus into a multiphase complex fluid mixture. With the novel active matter model built in the system, our 3D simulations show very good qualitative agreement with the experimental obtained images. The hydrodynamical model together with the GPU-based numerical solver provides an effective tool for studying cell mitosis theoretically and computationally. (Received August 11, 2015)

78 ► Optics, electromagnetic theory

1112-78-309 **Shaolin Allen Liao*** (sliao@anl.gov), 9700 S Cass Avenue, Lemont, IL 60439, and **Hua-Te Chien**. *On Fast Computation of Wave Scattering through Adaptive Multi-level Convolution.*

By exploring the conjugate bandwidth relation between spatial domain and spectral domain of electromagnetic scattering by the object geometry, we have formulated an adaptive multi-level local convolution algorithm to obtain the wave Fourier spectrum of the scattering wave. Also through Surface Integral Equation (SIE) method, both scattering far field and near field can be represented by the equivalent currents on the scattering object boundary. Starting with root-level spectrum/space tree (quadtree for 2D) and leaf-level space/spectrum tree, the adaptive multi-level algorithm traverse down the spectrum/space tree through spatial/spectral domain convolution of the spatial/spectral function with a set of spectrum/space band-limited convolution kernels; the algorithm keep traversing down on the spectrum/space tree until required spectrum/space resolution is obtained. During each traversal, the algorithm can perform local adaptive search for optimized level decrement in spectrum/space tree (increment in space/spectrum tree) based on local spectral/spatial bandwidth. The algorithm has an O(NlogN) complexity for an input dependent N data points. Numerical 2D example has been successfully performed to validate the algorithm. (Received August 07, 2015)

81 ► Quantum theory

1112-81-3 **Andrew Neitzke*** (neitzke@math.utexas.edu), The University of Texas at Austin, Austin, TX. *Some new geometric applications of quantum field theory.*

Supersymmetric quantum field theory has had considerable impact in geometry and topology over the last few decades, One of the main focal points was Seiberg and Witten's analysis of the low-energy behavior of $N = 2$ supersymmetric Yang-Mills theory in four dimensions, which led to significant progress in four-manifold topology. Recently it has been discovered that the very same field theories that Seiberg and Witten studied are also connected to Teichmüller theory, and lead to new constructions there. In this talk I will describe one such construction, which is completely concrete and geometric: it relates the trajectories of quadratic differentials (solutions of a certain differential equation in one variable) to a Hilbert space of supersymmetric particle states, and from there to various other things, including a new attach on the old problem of producing explicit solutions to Einstein's equations (Ricci-flat metrics). The work I will report is joint with Davide Gaiotto and Greg Moore, and builds on work of many others, especially Seiberg-Witten, Kontsevich-Soibelman, Joyce-Song, Fock-Goncharov, Hitchin, Lerche-Mayr-Vafa-Warner. (Received May 02, 2014)

1112-81-215 **Boris Tsygan*** (b-tsygan@northwestern.edu), 2033 Sheridan Rd, Evanston, IL 60201. *An extension of the Fedosov construction.* Preliminary report.

I will present an extension of the Fedosov construction of deformation quantization of symplectic manifolds. Recall that the Fedosov connection makes the space of differential forms with coefficients in the Weyl bundle a differential graded algebra. We enlarge this differential graded algebra in such a way that the category of differential graded modules over the new algebra becomes related to other categories defined from a symplectic manifold. (Received August 04, 2015)

82 ► Statistical mechanics, structure of matter

1112-82-589 **Julio C Armas-Perez**, **Jose A Martinez-Gonzalez**, **Xiao Li** and **Juan P Hernandez-Ortiz*** (jphernandezortiz@uchicago.edu), 5801 South Ellis Avenue, Jones 211, Institute for Molecular Engineering, University of Chicago, Chicago, IL 60637, and **Paul F Nealey** and **Juan J de Pablo**. *Avoiding local minima in chiral liquid crystals by a theoretically informed Monte Carlo: drops, complex geometries and interfaces.*

A theoretically informed coarse-grained Monte Carlo method is proposed to study confined liquid crystals. The free energy functional of the system is described in the framework of the Landau-de Gennes formalism. Two numerical approaches are used to integrate and approximate the alignment field and its gradients: finite differences and a finite element quadrature. The Monte Carlo approach presented is suitable to study situations where the free energy functional includes highly non-linear terms, like chirality and high-order deformation modes. While finite differences are restricted to relatively simple geometries, comprehensive schemes can be used to move solid inclusions within the domain. On the other hand, accurate geometrical descriptions are

included in the finite element approach, thereby allowing the analysis of complex geometries. The methods are illustrated in the context of embedded nano-particles in liquid crystal droplets, confined blue phases and chemically induced bistable devices. In these situations, a delicate balance between elastic distortions and free energy penalizations at surfaces control the LC structure and the assembly of particles. In addition, curvature may produce topological frustration that results in free energy landscapes with many local minima. (Received August 11, 2015)

90 ► Operations research, mathematical programming

1112-90-29 **Andrzej Ruszczynski*** (rusz@rutgers.edu) and **Darinka Dentcheva**. *Risk Preferences on the Space of Quantile Functions.*

We propose a novel approach to quantification of risk preferences on the space of nondecreasing functions. When applied to law invariant risk preferences among random variables, it compares their quantile functions. The axioms on quantile functions impose relations among comonotonic random variables. We infer the existence of a numerical representation of the preference relation in the form of a quantile-based measure of risk. Using conjugate duality theory by pairing the Banach space of bounded functions with the space of finitely additive measures on a suitable algebra, we develop a variational representation of the quantile-based measures of risk. Furthermore, we introduce a notion of risk aversion based on quantile functions, which enables us to derive an analogue of Kusuoka representation of coherent law-invariant measures of risk. (Received June 06, 2015)

1112-90-274 **Qiji J. Zhu***, Dept of Mathematics, Western Michigan University, Kalamazoo, MI 49008. *Convex Duality and the Fundamental Theorem of Asset Pricing.* Preliminary report.

The Fundamental Theorem of Asset Pricing (FTAP) relates arbitrage-free prices of financial assets to martingale measures and plays an important role in mathematical finance. Traditionally, this theorem is proven using a separation argument. We observe that by considering an individual agent's portfolio maximization problem and its convex dual, one can arrive at a more precise version of the FTAP which in a (realistic) incomplete market reveals how the agent's risk aversion relates to a corresponding martingale measure.

This talk is adapted from lectures of a special topic course in Courant Institute on convex duality and mathematical finance by Peter Carr and Qiji Zhu. (Received August 06, 2015)

1112-90-393 **Stephen J Wright*** (swright@cs.wisc.edu), Computer Sciences Department, University of Wisconsin, Madison, WI 53706, and **Adrian S Lewis**. *A Proximal Method for Composite Minimization.*

We consider minimization of functions that are compositions of convex or prox-regular functions (possibly extended-valued) with smooth vector functions. A wide variety of important optimization problems fall into this framework. We describe an algorithmic framework based on a subproblem constructed from a linearized approximation to the objective and a regularization term. Properties of local solutions of this subproblem underlie both a global convergence result and an identification property of the active manifold containing the solution of the original problem. Preliminary computational results on both convex and nonconvex examples are promising. (Received August 09, 2015)

1112-90-557 **S. Deng*** (sdeng@niu.edu), Dept of Mathematical Sciences, Northern Illinois University, DeKalb, IL 60115. *Exact Regularization and Weak Sharp Minima in Optimization.*

This presentation will focus on inner connections among exact regularization, exact penalization, and weak sharp minima in optimization. We will discuss some new insights about these connections. Along the way, we will illustrate with examples, how to obtain both new results and reproduce many existing results from a fresh perspective. (Received August 11, 2015)

91 ► Game theory, economics, social and behavioral sciences

1112-91-16 **Darinka Dentcheva*** (darinka.dentcheva@stevens.edu), 1 Castle Point on Hudson, Hoboken, NJ 07030, and **Andrzej Ruszczynski**. *Common mathematical foundations of the expected utility and the dual utility theory.*

We show that the main results of the expected utility and dual utility theories can be derived in a unified way based on two fundamental mathematical ideas: the separation principle of convex analysis, and the integral

representations of continuous linear functionals from functional analysis. Our analysis reveals the dual character of utility functions. Additionally, we derive new integral representations of dual utility models. (Received June 06, 2015)

1112-91-273 **Arash Fahim*** (fahim@math.fsu.edu), Department Of Mathematics, Florida State University, 1017 Academic Way, Tallahassee, FL 32306, and **Nizar Touzi** (nizar.touzi@polytechnique.edu), Centre de Mathématiques Appliquées, Ecole Polytechnique, UMR CNRS 7641, 91128 Palaiseau, Cedex, France. *Modeling the behavior of a large production firm in cap-and-trade emission market.*

The aim of this talk is to address the effect of the cap-and-trade allowance market on the production policy of a large production firm. We investigate this effect in two cases; when the firm cannot affect the risk premium of the allowance price, and when it can. In our model, we formulate the problem of optimal production by a stochastic optimization problem. Then by means of analytical and numerical results, we show that, as expected, the market reduces the optimal production policy in the first case. However, when the large producer activities can change the market risk premium, the cut on the production and consequently pollution cannot be guaranteed. In fact, if the producer is under financially distressed, its production increases if the cap is reachable. (Received August 06, 2015)

1112-91-281 **Carole Bernard** and **Stephan Sturm*** (ssturm@wpi.edu), Department of Mathematical Sciences, 100 Institute Road, Worcester, MA. *Cost efficiency in incomplete markets.* Preliminary report.

We consider a portfolio choice problem maximizing terminal wealth on a finite time horizon. The cost-efficiency in complete market characterizes the optimal portfolio as the minimizer of the risk neutral hedging costs among all random variables having the same distribution. We provide a generalization of the cost efficiency principle to incomplete markets and provide applications to the characterization of the rationality of portfolio choice. (Received August 06, 2015)

1112-91-339 **Tomasz R Bielecki*** (bielecki@iit.edu), 10 W 32nd Street, E1 Bldg, Room 208, Chicago, IL 60616, and **Igor Cialenco** and **Tao Chen**. *Dynamic Conic Finance via Backward Stochastic Difference Equations.*

We present an arbitrage free framework for modeling bid and ask prices of dividend paying securities in discrete time using theory of dynamic acceptability indices given in terms of solutions of backward stochastic difference. We introduce pricing operators that are defined in terms of dynamic acceptability indices. We define bid and ask prices for underlying securities and then for derivatives in this market. We discuss related hedging issues in terms of control problems for g-expectations. (Received August 08, 2015)

1112-91-582 **Gu Wang*** (robuw@umich.edu) and **Erhan Bayraktar**. *Quantile Hedging in a Semi-Static Market with Model Uncertainty.*

With model uncertainty characterized by a convex, possibly non-dominated set of probability measures, the investor minimizes the cost of hedging a path dependent contingent claim with a given expected success ratio, in a discrete-time, semi-static market of stocks and options. We prove duality results that link the problem of quantile hedging to a randomized composite hypothesis test. By assuming a compact path space, an arbitrage-free discretization of the market is proposed as an approximation. The discretized market has a dominating measure, which enables us to calculate the quantile hedging price by applying the generalized Neyman-Pearson Lemma. Finally, the performance of the approximate hedging strategy in the original market and the convergence of the quantile hedging price are analyzed. (Received August 11, 2015)

1112-91-648 **Oleg Bondarenko*** (olegb@uic.edu), Department of Finance (MC 168), 601 S. Morgan Street, Chicago, IL 60607. *Robust Replication of Variance Derivatives.*

The demand for new volatility instruments has grown exponentially over the past decade. In this talk, I will discuss a novel approach for valuing variance derivatives in incomplete markets. The approach deviates from the existing literature by focusing on the empirically relevant realized variance, as opposed to the unobservable integrated variance. This distinction is critical for hedging actual variance instruments, such as OTC variance swaps and the CBOE variance futures. The new approach is completely model-free. It allows for jumps in the underlying price process and applies to any sampling partition. I introduce and characterize the whole class of generalized variance payoffs which can be exactly replicated under these general conditions. (Received August 11, 2015)

92 ► Biology and other natural sciences

1112-92-23 **Elizabeth Allman**, **John Rhodes** and **Seth Sullivant***, smsulli2@ncsu.edu.
Statistically consistent k-mer methods for phylogenetic tree reconstruction.

Algorithms based on k-mer distances are used to reconstruct phylogenetic trees without first constructing a multiple sequence alignment. We show that the standard method for reconstructing trees based on k-mer distances is statistically inconsistent (that is, they reconstruct the wrong tree even with increasing amounts of data) and we also derive statistically consistent model-based distance corrections in the case of sequences without gaps. We report on numerous simulations which show that the new formulas significantly out-perform older (statistically inconsistent) methods, even in sequences with gaps. These results also have implications for multiple sequences alignment, since many widely used multiple sequence alignment programs use the statistically inconsistent methods to construct a guide tree for multiple sequence alignment. (Received May 31, 2015)

1112-92-76 **Barbara Holland**, **Peter D. Jarvis**, **Jeremy G. Sumner** and **Amelia Taylor*** (amelia.taylor@coloradocollege.edu). *Developing a Statistically Powerful Measure for Phylogenetic Tree Inference using Phylogenetic and Markov Invariants.* Preliminary report.

In the late 1980's Cavendar and Felsenstein and Lake introduced the idea of phylogenetic invariants; a class of polynomials useful in the study of phylogenetic trees. Allman and Rhodes renewed interest in these polynomials taking the point of view of algebraic geometry and giving a comprehensive description of the set of polynomials which lead to their use studying numerous analytical questions like identifiability. As part of this renaissance Casanellas and Fernandez – Sanchez provided one of the first simulation studies exploring the use of the polynomials for tree inference, leaving many open questions about using the polynomials directly for tree inference. Around the same time Sumner and coauthors suggested an alternative perspective using group representation theory. We briefly present the two perspectives for the two-state general Markov model on quartet trees and then describe our study of using polynomials from each perspective to build a statistically powerful measure for tree inference, and argue for one particular measure including simulation results. (Received July 15, 2015)

1112-92-96 **Anne Shiu*** (annejls@math.tamu.edu), Mailstop 3368, Texas A&M University, College Station, TX 77843, and **Badal Joshi**. *Which small reaction networks are multistationary?* Preliminary report.

A chemical reaction network gives rise to a parametrized family of polynomial systems of ODEs by way of mass-action kinetics. An important question is the following: which reaction networks admit multiple steady states, that is, which of these polynomial systems have multiple positive solutions? There is no complete answer to this question, but over the last 40 years various criteria have been developed that can answer this question in certain cases. This talk describes recent work which seeks to answer the question for small networks. Also, we highlight some open questions. (Received July 22, 2015)

1112-92-109 **Meritxell Sáez*** (meritxell@math.ku.dk), Universitets Parken 5, 2100 Copenhagen, Denmark, and **Carsten Wiuf** and **Elisenda Feliu**. *Recovering a reaction network after linear elimination of species.*

Reaction networks can be highly complex, hence, elimination of some of the species may be desirable. Elimination of certain species in the network is closely linked to the procedure known as the quasi-steady state approximation, which is often employed to simplify the modeling equations. Under the quasi-steady state approximation, some reactions are assumed to occur at a much faster rate than other reactions, that is, there is a separation of time scales, such that a steady state effectively has been reached for the fast reactions. In this setting, the goal is to study the evolution of the species that have not reached steady state, as a new reaction network on their own.

Following the ideas introduced in (Feliu and Wiuf, 2012), where a method for the elimination of so-called non-interacting species is described, we give a graphical method to find a reaction network on the slow variables as well as their production rates. Our method reinterprets the system of equations obtained after substitution of the eliminated variables, as a new reaction network with certain kinetics. The procedure is based on the analysis of the species graph and the subgraph corresponding to the eliminated variables. (Received July 24, 2015)

1112-92-155 **Colby Long*** (celong2@ncsu.edu) and **Seth Sullivant** (smsulli2@ncsu.edu). *Tying Up Loose Strands: Defining Equations of the Strand Symmetric Model.*

The strand symmetric model is a phylogenetic model designed to reflect the symmetry inherent in the double-stranded structure of DNA. We show that the set of known phylogenetic invariants for the general strand symmetric model of the three leaf claw tree entirely defines the ideal. This knowledge allows one to determine the vanishing ideal of the general strand symmetric model of any trivalent tree. Our proof of the main result is

computational. We use the fact that the Zariski closure of the strand symmetric model is the secant variety of a toric variety to compute its dimension. We then show that the known equations generate a prime ideal of the correct dimension using elimination theory. (Received July 30, 2015)

1112-92-192 **James H Degnan*** (jamdeg@unm.edu), Department of Mathematics and Statistics, 311 Terrace NE, Albuquerque, NM 87131, and **Sha Zhu**, Wellcome Trust Centre for Human Genetics, University of Oxford, Oxford, United Kingdom. *Displayed Trees Do Not Determine Distinguishability Under the Network Multispecies Coalescent.* Preliminary report.

Recent work in estimating species relationships from gene trees have included inferring networks assuming that past hybridization has occurred between species. Probabilistic models using the multispecies coalescent can be used in this framework for likelihood-based inference of both network topologies and parameters, including branch lengths and hybridization parameters. A difficulty for such methods is that it is not always clear whether, or to what extent, networks are identifiable — i.e., whether there could be two distinct networks that lead to the same distribution of gene trees. We present a new representation of the species network likelihood that represents the probability distribution of the gene tree topologies as a linear combination of gene tree distributions given a set of species trees. This representation makes it clear that in some cases in which two distinct networks give the same distribution of gene trees when sampling one allele per species, the two networks can be distinguished theoretically when multiple individuals are sampled per species. This result means that network identifiability is not only a function of the trees displayed by the networks. (Received August 03, 2015)

1112-92-230 **Alan D. Rendall*** (rendall@uni-mainz.de), University of Mainz, Staudingerweg 9, 55099 Mainz, Germany. *Overload breakdown in models of photosynthesis.*

In one part of photosynthesis, known as the Calvin cycle, carbohydrates are produced using carbon dioxide from the atmosphere. This process can be modelled using systems of ordinary differential equations for the concentrations of the substances involved. The main subject of this talk is some work done together with Dorothea Möhring on the qualitative behaviour of solutions of some of these systems. In particular the phenomenon known as overload breakdown will be discussed. Mathematically this means that the concentrations of some of the substances in the system tend to zero at late times. The biological background is the following. If carbohydrates are exported too fast from the chloroplast the production in the cycle cannot keep up. It is overloaded and breaks down. The main methods used in this work are the derivation of restrictions on ω-limit points with zero concentrations of positive solutions and the use of Lyapunov functions. In this way information can be obtained on the circumstances under which overload breakdown takes place in a given model and which concentrations tend to zero at late times when it does so. This provides criteria for deciding on the appropriateness of different models. (Received August 05, 2015)

1112-92-289 **Carsten Wiuf*** (wiuf@math.ku.dk), Department of Mathematical Sciences, Universitetsparken 5, Copenhagen, 2100, and **Elisenda Feliu**, Department of Mathematical Sciences, Universitetsparken 5, Copenhagen, 2100. *Model Simplification in Reaction Network Theory.*

Dynamical systems of biochemical reactions might be described by systems of ordinary differential equations (ODEs). The ODEs typically contain many variables (concentrations of chemical species) and many unknown parameters. It is therefore custom to simplify or reduce the system in various (often ad hoc) ways.

In this talk, we will discuss model simplification from different perspectives. In particular the focus will be on graphical approaches in relation to reduction of a original reaction network to a smaller network. We will discuss how such approaches might be applied to

1. gain information about the original network from the reduced, such as information about multistationarity and persistence,

2. obtain simplified models of the original network

The procedures might be applied iteratively to reduce the original network in some cases to very simple networks, such as monomolecular networks.

The discussion will be placed in a historical context showing relationship to both the standard QSSA and graphical procedures developed in the 50ies and 60ies. (Received August 06, 2015)

1112-92-315 **Stefan Forcey*** (sforcey@uakron.edu), **Logan Keefe** and **William Sands**. *Facets of Balanced Minimal Evolution polytopes.*

I'll review how the balanced minimal evolution (BME) method reconstructs a phylogenetic tree from a given distance matrix, by performing the simplex algorithm for a simple example. New and improved algorithms

might be available if we had enough facets of the BME polytope in order to pose a relaxed linear programming problem. So far we have found all the facets up to dimension 5 and several classes of large facets that extend to all dimensions. We'll go over facets from caterpillars, necklaces, intersecting cherries, and big splits. We'll mention some interesting connections to matching polytopes like the Birkhoff polytope, and list some open questions about counting and geometry. (Received August 07, 2015)

1112-92-360 **Emily Castner**, **Brent Davis** and **Joe Rusinko*** (rusinko@hws.edu), NY. *Nearest Point Phylogenetic Reconstruction using Numerical Algebraic Geometry.*

We propose a phylogenetic reconstruction algorithm which uses the distance to the nearest point on the phylogenetic model to select the tree of best fit. Our implementation is currently for quartet trees which can be then used to reconstruct larger trees using a quartet amalgamation algorithm. This algorithm allows for data dependent hypothesis testing which helps identify when trees have been accurately reconstructed an important feature since quartet amalgamation algorithms are sensitive to error in input trees but do not require a complete set of quartet trees as inputs. We present initial findings for the Jukes-Cantor, Kimura 2 and 3 parameter models and the general Markov model of evolution. (Received August 09, 2015)

1112-92-371 **Matthew D Johnston*** (matthew.johnston@sjsu.edu), San Jose State University, One Washington Square, San Jose, CA 95192, and **David F Anderson**, **Gheorghe Craciun** and **Robert Brijder**. *Extinction and Persistence in Discrete Chemical Reaction Systems.* Preliminary report.

The evolution of a well-mixed chemical reaction system can be modeled as either a deterministic system of ordinary differential equations, which tracks continuous molecular concentrations, or as a stochastic continuous-time Markov chain, which tracks discrete molecular counts. Although the stochastic model is known to converge in probability to the deterministic model in an appropriate scaling limit, surprisingly, many examples are known where the long-term behavior of the two models is starkly different. In particular, the discrete model may permit extinction events not seen in the continuous-state model. In this talk, I introduce methods from Petri Net theory which have been recently applied to chemical reaction systems to given conditions for extinction in the discrete systems. (Received August 09, 2015)

1112-92-383 **Balázs Boros*** (borosbalazs84@gmail.com). *On the existence of positive steady states for deficiency-one mass action systems with two linkage classes.* Preliminary report.

The mass action differential equation of chemical reaction networks takes the form $\dot{x}(\tau) = Y \cdot A_\kappa \cdot x(\tau)^Y$, where Y is the matrix of complexes, κ is the reaction rate coefficient function, A_κ is the Laplacian of the laballed Feinberg-Horn-Jackson graph, and x^Y is a shorthand notation for the function with monomial coordinates with the powers being the entries of Y. The existence of positive steady states of such ODE's is of interest. Clearly, the existence of a positive vector in the kernel of $Y \cdot A_\kappa$ is a *prerequisite* for the existence of a positive steady state. Based on general theorems, for several mass action systems, the existence of such a positive vector in the kernel of $Y \cdot A_\kappa$ is also *sufficient* for the existence of a positive steady state. In this talk, we will examine the sufficiency for deficiency-one mass action systems with two linkage classes. (Received August 09, 2015)

1112-92-422 **Mercedes Perez Millan*** (mpmillan@dm.uba.ar), Departamento de Matemática, Ciudad Universitaria - Pabellón I, C1428EGA Buenos Aires, Argentina, and **Alicia Dickenstein** (alidick@dm.uba.ar). *Mixed and basic MESSI biological systems.*

Many processes within cells that involve some kind of post-translational modification of proteins lie in the framework of MESSI systems (systems that present Modifications of type Enzyme-Substrate or Swap with Intermediates). We give combinatorial conditions for some of these systems, which we call mixed and basic MESSI systems, that determine multistationarity and the occurrence of boundary steady states. (Received August 10, 2015)

1112-92-453 **Bret Larget*** (bret.larget@wisc.edu), 430 Lincoln Avenue, Department of Botany, Madison, WI 53706. *Recent Advances in Bayesian Concordance Analysis.*

Bayesian concordance analysis, as implemented in the software BUCKy, is a method to simultaneously estimate multiple gene trees with prior information that trees from different genes relating the same set of taxa are likely to be similar, if not identical. Information is shared between genes, but discordance among genes is allowed. Recent advances include a cluster model where discordant gene trees are expected to be topologically similar, as many biological processes that create gene tree discordance predict. We review recent advances in this research area. (Received August 10, 2015)

1112-92-461 **James D Brunner*** (jdbrunner@math.wisc.edu), UW Madison Department of Mathematics, Van Vleck Hall, 480 Lincoln Drive, Madison, WI 53706, and **Gheorghe Craciun**. *Permanence of power law systems.* Preliminary report.

Permanence of an ODE model of a chemical reaction network may informally be considered equivalent to the existence of compact attracting subset of $\mathbb{R}^d_{\geq 0}$. Permanence of power law systems has not been fully characterized, even in two dimensions. Inspired by chemical reaction networks, we use the geometrical properties of a power law system with non-constant coefficient functions to investigate permanence. Using the *geometrically embedded graph* of a power law system, have characterized a robust type of permanence in $\mathbb{R}^2$, and seek to extend this to higher dimensions. (Received August 10, 2015)

1112-92-532 **Nicolette Meshkat*** (nmeshkat@scu.edu), **Heather Harrington** and **Kenneth Ho**. *Model rejection using differential algebra.*

A common problem in biological modeling is the issue of model selection/rejection. Model selection involves determining the most appropriate model for a process given observed data and a set of candidate models for the process generating that data. On the other hand, model rejection asks the question of which candidate models are incompatible with the observed data. We consider the model rejection problem by applying methods from differential algebra to obtain structural invariants known as input-output equations. Then, given time course data and estimates of higher order derivatives of the associated input/output variables, we determine the extent to which the data satisfies these input-output equations. We employ methods from statistics to obtain a criteria for model rejection and demonstrate this approach on some linear and nonlinear biological models. This is joint work with Heather Harrington and Kenneth Ho. (Received August 11, 2015)

1112-92-584 **Gilles Gnacadja*** (gilles.gnacadja@gmail.com), Amgen, 1120 Veterans Boulevard, Mail Stop ASF3-3, South San Francisco, CA 94080. *Reaction Networks, Species Composition, and Reversibility.*

In several prior presentations, I have alluded in a hand-wavy way to notions of species composition and reversibility I developed and applied to results on uniqueness of equilibria and persistence. In this presentation I will focus on explaining and making relevant these notions. (Received August 11, 2015)

1112-92-613 **Sebastien Roch*** (roch@math.wisc.edu), Department of Mathematics, UW-Madison. *Mathematics of the Tree of Life—From Genomes to Phylogenetic Trees and Beyond.*

The reconstruction of the Tree of Life is an old problem in evolutionary biology which has benefited from various branches of mathematics, including probability, combinatorics, algebra, and geometry. Modern DNA sequencing technologies are producing a deluge of new data on a vast array of organisms—transforming how we view the Tree of Life and how it is reconstructed. I will survey recent progress on some mathematical and computational questions that arise in this context. No biology background will be assumed. (Received August 11, 2015)

1112-92-650 **Elizabeth Gross**, **Heather A Harrington** and **Zvi Rosen*** (zur10@psu.edu), 205 McAllister Building, Pennsylvania State University, University Park, PA 16801, and **Bernd Sturmfels**. *Algebraic Systems Biology: A Case Study for the Wnt Pathway.*

We study the algebraic variety arising from the shuttle model of the Wnt signaling pathway. Here the variety is described by a polynomial system in 19 unknowns and 36 parameters. Current methods from computational algebraic geometry and combinatorics are applied to analyze this model; this talk will focus on the matroidal perspective. (Received August 11, 2015)

93 ► Systems theory; control

1112-93-262 **Ananda Weerasinghe** and **Chao ZHu*** (zhu@uwm.edu), Department of Mathematical Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI 53201. *Optimal Inventory Control with Path-Dependent Cost Criteria.*

This work deals with a stochastic control problem arising from inventory control, in which the cost structure depends on the current position as well as the running maximum of the state process. A control mechanism is introduced to control the growth of the running maximum which represents the required storage capacity. The infinite horizon discounted cost minimization problem is addressed and it is used to derive a complete solution to the long-run average cost minimization problem. An associated control cost minimization problem subject to a storage capacity constraint is also addressed. Finally, as an application of the above results, this paper also formulates and solves an infinite-horizon discounted control problem with a regime-switching inventory model.

This is a joint work with Ananda Weerasinghe (Iowa State University). (Received August 06, 2015)

1112-93-588 **Michael Malisoff*** (malisoff@lsu.edu), Department of Mathematics, Louisiana State University, 303 Lockett Hall, Baton Rouge, LA 70803-4918. *Robustness of Adaptive Control under Time Delays for Three-Dimensional Curve Tracking.*

We study the robustness of a class of controllers that ensure three-dimensional curve tracking by a free moving particle. The free particle tracks a closest point on a curve. By constructing a strict Lyapunov function and a set of robustly forwardly invariant sets, we show input-to-state stability under predictable safety and tolerance bounds that ensure robustness under control uncertainty, input delays, and a set of polygonal state constraints. Our work ensures adaptive tracking and parameter identification when there are unknown control gains. This understanding can ensure that performance objectives are met, when the control laws are applied in real life systems. This is joint work with Fumin Zhang, and is based on our 2015 article in SIAM Journal on Control and Optimization. (Received August 11, 2015)

94 ► Information and communication, circuits

1112-94-82 **Vladimir D Tonchev*** (tonchev@mtu.edu), Michigan Technological University, 1400 Townsend Drive, Houghton, MI 49931. *The weight distribution of the self-dual* $[128, 64]$ *polarity design code.* Preliminary report.

The weight distribution of the binary self-dual $[128, 64]$ code being the extended code C^* of the code spanned by the incidence vectors of the blocks of the polarity design in $PG(6, 2)$ is computed. The code C^* has the same weight distribution as the 3rd order Reed-Muller code of length 128. (Received July 23, 2015)

1112-94-89 **Ian F. Blake*** (ifblake@ece.ubc.ca), Department of Electrical and Computer Eng., 2332 Main Mall, University of British Columbia, Vancouver, BC V6T 1Z4, Canada. *Graph spectra and coding.*

Graph theory has played an important role in coding theory from its inception. Many of the investigations, from the iterative algorithms inspired by the work of Gallager to the efficient decoding algorithms of Spielman, involve aspects of the spectra of the graphs involved. This talk considers some of the recent directions this work has taken with special reference to the important class of biregular bipartite graphs. It relates the spectral properties of these graphs to aspects of the error performance of the related codes. The role of the second largest eigenvalue of the adjacency marix of the graph is of special interest in many of these directions. (Received July 21, 2015)

1112-94-200 **Harold N. Ward*** (hnw@virginia.edu), Department of Mathematics, University of Virginia, Charlottesville, VA 22904. *Thirty-six officers and their codes.*

The truth of Euler's famous 36 officers conjecture is equivalent to the nonexistence of a (6,4) net. Steven Dougherty proved the nonexistence by a dimension argument for the binary code of the net [Des. Codes Cryptography 4 (1996), 123–128]. The proof involved a configuration of eight lines, two in each parallel class, supported on 24 points. This he showed to be impossible, paralleling a combinatorial argument of Douglas Stinson [J. Combin. Theory A 36 (1984), 373–376].

In this talk we shall use the ternary code of the net in the presence of that configuration to derive a contradiction. The projection of the code on the 24 points does exist as a code in its own right. It is only the lift to the 36 points and 24 lines of the net that cannot be done. (Received August 03, 2015)

1112-94-290 **Jessalyn Bolkema*** (jessalyn.bolkema@huskers.unl.edu), **Katherine Morrison** and **Judy L. Walker**. *Graph Realizations of Polar Codes.* Preliminary report.

In 2008, Arikan introduced a powerful family of codes that he termed *polar codes*. These schemes are built on (and named for) the phenomenon of *channel polarization*: a mechanism for recursively combining N independent copies of a given channel into N distinct channels, some fraction of which are noiseless while the remaining channels are useless. The resulting coding scheme was the first to demonstrably achieve Shannon capacity on symmetric binary-input memoryless channels. While the first decoding algorithm proposed proposed for polar codes was successive cancellation, there has been much interest recently in graph-based decoding algorithms for these codes. It has also been established that channel polarization is a very general phenomenon. We discuss families of graph realizations of polar codes, suitable for message-passing decoding algorithms. Graphical and algebraic properties of these families are addressed. Further, we consider the relevance of these properties to code performance. (Received August 06, 2015)

1112-94-372 **Steve Szabo*** (steve.szabo@eku.edu), Richmond, KY , and **Felix Ulmer** (felix.ulmer@univ-rennes1.fr), Rennes, France. *Duality Preserving Grey Maps.*

Given a finite ring A which is a free left module over a subring R of A, two types of R-bases are defined which in turn are used to define duality preserving maps from codes over A to codes over R. (Received August 09, 2015)

1112-94-506 **Gretchen Matthews*** (gmatthe@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29631. *On locally decodable codes from AG codes.* Preliminary report.

In some applications, it is necessary to determine a single or perhaps a small number of message or codeword symbol(s) without having access to the entire received word. This is in contrast to the traditional setting where a decoder takes as input a received word w and uses w to produce an estimate of the codeword originally sent. Here, the notion of locally decodable codes is needed. In this talk, we discuss preliminary results on locally decodable codes constructed from algebraic geometric codes. (Received August 10, 2015)

1112-94-512 **Sarah E. Anderson*** (sarah5@g.clemson.edu), St. Paul, MN 55105. *Stopping sets of algebraic geometric codes from hyperelliptic curves.*

Stopping sets are combinatorial structures that govern the performance of a linear code over the binary erasure channel when coupled with an iterative decoding algorithm. For a code C with parity-check matrix H and a set S of column indices of H, S is a stopping set of C if and only if the restriction of H to S does not have a row of weight 1. Stopping sets of algebraic geometric codes were first studied in 2014 by Zhang, Fu, and Wan. They determine stopping sets of algebraic geometric codes from the rational function field and elliptic function fields by studying related Reimann-Roch spaces. In this talk, we classify stopping sets of algebraic geometric codes codes over hyperelliptic function fields of genus 2. (Received August 10, 2015)

1112-94-594 **Hai Q Dinh*** (hdinh@kent.edu), Department of Mathematical Sciences, Kent State University, Warren, OH 44483. *On an equivalence of constacyclic codes and applications.*

Let p be a prime, and $q = p^m$, a new equivalence relation " $\sim_n$ " is introduced on the nonzero elements of the finite field $\mathbb{F}_q$ to classify constacyclic codes of length n over $\mathbb{F}_q$ such that the constacyclic codes belonging to the same isometry class have the same distance structures and the same algebraic structures. Some necessary and sufficient conditions for any two nonzero elements of $\mathbb{F}_q$ to be equivalent to each other are presented. We show that if $\lambda \sim_n \mu$ then there exists a very explicit $\mathbb{F}_q$-algebra isomorphism φ between $\mathbb{F}_q[X]/\langle X^n - \lambda\rangle$ and $\mathbb{F}_q[X]/\langle X^n - \mu\rangle$.

As an application, we provide all the equivalence classes induced by " $\sim_{\ell p^s}$ ", and characterize all constacyclic codes of length ℓp^s over $\mathbb{F}_{p^m}$ and their duals, where ℓ is a prime different from p. (Received August 11, 2015)

1112-94-651 **Jay A. Wood*** (jay.wood@wmich.edu), Department of Mathematics, Western Michigan University, 1903 W. Michigan Ave., Kalamazoo, MI 49008. *Isometry Groups of Additive Codes.*

A classical result of MacWilliams says that any linear isometry with respect to the Hamming weight of a linear code over a finite field must extend to a monomial transformation. This result fails to hold for additive codes over non-prime finite fields.

Given two subgroups $H_1 \subseteq H_2$ of $GL(m, \mathbb{F}_p)$ (subject to some natural necessary conditions), there exists an additive code C over $\mathbb{F}_q$, $q = p^\ell$, $\ell \geq 2$, with $\dim_{\mathbb{F}_p} C = m$, such that the group of Hamming isometries of C is H_2, but only those isometries belonging to H_1 extend to monomial transformations. For example, the result applies to the minimal possible $H_1 = \{\alpha \cdot I_m : \alpha \in \mathbb{F}_p^\times\}$ and maximal $H_2 = GL(m, \mathbb{F}_p)$. (Received August 11, 2015)

1112-94-655 **Christine A Kelley*** (ckelley2@math.unl.edu), Department of Mathematics, 203 Avery Hall, Lincoln, NE 68588. *Bounds on the error correction capability of graph-based codes.* Preliminary report.

In this talk we will present some new results on the error correction capability of a family of graph-based codes. (Received August 11, 2015)

97 ► Mathematics education

1112-97-185 **Zalman Usiskin*** (z-usiskin@uchicago.edu), 1245 Sunset Road, Winnetka, IL 60093.

How Long Does It Take Newly Found Mathematics to Reach School Classrooms?

Preliminary report.

Newly found mathematical ideas and results today can be immediately communicated worldwide, a very new development in the history of mathematics. This paper discusses the time it has taken for selected results to appear in K-12 textbooks, that is, to the typical pre-college student. Historical and present-day examples from arithmetic, algebra, geometry, and statistics are offered. (Received August 02, 2015)

00 ► General

1113-00-58 **Amrita Acharyya*** (amrita.acharyya@utoledo.edu), **Jon M Corson** and **Bikash C Das**. *Coverings of Profinite Graphs.*

We define a covering of a profinite graph to be a projective limit of a system of covering maps of finite graphs (Our finite graphs are graphs in the sense of Serre). With this notion of covering, we develop a covering theory for profinite graphs which is in many ways analogous to the classical theory of coverings of abstract graphs and coverings of topological spaces. For example, it makes sense to talk about the lifting criterion of a map of profinite graphs. Also we show that universal cover of a connected profinite graph always exists and is unique. We define the profinite fundamental group of a profinite graph and show that a connected cover of a connected profinite graph is the universal cover if and only if its profinite fundamental group is trivial. (Received August 06, 2015)

1113-00-59 **Amrita Acharyya** (amrita.acharyya@utoledo.edu), **Jon M Corson** and **Bikash C Das*** (bikash.das@ung.edu). *Cofinite graphs and groupoids and their profinite completions.*

We define cofinite graphs and cofinite groupoids in a unified way that extends the notion of cofinite groups introduced by B. Hartley. The common underlying structure of all these objects is that they are directed graphs endowed with a certain type of uniform structure, that we call a cofinite uniformity. We begin by exploring the fundamental theory of cofinite directed graphs in full generality. The general theory turns out to be almost completely analogous to that of cofinite groups. For instance, every cofinite directed graph has a unique completion which is a compact cofinite direct graph. Moreover, compact cofinite directed graphs are precisely the profinite directed graphs, i.e., projective limits of finite discrete topological directed graphs. We then apply the general theory to directed graphs with additional structure such as graphs (in the sense of Serre) and groupoids, thus leading to the notions of cofinite graphs and cofinite groupoids. Cofinite groupoids with only finitely many identities behave much the same as cofinite groups, which are the same thing as cofinite groupoids with a single identity. However the situation for cofinite groupoids with infinitely many identities is more complicated. (Received August 06, 2015)

1113-00-152 **Taufiquar R Khan*** (khan@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634. *Sparse Reconstruction in Diffuse Optical Tomography.*

In this talk, a short overview of the basics of image reconstruction in diffuse optical tomography (DOT) will be presented. A sparsity constrained reconstruction problem in DOT for determining the optical parameters from boundary measurements will be presented. The sparsity of the inclusion with respect to a particular basis is assumed a priori. The proposed approach is based on a sparsity promoting l1-penalty term similar to the approach recently proposed in electrical impedance tomography. We will present some preliminary simulation results and discuss present and future work in sparsity approach in DOT. (Received August 19, 2015)

03 ► Mathematical logic and foundations

1113-03-14 **Takeelie Niche Hicks** (teachingeverydaymath@gmail.com), 6167 Swabia Court, Stone Mountain, GA 30087, and **Ebony Bass*** (teachingeverydaymath@gmail.com), 6167 Swabia Court, Stone Mountain, GA 30087. *Accessing all learning styles through Math Poetry and Music Experience.*

Music, Music, Music is what society use to reach students on a daily basis. This session will focus on how rap music and poetry can be used in the classroom to improve student growth percentiles and address all learning styles. Attendees will leave with strategies and an understanding of how to incorporate music in the classroom daily to promote student engagement. Presenters T. Hicks and E. Bass are experienced Teachers with high levels of student growth who currently use the strategies in the session to accomplish achievements. (Received April 14, 2015)

05 ► Combinatorics

1113-05-28 **Kevin Ford*** (ford@math.uiuc.edu), Department of Mathematics, 1409 West Green Street, Urbana, IL 61802, **Ben Green** (ben.green@maths.ox.ac.uk), Mathematical Institute, Radcliffe Observatory Quarter, Woodstock Road, Oxford, OX2 6GG, United Kingdom, **Sergei Konyagin** (konyagin@mi.ras.ru), 8 Gubkin Street, Moscow, 119991, Russia, **James Maynard** (james.alexander.maynard@gmail.com), Mathematical Institute, Radcliffe Observatory Quarter, Woodstock Road, Oxford, OX2 6GG, United Kingdom, and **Terence Tao** (tao@math.ucla.edu), Department of Mathematics, 405 Hilgard Ave, Los Angeles, CA 90095. *Efficient hypergraph covering.*

Recently, the authors improved the bound on the largest gaps between consecutive prime numbers. An important ingredient in the proof is a new result on efficient covering of hypergraphs, which extends a well-known theorem of Pippenger and Spencer from 1989. The Pippenger-Spencer theorem ensures the existence of a near-perfect packing of a hypergraph $H = (V, E)$ under three basic assumptions on H: (a) uniformity - all hyperedges $e \in E$ have the same (bounded) cardinality k; (b) regularity - the degree of each vertex $v \in V$ is asymptotically the same; (c) small codegrees - for all distinct $v, w \in V$, there are "few" edges containing both v and w. Our new theorem gives essentially the same conclusion (not necessarily a packing, but an efficient near-covering) with a substantial weakening of hypotheses (a) and (b), while retaining (c) and the main hypothesis. (Received July 09, 2015)

1113-05-43 **Andrzej Dudek** and **Linda Lesniak*** (lindalesniak@gmail.com), Department of Mathematics, Western Michigan University, Kalamazoo, MI 49008. *Some remarks on vertex size-Ramsey numbers.*

Here we study an analogue of size-Ramsey numbers for vertex colorings. For a given number of colors r and a graph G, the *the vertex size-Ramsey number of* G, denoted by $\hat{R}_v(G)$, is the least number of edges in a graph H with the property that any r-coloring of the vertices of H yields a monochromatic copy of G. We observe that $\Omega(\Delta) = \hat{R}_v(G) = O(n^2)$ for any graph G of order n and maximum degree Δ, and prove that for some graphs these bounds are tight. On the other hand, we show that even 3-regular graphs can have nonlinear vertex size-Ramsey numbers. (Received July 31, 2015)

1113-05-64 **Jozsef Balogh*** (jozsebal@gmail.com), **Hong Liu**, **Maryam Sharifzadeh** and **Andrew Treglown**. *On problems of Cameron and Erdos.*

In 1990 and 1999, Cameron and Erdos proposed several problems in additive combinatorics. They asked about the number of sum-free sets, number of maximal sum-free sets, number of Sidon sets in [n]. Additionally they asked the number of sets in [n] without k-term arithmetic progression. In the talk we survey the recent progress on these questions. (Received August 07, 2015)

1113-05-68 **Victor Falgas-Ravry*** (victor.falgas-ravry@vanderbilt.edu), **Klas Markström** and **Jacques Verstraëte**. *Full subgraphs of a graph.*

Let G be an n-vertex graph with edge-density p. Following Erdős, Łuczak and Spencer, an m-vertex subgraph H of G is called *full* if it has minimum degree at least $p(m-1)$. Let $f(G)$ denote the order of a largest full subgraph of G, and let $f_p(n)$ denote the minimum of $f(G)$ over all n-vertex graphs G with edge-density p.

We show that for $p: \ n^{-\frac{1}{3}} < p < 1 - n^{-\frac{1}{5}}$, the function $f_p(n)$ is of order at least $(1-p)^{\frac{1}{3}} n^{\frac{2}{3}}$, improving on a lower bound of Erdős, Łuczak and Spencer in the case $p = \frac{1}{2}$ and extending work of Erdős, Faudree, Jagota and Łuczak. Moreover we show that this bound is tight: for infinitely many p near the elements of $\{\frac{1}{2}, \frac{2}{3}, \frac{3}{4}, \ldots\}$ we have $f_p(n) = \theta(n^{\frac{2}{3}})$.

As an ingredient of the proof, we show that every graph G on n vertices has a subgraph H on m vertices with $\lfloor \frac{n}{r} \rfloor \leq m \leq \lceil \frac{n}{r} \rceil + 1$ such that for every vertex $v \in V(H)$ the degree of v in H is at least $\frac{1}{r}$ times its degree in G. Finally, we discuss full subgraphs of random and pseudorandom graphs, and introduce several open problems. (Received August 10, 2015)

1113-05-90 **Art M. Duval**, **Bennet Goeckner**, **Caroline J. Klivans** and **Jeremy L. Martin*** (jlmartin@ku.edu). *A non-partitionable Cohen-Macaulay simplicial complex.*

A long-standing conjecture of Stanley states that every Cohen-Macaulay simplicial complex is partitionable. We disprove the conjecture by constructing an explicit counterexample. Due to a result of Herzog, Jahan and Yassemi, our construction also disproves the conjecture that the Stanley depth of a monomial ideal is always at least its depth. (Received August 13, 2015)

1113-05-98 **Z. Füredi**, **A. Kostochka*** (kostochk@math.uiuc.edu) and **J. Verstraëte**. *Stability results on cycles and paths.* Preliminary report.

The classical Erdős-Gallai theorems from 1959 on the most edges in n-vertex graphs not containing paths or cycles with k edges were sharpened later by Faudree and Schelp, Woodall, and Kopylov. For $n \geq 5k/4$ the strongest result was: if $t \geq 2$, $k = 2t+1$, $n \geq \frac{5t-3}{2}$, and G is an n-vertex 2-connected graph with at least $h(n,k,t) = \binom{k-t}{2} + t(n-k+t)$ edges, then G contains a cycle of length at least k unless $G = H_{n,k,t} := K_n - E(K_{n-t})$. We prove stability versions of these results. In particular, if $n \geq 3t > 3$, $k = 2t+1$ and the number of edges in an n-vertex 2-connected graph G with no cycle of length at least k is greater than $h(n,k,t-1) = \binom{k-t+1}{2} + (t-1)(n-k+t-1)$, then G is a subgraph of $H_{n,k,t}$. The lower bound on $e(G)$ is tight. (Received August 13, 2015)

1113-05-103 **Ruth E Davidson*** (redavid2@illinois.edu), **Augustine O'Keefe** (augustine.okeefe@conncoll.edu) and **Daniel Parry** (dan.t.parry@gmail.com). *A new shellability proof of an old identity of Dixon.*

We give a new proof of an old identity of Alfred Cardew Dixon (1865-1936). The new proof uses tools from topological combinatorics. Dixon's identity is re-established by constructing a family of non-pure shellable simplicial complexes $\Delta(n)$, whose structure is a function of any positive integer n. The alternating sum of the numbers of faces of $\Delta(n)$ of each dimension is the left-hand side of the the identity, and we show that the alternating sum of the Betti numbers of the complex is equal to the right-hand side of the identity. In other words, Dixon's identity is re-established by using the Euler-Poincaré relation for $\Delta(n)$. The Betti numbers are calculated by showing that for any n, $\Delta(n)$ is shellable. Then, using the well-known fact that a (possibly non-pure) shellable simplicial is homotopy equivalent to a wedge of spheres, we count the number of faces of $\Delta(n)$ of each dimension that attach along their entire boundary-also known as homology facets-in the shelling order, thereby computing the Betti numbers of $\Delta(n)$. This is joint work with Augustine O'Keefe and Daniel Parry. (Received August 13, 2015)

1113-05-105 **David Galvin***, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Asymptotic normality of restricted Stirling numbers.*

Harper showed that the Stirling numbers of the second kind exhibit asymptotic normality — the distribution of the number of classes in a uniformly chosen equivalence relation on $[n]$, appropriately normalized, approaches the standard normal as n grows.

Here we extend Harper's setting, considering equivalence relations that respect certain pair-restrictions. We encode the set of restrictions in a graph on vertex set $[n]$, with an edge between two vertices indicating that the corresponding two elements cannot be in the same class as each other. We extend Harper's result by exhibiting a class of restriction graphs, that includes all forests, for which asymptotic normality of the (now restricted) Stirling numbers continues to hold.

Our proof uses some of Harper's ideas, but takes a surprising detour into various old and new combinatorial approaches to the normal order problem for the Weyl algebra. (Received August 13, 2015)

1113-05-109 **Craig Timmons*** (craig.timmons@csus.edu). *Extremal results in finite quasifields.*

Using a graph theoretic approach, we generalize several results that hold in finite fields to the setting of finite quasifields. This includes sum-product type estimates and a Szemerédi-Trotter type theorem. Fundamental to our proofs is estimating eigenvalues of algebraically defined graphs. This is joint work with Thang Pham, Michael Tait, and Le Anh Vinh. (Received August 14, 2015)

1113-05-112 **Suil O*** (suil.oh@gmail.com). *Some applications of interlacing theorems.* Preliminary report.

In this talk, we introduce some applications of two fundamental interlacing theorems. (Received August 15, 2015)

1113-05-116 **Colton R. Magnant*** (cmagnant@georgiasouthern.edu), PO Box 8093, Georgia Southern University, Statesboro, GA 30460. *Graph linkage with distance constraints.*

In this talk, we survey some recent results concerning linking vertices together using internally disjoint paths of prescribed lengths. This includes placing selected vertices on a Hamiltonian cycle in order at prescribed distances and linking pairs of vertices with disjoint paths in addition to other more general structures. (Received August 16, 2015)

1113-05-117 **Franklin H. J. Kenter*** (franklin.h.kenter@rice.edu). *Spectral Results for Adaptations of Graph Coloring.*

Hoffman proved that for a simple graph G, the chromatic number, $\chi(G)$, obeys $\chi(G) \leq 1 - \lambda_{\max}/\lambda_{\min}$ where $\lambda_{\max}$ and $\lambda_{\min}$ are the maximal and minimal eigenvalues of the adjacency matrix of G respectively.

We give a short probabilistic proof of Hoffman's theorem, Then, we extend the technique to variations of graph coloring with additional restrictions and/or relaxations. Our results include necessary spectral conditions for coloring 3-, 4-, and 5-uniform hypergraphs; for coloring graphs limiting the use of colorings with a neighborhood (i.e., frugal coloring); and coloring directed graphs where no color class is a strongly connected component. (Received August 16, 2015)

1113-05-120 **Zhanar Berikkyzy** and **Ryan R Martin*** (rymartin@iastate.edu), Department of Mathematics, Iowa State University, 396 Carver Hall, Ames, IA 50011, and **Chelsea Peck**. *The edit distance of powers of cycles.* Preliminary report.

The edit distance between two graphs on the same labeled vertex set is defined to be the size of the symmetric difference of the edge sets, divided by $\binom{n}{\lfloor n/2 \rfloor}$. The edit distance function of a hereditary property $\mathcal{H}$ is a function of $p \in [0,1]$ that measures, in the limit, the maximum normalized edit distance between a graph of density p and $\mathcal{H}$. It is also, again in the limit, the edit distance of the Erdős-Rényi random graph $G(n,p)$ from $\mathcal{H}$.

In this talk, we address the edit distance function for forb(H), where $H = C_h^t$, the t^{th} power of the cycle of length h. For $h \geq 2t(t+1)+1$ and h not divisible by $t+1$, we determine the function for all values of p. For $h \geq 2t(t+1)+1$ and h divisible by $t+1$, the function is obtained for all but small values of p. We also obtain some results for smaller values of h. (Received August 16, 2015)

1113-05-127 **Michael S Jacobson*** (michael.jacobson@ucdenver.edu), Campus Box 170, PO. Box 173364, Denver, CO 80217-3364. *Minimum degree and even cycle lengths.*

Dirac showed that if G is a 2-connected graph of order n with minimum degree $\delta \geq 3$, then G contains a cycle of length at least $\min\{n, 2\delta\}$. We conjecture that there are $\delta - 1$ even cycles of different lengths and when G is non-bipartite there are $\delta - 1$ odd cycles of different lengths. We prove this conjecture when $\delta = 3$. Related results concerning the number of different even cycle lengths supporting the conjecture are also included. In particular, we show that there are always at least $(\delta - 1)/2$ even cycles of different lengths. Further, we prove the conjecture for even cycles when $\delta \geq 3$.

This was joint work completed with Ralph Faudree, Ronald Gould and Colton Magnant. This work was one of the final projects on which we collaborated with Ralph Faudree. (Received August 17, 2015)

1113-05-130 **Robert E.L. Aldred**, **Quili Li**, **Michael D. Plummer*** (michael.d.plummer@vanderbilt.edu), **Dong Ye** and **Heping Zhang**. *Matching Extension in Toroidal Quadrangulations: the 3-extendable Case.*

A graph G containing a perfect matching is said to be m-extendable if $m \leq (|V(G)|-2)/2$ and for every matching M in G with $|M| = m$, there is a perfect matching F in G such that $M \subseteq F$. In an earlier paper, four of the present five authors characterized those quadrangulations of the torus which are 2-extendable. In this talk a characterization of those which are 3-extendable will be presented. Since no quadrangulation of the torus can be m-extendable for any $m \geq 4$, this completes the classification of m-extendable toroidal quadrangulations. Moreover, by a previous result of the third author, it then follows that we have therefore characterized all 3-extendable toroidal graphs. (Received August 17, 2015)

1113-05-132 **Rafael S. González D'León*** (rafaeldleon@uky.edu). *The colored symmetric and exterior algebras.* Preliminary report.

We study colored generalizations of the symmetric algebra and its Koszul dual, the exterior algebra. The symmetric group acts on the multilinear components of these algebras and we use poset topology techniques to understand these representations. We introduce a poset of weighted subsets and prove that the multilinear components of the colored exterior algebra are isomorphic as representations to the top cohomology of its maximal intervals. We use this isomorphism and a technique of Sundaram to compute the multiplicities of the irreducibles inside these representations. (Received August 21, 2015)

1113-05-142 **Ralph J Faudree** (rg@mathcs.emory.edu), Atlanta, GA 30322, **Ronald J Gould*** (rg@mathcs.emory.edu), Department of Math and Computer Science, Emory University, Atlanta, GA 30322, and **Michael S Jacobson** and **Douglas B. West**. *Minimum Degree and Dominating Paths.*

A *dominating path* in a graph is a path P such that every vertex outside P has a neighbor on P. A result of Broersma from 1988 implies that if G is an n-vertex k-connected graph and $\delta(G) \geq \frac{n-k}{k+2}$, then G contains

a dominating path. The lengths of dominating path include all values from the shortest up to at least min $\{n-1, 2\delta(G)\}$. For $\delta G > an$, where a is a constant greater that $1/3$, the minimum length of a dominating path is at most logarithmic in n when n is sufficiently large (the base of the logarithm depends upon a). The preceding results are sharp. For constant s and $c' < 1$ an s-vertex dominating path is guaranteed by $\delta(G) \geq n - 1 - c'n^{1-1/s}$ when n is sufficiently large, but $\delta(G) \geq n - c(s\ ln\ n)^{1/s}n^{1-1/s}$ (where $c > 1$) does not even guarantee a dominating set of size s. We obtain minimum degree conditions for the existence of a spanning tree obtained from a dominating path by giving the same number of leaf neighbors to each vertex. (Received August 18, 2015)

1113-05-156 **Josh Brown Kramer**, **Jonathan Cutler*** (jonathan.cutler@montclair.edu) and **A. J. Radcliffe**. *The k-step Friendship Paradox.*

In this talk, we will investigate a couple of generalizations of the Friendship Paradox due to Feld, which states that, on average, your friends have more friends than you do. This is, of course, a statement about a graph where people are vertices and edges are friendships. The model in the Friendship Paradox chooses a vertex from a graph uniformly at random and then a uniform neighbor of this vertex, and then compares the expected degree of these vertices. One could generalize this model by choosing a vertex uniformly at random from a graph and then taking a random walk from this vertex. We study this model (and another related model), answer some questions, and present some open problems. (Received August 19, 2015)

1113-05-157 **Federico Ardila**, **Federico Castillo** and **Jose Alejandro Samper*** (samper@math.washington.edu). *The topology of the external activity complex of a matroid.*

Given an ordered matroid M, Ardila and Boocher defined the so-called external activity complex of M. Their motivation came from studying varieties that result from embedding a linear space into a product of projective lines. Ardila and Boocher showed that this simplicial complex is Cohen-Macaulay and asked if it is, in fact, shellable. We study the combinatorics of the external activity complex of M and prove that it admits a lot of interesting shelling orders that are deeply related to both the lexicographic shelling of M and the lexicographic shelling of its dual matroid M*. In particular, the external activity complex has the same h-vector as the independence complex, contains a naturally embedded copy of the independence complex, and it is almost always (except in a few trivial cases) contractible when all its cone points are removed. This means that the external activity complex provides a topologically simpler model for several combinatorial invariants of the matroid, and as a result, opens the door for studying such invariants from different algebraic and topological perspectives. (Received August 19, 2015)

1113-05-159 **Neal Bushaw*** (neal@asu.edu), SoMSS, Arizona State University, PO Box 871804, Tempe, AZ 85287, and **Nathan Kettle**. *Threshold Pebbling on Grids of Arbitrary Dimension.*

We discuss zero sum sequences and their surprising connection to graph pebbling. In particular, we discuss recent work on the randomized 'threshold pebbling' problem for grids of arbitrary dimension.

Given a connected graph G and a configuration of t pebbles on the vertices of G, a q-pebbling step consists of removing q pebbles from a vertex and adding a single pebble to one of its neighbors. Given a vector $q = (q_1, \ldots, q_d)$, q-pebbling consists of allowing q_i-pebbling in coordinate i. A distribution of pebbles is called solvable if it is possible to transfer at least one pebble to any specified vertex of G via a finite sequence of pebbling steps.

In this talk, we will discuss recently joint work with N. Kettle in which we prove a weak threshold result for q-pebbling on the sequence of grids $[n]^d$ for fixed d and q as $n \to \infty$. Further, we determine the strong threshold for q-pebbling on the sequence of paths of increasing length.

This improves recent results of Czygrinow and Hurlbert, and Godbole, Jablonski, Salzman, and Wierman. It is the randomized version of much earlier deterministic results due to Chung. (Received August 19, 2015)

1113-05-163 **Charles Brittenham**, **Andrew Carroll** and **T. Kyle Petersen***, Department of Mathematical Sciences, DePaul University, 2320 N. Kenmore, Chicago, IL 60614, and **Connor Thomas**. *Unimodality the hard way.* Preliminary report.

Many families of integer polynomials have nonnegative and palindromic coefficients, e.g., h-polynomials of spheres. For such a polynomial, unimodality is equivalent to having a nonnegative g-vector.

A sufficient, but not necessary condition for unimodality is having a nonnegative γ-vector. However, there are γ-vectors with negative entries whose corresponding h-polynomials are unimodal. We will give a straightforward characterization of such γ-vectors, and describe a paradigm for proving unimodality results via thorough understanding of γ-vectors, even when these vectors have negative entries. (Received August 19, 2015)

1113-05-167 **Pawel Pralat*** (pralat@ryerson.ca) and **Nick Wormald**. *Almost all 5-regular graphs have a 3-flow.*

Tutte conjectured in 1972 that every 4-edge connected graph has a nowhere-zero 3-flow. This has long been known to be equivalent to the conjecture that every 5-regular 4-edge-connected graph has an edge orientation in which every out-degree is either 1 or 4. Using the small subgraph conditioning method of Robinson and Wormald, we show that the assertion of the conjecture holds asymptotically almost surely for random 5-regular graphs. It follows that the conjecture holds for almost all 4-edge connected 5-regular graphs. (Received August 20, 2015)

1113-05-168 **Mark Ellingham*** (mark.ellingham@vanderbilt.edu), **Emily Marshall**, **Tom McCourt** and **Tony Nixon**. *Excluding small minors of connectivity* 2.

Much is known about graphs that exclude specific small 3-connected graphs as minors. Besides a number of results on specific important graphs, a systematic study has been conducted by Ding and Liu. However, much less is known about graphs that exclude specific small graphs of connectivity 2 as a minor. Excluded minors of connectivity 2 occur, for example, when examining minor-closed addable classes of graphs, or in certain problems related to the traveling salesman problem. We report on a systematic study of the results of excluding particular small graphs of connectivity 2 as a minor. (Received August 20, 2015)

1113-05-175 **Bruno Benedetti***, Department of Mathematics, University of Miami, Coral Gables, FL 33124, and **Frank H Lutz** and **Karim A Adiprasito**. *Optimal discrete Morse vectors are not unique.*

In classical Morse theory, for any given manifold there is always a unique optimal Morse vector (=the vector counting the number of critical points of index 0,1,..., up to the dimension). It turns out that in Forman's discrete version of Morse theory, this is no longer the case. I will sketch how to construct a contractible 3-complex on which the 'best' discrete Morse vectors are (1,0,1,1) and (1,1,1,0), because (1,0,0,0) is unreachable. (Received August 20, 2015)

1113-05-176 **Harrison Craig Chapman*** (hchapman@math.uga.edu). *Asymptotics of random knot diagrams.*

We consider a model of random knots akin to the one proposed by Dunfield et. al.; a random knot diagram is a random immersion of the circle into the sphere with randomly assigned crossings. By studying diagrams as annotated maps, we are able to show that any given tangle diagram almost certainly occurs many times in a random knot diagram with sufficiently many crossings. Thus, in this model, it is exponentially unlikely for a diagram with n crossings to represent an unknot as $n \to \infty$. This asymptotic behavior is similar to that seen in other models of random knots such as random lattice walks and random polygons. (Received August 20, 2015)

1113-05-217 **Anton Dochtermann*** (dochtermann@math.utexas.edu). *Commutative algebra of generalized permutohedra.* Preliminary report.

Realized as signed sums of simplices, the vertices and lattice points of 'generalized permutohedra' give rise to various monomial ideals. These include the class of matroidal ideals as well as certain artinian ideals generalizing powers of the maximal ideal. We study cellular resolutions of these ideals and seek to interpret their Betti numbers - a simple motivating example is the Koszul resolution of the maximal ideal supported on a simplex.

For example we show that the ideal generated by the lattice points of a sum of simplices (of various dimensions) has a minimal resolution supported on any regular subdivision of the underlying polytope. These ideals are closely related to initial ideals of 'ladder determinantal ideals', and the polyhedral complexes supporting the resolutions are connected to the geometry/topology of 'tropical' hyperplane arrangements. We discuss some combinatorial and algebraic applications of our results. This is joint work with Alex Fink and Raman Sanyal. (Received August 22, 2015)

1113-05-223 **Niraj Khare**, **Rudolph Lorentz** and **Catherine Yan*** (cyan@math.tamu.edu), Department of Mathematics, Texas A&M University, MS 3368, College Station, TX 77843-3368. *Moments of Matching Statistics.* Preliminary report.

We show that for a large family of combinatorial statistics on perfect matchings, the moments can be expressed as a linear combination of double factorials with constant coefficients. This gives a stronger analogous result of Chern, Diaconis, Kane and Rhoades on statistics of set partitions, in which case the moments can be expressed as linear combinations of shifted Bell numbers, but with polynomial coefficients. In particular, we present formulas for moments of the numbers of crossings and nestings, the level statistic and the dimension exponent. Some of them are topological indices arisen from Super-character theory. (Received August 23, 2015)

1113-05-232 **Jill Faudree**, **Ralph Faudree**, **Ron Gould**, **Paul Horn*** (paul.horn@du.edu) and **Michael Jacobson**. *Degree sum and vertex dominating paths.*

We investigate degree sum conditions which guarantee that a graph contains a short dominating path. In particular we show that a graph satisfying $\sigma(2) \geq \frac{2n}{k+2} + c(k)$ contains a dominating path whose length is the same order as the size of a smallest dominating set. Along the way we answer some questions in a recent paper of Faudree, Gould, Jacobson and West. (Received August 23, 2015)

1113-05-241 **Peter Csikvari*** (peter.csikvari@gmail.com), Ames street 40, Office E18-378, Cambridge, MA 02139. *Tree-walks and spectral entropy.*

In this talk I will survey some inequalities about the number of homomomorphisms of a tree into a graph. One of the most surprising inequality is the following: if T_m is a tree on m vertices then for any graph G we have

$$\hom(T_m, G) \geq \exp(H_\lambda(G))\lambda^{m-1},$$

where λ is the largest eigenvalue of the graph G, $H_\lambda(G)$ is a quantity which we call spectral entropy. I will give many applications of this result together with some open problems.

This is a joint work with Zhicong Lin. (Received August 24, 2015)

1113-05-250 **Karen Gunderson*** (karen.gunderson@umanitoba.ca), Department of Mathematics, 342 Machray Hall, 186 Dysart Road, University of Manitoba, Winnipeg, MB R3T 2N2, Canada. *Time for graph bootstrap percolation.*

Bootstrap processes are types of cellular automata on graphs with two possible states, called 'healthy' and 'infected'. For a graph F and a collection of infected edges in a large complete graph, the F-bootstrap process is an update rule for the states of edges: infected edges remain infected forever and a healthy edge becomes infected if it is the only healthy edge in a copy of F. The initial set of infected edges is said to *percolate* if every edge is eventually infected. The notion of F-bootstrap percolation was introduced by Bollobás in 1968 with the name *weak-saturation*. I will give some of the history of the F-bootstrap process in the case where the initially infected edges are the edges of an Erdős-Rényi random graph and will discuss some new results on the time to percolation in the K_r-bootstrap process when the initially infected edges are chosen randomly. (Received August 24, 2015)

1113-05-254 **Bobby DeMarco** and **Arran Hamm*** (hamma@winthrop.edu), 142 Bancroft Hall, Rock Hill, SC 29733, and **Jeff Kahn**. *On the Triangle Space of a Random Graph.*

The clique complex of a graph G is the (abstract) simplicial complex where the vertex set of each clique of size k corresponds to a $(k-1)$-face and it is denoted $X(G)$. M. Kahle conjectured a value of p so that a.s. the k^{th} homology group over a field Γ of $X(G)$ vanishes. We settle the case where $k = 1$ and $\Gamma = \mathbb{Z}_2$; in this setting, the problem reduces to showing that a.s. the triangle space equals the cycle space. If time permits, generalizations to higher homology groups and other fields will be discussed. (Received August 24, 2015)

1113-05-261 **Csaba Biró**, **Peter Hamburger**, **H. A. Kierstead**, **Attila Pór**, **William T. Trotter*** (trotter@math.gatech.edu) and **Ruidong Wang**. *An Application of the Lovász Local Lemma to Stability Analysis of Dimension.* Preliminary report.

Let $f(c)$ denote the least integer so that if P is a poset with $|P| = 2n+1$ and $\dim(P) \geq n-c$, then P contains a standard example of dimension $d = n - f(c)$, provided of course that n is sufficiently large. In earlier work, Biró, Hamburger, Pór and Trotter showed that $f(c)$ exists and satisfies $f(c) = O(c^2)$. From below, they used finite projective planes to show that $f(c)$ must be at least as large as $c^{4/3}$. As part of a comprehensive revisit to the subject of the dimension of random posets of height 2 first investigated by Erdős, Kierstead and Trotter more than 20 years ago, we extract an application of the celebrated Lovász Local Lemma to show that $f(c)$ must be at least $c^{3/2}$, ignoring multiplicative terms involving $\log c$. (Received August 24, 2015)

1113-05-262 **Joshua N Cooper***, 1523 Greene St., Columbia, SC 29208. *Spectra of Random Symmetric Hypermatrices and Random Hypergraphs.*

We discuss progress on the problem of asymptotically describing the complex homogeneous adjacency eigenvalues of random and complete uniform hypergraphs. There is a natural conjecture arising from analogy to random matrix theory that connects these spectra to that of the all-ones hypermatrix. Several of the ingredients along a possible path to this conjecture are established, and may be of independent interest in spectral hypergraph/hypermatrix theory. In particular, we provide a bound on the spectral radius of the symmetric Bernoulli hyperensemble. (Received August 24, 2015)

1113-05-263 **Guantao Chen*** (gchen@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303, and **Yuping Gao** and **Songling Shan**. *Chromatic index determined by fractional chromatics index.* Preliminary report.

Given a graph G, denote by χ' the *chromatic index* of G, χ'_f the *fractional chromatic index*, Δ the maximum degree and μ the multiplicity of G. It is known that $\Delta \leq \chi'_f \leq \chi' \leq \Delta + \mu$, where the upper bound in a classic result of Vizing. While deciding exact value of χ' is a classic NP-complete problem, the computing χ'_f is polynomial time. In fact, it is shown that if $\chi'_f > \Delta$ then $\chi'_f = \max \frac{|E(H)|}{\lfloor |V(H)|/2 \rfloor}$, where the maximality is over all induced subgraphs H of G. Goldberg (1973), Anderson (1977), and Seymour (1979) conjectured that $\chi' = \lceil \chi'_f(G) \rceil$ if $\chi'(G) \geq \Delta + 2$. We show that if $\chi' \geq \Delta + \sqrt[3]{\Delta/2}$ then $\chi' = \lceil \chi'_f(G) \rceil$. It has been shown that the Goldberg conjecture is equivalent to the following conjecture of Jakobsen: *For any positive integer m with $m \geq 3$, every graph G with $\chi' > \frac{m}{m-1}\Delta + \frac{m-3}{m-1}$ satisfies $\chi' = \lceil \chi'_f(G) \rceil$.* The Jakobsen conjecture has been verified for $m \leq 15$ by a series of papers since 1973. We show that it is true for $m \leq 19$. (Received August 24, 2015)

1113-05-275 **Ivan Izmestiev** and **Steven Klee***, Seattle University Department of Mathematics, 901 12th Avenue, Seattle, WA 98122, and **Isabella Novik**. *Simplicial moves on balanced manifolds.*

A famous result in combinatorial topology states that two triangulated manifolds are homeomorphic if and only if they can be connected through a sequence of local operations called bistellar flips.

A d-dimensional simplicial complex is called balanced if its vertices can be colored with a set of $d+1$ colors so that no two adjacent vertices receive the same color. While bistellar flips preserve the homeomorphism type of a simplicial complex, they do not necessarily preserve balancedness.

In this talk, we will introduce a new family of local operations, called cross-flips, that preserve both balancedness and the homeomorphism type of a simplicial complex. (Received August 24, 2015)

1113-05-279 **Clifford Smyth*** (cdsmyth@uncg.edu). *A probabilistic characterization of the dominance order on partitions.* Preliminary report.

The dominance order is an important partial order of the set of partitions. We prove a probabilistic characterization of when one partition dominates another based on a certain random process that places balls into the cells of the partitions' respective Ferrers diagrams. (Received August 24, 2015)

1113-05-280 **Linyuan Lu*** (lu@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208, and **Shoudong Man**. *Connected Hypergraphs with Small Spectral Radius.*

In 1970 Smith classified all connected graphs with the spectral radius at most 2. In this talk, we will generalize Smith's theorem to r-uniform hypergraphs. We discover a novel method for computing the spectral radius of certain hypergraphs, and classified all connected r-uniform hypergraphs with spectral radius small enough. (Joint work with Shoudong Man) (Received August 24, 2015)

1113-05-281 **Dong Ye*** (dong.ye@mtsu.edu), Department of Mathematical Sciences, Middle Tennessee State University, Murfreesboro, TN 37132. *Bounding Median Eigenvalues of Graphs.*

Let G be a graph with n vertices. Its eigenvalues of G can be ordered as $\lambda_1 \geq \lambda_2 \geq \cdots \geq \lambda_n$. The median eigenvaules of G is λ_H and λ_L, where $H = \lfloor (n+1)/2 \rfloor$ and $L = \lceil (n+1)/2 \rceil$. Median eigenvalues has physical meanings in Quantum Chemistry. In this talk, we present recent developments in bounding median eigenvalues of graphs by using graph inverses and squared graphs. This talk is based on joint work with D. Klein and Y. Yang. (Received August 24, 2015)

1113-05-283 **Christopher A. Francisco**, **Jeffrey Mermin** and **Jay Schweig*** (jayschweig@gmail.com), Stillwater, OK 74078. *LCM Lattices of Pure Resolutions.*

If I is a monomial ideal, the multigraded Betti numbers of I are encoded in its LCM-lattice, which is the set of least common multiples of subsets of generators of I, ordered by divisibility. We give necessary and sufficient conditions on an LCM lattice for it to correspond to some ideal I whose minimal resolution is pure. (Received August 25, 2015)

1113-05-284 **Baogang Xu** and **Xiaoya Zha*** (xzha@mtsu.edu), Department of Mathematical Sciences, Middle Tennessee State University, Murfreesboro, TN 37132. *Thickness and outerplanar thickness for embedded graphs.*

The *thickness* $\theta(G)$ of a graph G is the minimum number of planar subgraphs whose union is G, and the *outerplanar thickness* $\theta_o(G)$ is obtained where the planar subgraphs in the definition of thickness are replaced

by outer planar graphs. Dean and Hutchinson provided upper bounds for thickness of graphs in terms of their orientable genus. Concalves proved that the outerplanar thickness of any planar graph is at most 2. We apply the method of deleting spanning disks of embeddings to approximate the thickness and outerplanar thickness of graphs. We first obtain better upper bounds for thickness. We then use a similar approach to provide upper bounds for outerplanar thickness of graphs in terms of their orientable and nonorientable genera. Finally we show that the outerplanar thickness of the torus (the maximum outerplanar thickness of all toroidal graphs) is 3. We also show that all graphs embeddable in the double torus have thickness at most 3 and outerplanar thickness at most 5. (Received August 25, 2015)

1113-05-286 **Jason S Williford*** (jwillif1@uwyo.edu), University of Wyoming, Dept 3036, 1000 E. University Ave., Laramie, WY 82071. *Graphs With Schur-Closed Adjacency Algebras.*

Given a labeled graph G with adjacency matrix A, we define the adjacency algebra of G to be the matrix algebra $\mathcal{A}$ generated by A. Since A is diagonalizable, the dimension of $\mathcal{A}$ is simply the number of distinct eigenvalues of A. If G is connected and this algebra is also closed under the Schur (entrywise) product of matrices, we will call the graph G an S-graph.

Distance-regular graphs are examples of S-graphs, however many other interesting graphs which are not distance-regular fall into this class as well. This talk will begin with a combinatorial characterization of S-graphs followed by examples. We will then discuss the ongoing search for examples of certain types of S-graphs, including those with the so-called Q-polynomial property. These are S-graphs whose idempotents $E_0, E_1, \ldots, E_d$ in the spectral decomposition of A can be ordered so that E_i is a degree i polynomial of E_1, where multiplication is the Schur product. (Received August 25, 2015)

1113-05-294 **István Heckenberger**, **John Shareshian*** (shareshi@math.wustl.edu) and **Volkmar Welker**. *Subrack lattices of conjugation racks.*

Let G be a finite group. The conjugation rack $R(G)$ has underlying set G and binary operation given by $a.b := a^{-1}ba$. We call the collection of subsets of G that are closed under this operation, partially ordered by inclusion, the subrack lattice of G. We show that if G is solvable and the subrack lattice of H is isomorphic to that of G, then H is also solvable. The same result holds if we replace "solvable" with "abelian", "nilpotent" or "simple". We show also that the order complex of the (reduced) subrack lattice has the homotopy type of a sphere. One can also investigate the order complexes of various subposets of the subrack lattice. I will present some results and questions arising from such investigations. (Received August 25, 2015)

1113-05-296 **Mary Radcliffe***, Department of Mathematical Sciences, Wean Hall 6113, Carnegie Mellon University, Pittsburgh, PA 15213. *Nonlinear Eigenvalues of Graphs.*

From a geometrical perspective, one can view the first eigenvalue of graph as a measure of the distortion obtained when embedding a graph into $\mathbb{R}$. This measurement can be generalized by embedding the graph into an arbitrary metric space X, to obtain what has been called a nonlinear or geometric eigenvalue. We here discuss some structural results of the nonlinear eigenvalue when the metric space X is itself a graph. Further, we connect nonlinear eigenvalues to k-fold Cheeger constants and expansion in graphs. (Received August 25, 2015)

1113-05-298 **Jill Faudree*** (jrfaudree@alaska.edu), Department of Mathematics and Statistics, University of Alaska Fairbanks, Fairbanks, AK 99775-6660, and **Ralph J Faudree**, **Paul Horn**, **Ron Gould** and **Michael Jacobson**. *Degree Sum and Vertex Dominating Paths.*

A graph G is called $H-$*saturated* if G contains no copy of H, but for any edge e in the complement of G, the graph $G+e$ contains some copy of H. The minimum size of an n-vertex H-saturated graph is denoted by $\mathbf{sat}(n;H)$ and is called the *saturation number of* H. Kászonyi and Tuza determined the values of $\mathbf{sat}(n;H)$ when H is a path or a disjoint union of edges. In this paper, we determine the values of $\mathbf{sat}(n;H)$ for the disjoint union of paths (a linear forest) within a constant depending only on H. Moreover, we obtain exact values for some special classes and include several conjectures. (Received August 25, 2015)

1113-05-307 **Charles Tomlinson*** (ctomlinson2@math.unl.edu), 203 Avery Hall, PO BOX 880130, Lincoln, NE 68588, and **Dominik Vu**. *Counting cycles in randomly constructed cellular automata.*

We discuss the behavior of cellular automata in which update rules are determined randomly for each cell. This investigation of random cellular automata follows that of many studies of the related Kauffman model, a random boolean network. Instead of defined geometric neighborhoods like in an automata, in the (n,k)-Kauffman model each cell has k randomly selected neighbors from among the n cells. Further, update rules are independently and randomly selected for each cell. The issues of how many limit cycles exist and how stable they are, have been central to the study of the model. Kauffman's original conjecture was that the expected number of cycles

is $\sqrt{n}/2$. However, it was later shown the number of c-cycles, C_c, has the average behavior $E[C_c] > n^{l_c}$ where l_c tends to infinity with c; so the number of cycles is superpolynomial.
We study inhomogenous cellular automata along the same lines. In the more structured case of a k neighbor automata, with each cell's update rule selected independently and uniformly randomly, we show that $E[C_c] > 2^{a_c n}$ for sufficiently large n where a_c is independent of n. In the process we prove the existence of c cycles which can be used as the building blocks of larger automata for all c. (Received August 25, 2015)

1113-05-309 **Stephen J Young*** (stephen.young@pnnl.gov). *The Alon-Boppana Theorem for the normalized Laplacian.*

The Alon-Boppana Theorem gives an asymptotic lower bound for the second largest eignenvalue of the adjacency matrix of a d-regular graph. We generalize this result to the normalized Laplacian of irregular graphs. (Received August 25, 2015)

1113-05-312 **Richard Ehrenborg*** (jrge@ms.uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506, and **Dustin Hedmark** (dustin.hedmark@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *On filters of the partition lattice.* Preliminary report.

Given a set F of integer partitions of n. We study the filter $\Pi(F)$ of the set partition lattice Π_n generated by the set partitions which has their types in F. We obtain the homology groups for the associated order complex $\Delta(\Pi(F))$. Our results extend work of Calderbank, Hanlon and Robinson, and Wachs on the d-divisible partition lattice and work by Ehrenborg and Jung. (Received August 25, 2015)

1113-05-315 **Rafael S. Gonzalez D'Leon** and **Michelle L. Wachs*** (wachs@math.miami.edu). *Weighted bond posets and graph associahedra.* Preliminary report.

We consider a weighted version of the bond lattice of a graph. This generalizes the poset of weighted partitions introduced by Dotsenko and Khoroshkin and studied in previous papers of the authors. We show that for cordal graphs, each interval of the weighted bond poset has the homotopy type of a wedge of spheres, and we present an intriguing connection with h-vectors of graph associahedra studied by Postnikov, Reiner and Williams, and others. For linear graphs, there is also an interesting connection with parking symmetric functions. (Received August 25, 2015)

1113-05-318 **Penny Haxell***, Combinatorics and Optimization Dept, University of Waterloo, Waterloo, ON N2L 3G1, Canada. *Matchings in regular hypergraphs.*

Every r-regular 3-partite 3-uniform hypergraph with n vertices in each class has a matching of size at least $n/2$. This is tight for certain special hypergraphs. We investigate how this bound can be improved for all other hypergraphs. (Received August 25, 2015)

06 ► Order, lattices, ordered algebraic structures

1113-06-56 **Bernd S. W. Schroeder*** (bernd.schroeder@usm.edu), Department of Mathematics, The University of Southern Mississippi, 118 College Drive, #5045, Hattiesburg, MS 39406. *Is there a Polynomial Algorithm that Certifies the Fixed Point Property for an Ordered Set with a Collapsible Chain Complex?* Preliminary report.

An ordered set has the fixed point property iff every order-preserving self map has a fixed point. An ordered set with a collapsible chain complex has the fixed point property. To determine if a given simplicial complex is collapsible is NP-complete. A point a in an ordered set P is called retractable to $b \in P$ iff the function that fixes all points in $P \setminus \{a\}$ and that maps a to b is an order-preserving retraction. An ordered set is connectedly collapsible iff it is either a singleton or it has a retractable point a so that $P \setminus \{a\}$ and the center-deleted neighborhood $\updownarrow a \setminus \{a\}$ are connectedly collapsible. Connectedly collapsible ordered sets have a collapsible chain-complex. Although the complexity of checking connected collapsibility is unknown, it can be shown that direct verification via the definition is worst-case exponential. For a subclass of the class of connectedly collapsible ordered sets, it is possible to certify the fixed point property in polynomial time, without verifying connected collapsibility. This talk will illustrate questions surrounding attempts to find algorithms that do the same thing in larger classes of ordered sets, such as ordered sets whose chain complexes are collapsible. (Received August 06, 2015)

1113-06-166 **Mahir Bilen Can*** (mcan@tulane.edu), 6283 St. Charles Ave, New Orleans, LA 70118.
Set partitions and equivariant K-theory. Preliminary report.

It is well known for sometime that the combinatorics of the polytope of a toric variety captures its cohomological data. Following this philosophy, in this talk we will present a combinatorial model for the equivariant K theory of certain wonderful compactifications in terms of a lattice that is naturally associated to a toric variety. This talk is based on our joint work with Soumya Banerjee (Ben-Gurion University of the Negev). (Received August 20, 2015)

1113-06-212 **John Engbers***, 340 Cudahy, PO BOX 1881, Milwaukee, WI 53201, and **Adam Hammett**. *How often do two monotone triangles meet in the minimal element?*

A monotone triangle of size n (or Gog triangle, in Zeilberger's terminology) is a left-justified triangular array of positive integers, with i integers in row i and last row $n = (1, 2, ..., n)$, with the property that the integers weakly increase up columns and downward-right diagonals, and strictly increase across rows. Endowed with entry-wise comparisons, the collection of monotone triangles of size n becomes a poset that is a lattice, and this lattice is isomorphic to the smallest completion of the Bruhat order on S_n to a lattice. The set of monotone triangles of size n can be transformed bijectively into a number of sets of combinatorial objects, including the set of $n \times n$ alternating sign matrices.

Pittel and Canfield previously answered how often a randomly chosen set partition had trivial meet (or join), with answers to this question later being given for the lattice of set partitions of type B by Chen and Wang and for the weak order on S_n by the second author. In this talk, we consider the analogous problem for the lattice of monotone triangles, and give sharp asymptotics for the probability that r uniformly random monotone triangles meet (join) in the minimal (maximal, resp.) element. (Received August 22, 2015)

1113-06-266 **Shih-Wei Chao**, Department of Mathematics, University of North Georgia, Dahlonega, GA 30597, and **Matthew Macauley***, Department of Mathematical Sciences, Clemson University, Clemson, SC 29634. *Toric heaps and cyclic reducibility in Coxeter groups.*

A reduced word in a Coxeter group can be encoded by a labeled poset called a heap. Two words that differ by cyclic shifts are conjugate, and their corresponding heaps differ by a sequence of conversions of minimal into maximal elements. To formalize this, we introduce the notion of a *toric heap*. This is a labeled cyclic analogue of a poset called a *toric poset*, and this latter object arises as a chamber of a toric graphic hyperplane arrangement. Classic concepts and problems on reducibility in Coxeter groups turn into new problems on cyclic reducibility and conjugacy. If time allows, we will also discuss current and recent results on toric posets. (Received August 24, 2015)

11 ► Number theory

1113-11-256 **Mark van Hoeij*** (hoeij@math.fsu.edu), Dept. of Mathematics, Florida State Unversity, Tallahassee, FL 32306. *Solving problems with the LLL algorithm.*

Lattice basis reduction is a computational technique introduced by Lenstra, Lenstra, and Lovász (LLL). It has many applications in a wide variety of subjects. The talk will give a sample, and discuss in more details its application to factoring univariate polynomials. (Received August 24, 2015)

12 ► Field theory and polynomials

1113-12-30 **Ian H Greenhoe*** (ihg@ihgreenman.com), 521 La Plaza Ave S, St Petersburg, FL 33707. *"Why the discrete Z-transform is dead:" the debut exploration of a new field formed using discrete convolution over infinite sequences.* Preliminary report.

The debut exploration of a new field formed using discrete convolution over infinite sequences of elements from any specific field, presented by the discoverer.

This new field forms an algebra which can take as any element any field structure, including itself. (A similar ring structure can also be formed.)

This talk will include a basic outline of the proof of this field; requirements to construct it; implications; and several examples, including how to automatically generate Infinite Impulse Response digital filters with Finite Impulse Response filter level control. (Received July 15, 2015)

13 ► Commutative rings and algebras

1113-13-55 **David F. Anderson*** (anderson@math.utk.edu), Mathematics Department, The University of Tennessee, Knoxville, TN 37996-1320. *Zero-divisor graphs.* Preliminary report.

Let R be a commutative ring with identity. The zero-divisor graph of R, denoted by $\Gamma(R)$, is the (simple) graph with vertices $Z(R) \setminus \{0\}$, the set of nonzero zero-divisors of R, and two distinct vertices x and y are adjacent if and only if $xy = 0$. We will discuss the history, some of the main results, and several variants of the zero-divisor graph. (Received August 06, 2015)

1113-13-79 **Brent Joseph Holmes*** (brentholmes@ku.edu), 1011 Missouri St, Apt B4, Lawrence, KS 66044. *Bounds on the diameters of Hochster-Huneke graphs.* Preliminary report.

Given an ideal in a polynomial ring, S, one can form a graph from the minimal prime ideals of $R = S/I$, where the vertices of the graph are the minimal prime ideals of R and an edge connects two vertices, v_1, v_2 if and only if height $(v_1 + v_2) \leq 1$. It is known as the Hochster-Huneke or dual graph of R. The S_2 property of R implies the connectedness of this graph. We will discuss lower bounds and upper bounds for the diameter of the dual graph in the case that R is S_2 and I is a square free monomial ideal. (Received August 12, 2015)

1113-13-97 **Ian M Aberbach*** (aberbachi@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Observations on the deformation of F-injectivity.* Preliminary report.

Recall that a local ring R of positive prime characteristic is F-injective if the Frobenius map induces an injection on all the local cohomology modules of R with respect to the maximal ideal. In a recent paper of Horiuchi, Miller, and Shimomoto, it was shown that if R has perfect residue field, x is a nonzerodivisor, R/xR has finite local cohomology, and R/xR is F-injective, then R is F-injective (i.e., under these conditions, the condition of being F-injective deforms). We explore some methods which may allow more general results on deformation of F-injectivity(still in the case of perfect residue field). (Received August 13, 2015)

1113-13-123 **Chris Francisco*** (chris.francisco@okstate.edu), Department of Mathematics, 401 MSCS, Oklahoma State University, Stillwater, OK 74078, and **Jeffrey Mermin** and **Jay Schweig**. *LCM lattices supporting a pure resolution.*

We describe which LCM lattices support a pure resolution of a monomial ideal. (Received August 16, 2015)

1113-13-137 **Florian Enescu*** (fenescu@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303, and **Yongwei Yao**, Department of Mathematics and Statistics, Georgia State University, Atlanta, GA. *The Frobenius complexity of determinantal rings.* Preliminary report.

In this talk we will describe the concept of Frobenius complexity of a local ring of prime characteristic, which measures asymptotically the number of Frobenius actions on the injective hull of the residue field of the ring. Various computations will be presented with a focus on determinantal rings. (Received August 18, 2015)

1113-13-139 **Aaron Feickert**, NDSU, and **Sean Sather-Wagstaff***, Clemson University. *Gorenstein injective filtrations over Cohen-Macaulay rings with dualizing modules.* Preliminary report.

Over a noetherian ring, it is a classic result of Matlis that injective modules admit direct sum decompositions into injective hulls of quotients by prime ideals. We show that over a Cohen-Macaulay ring admitting a dualizing module, Gorenstein injective modules admit similar filtrations. We also investigate Tor-modules of Gorenstein injective modules over such rings. This extends work of Enochs and Huang over Gorenstein rings.

Furthermore, we give examples showing the following: (1) the class of Gorenstein injective R-modules need not be closed under tensor products, even when R is local and artinian; (2) the class of Gorenstein injective R-modules need not be closed under torsion products, even when R is a local, complete hypersurface; and (3) the filtrations given in our main theorem do not yield direct sum decompositions, even when R is a local, complete hypersurface. (Received August 18, 2015)

1113-13-154 **Nicholas R. Baeth*** (baeth@ucmo.edu), W. C. Morris 213, University of Central Missouri, Warrensburg, MO 64093. *Factorization of upper triangular Toeplitz matrices.* Preliminary report.

Let R be a commutative ring. For a positive integer n, let I_n denote the $n \times n$ identity matrix and let $B = [b_{ij}]$ denote the $n \times n$ matrix with $b_{ij} = 1$ if $j = i + 1$ and $b_{ij} = 0$ if $j \neq i + 1$. Then $B^n = 0$ and $T_n(R)$ denotes the commutative ring of upper triangular Toeplitz matrices over R — those matrices of the

form $r_0I_n + r_1B + r_2B^2 + \cdots + r_{n-1}B^{n-1}$ with each $r_i \in R$. It is easy to see that $T_n(R) \cong R[x]/(x^n)$ and that if $n = 2$, $T_2(R) \cong R \ltimes R$, the self-idealization of R.

If R is Noetherian, so is $T_n(R)$ and every nonzero nonunit in $T_n(R)$ can be written as a product of finitely many irreducible elements. Chang and Smertnig began the study of factorization in $T_2(R)$ when R is a principal ideal ring. In particular, they classified, except in special anomalous cases, all possible lengths of factorizations of elements as products of irreducibles. In this talk we discuss their results as well as generalizations to the anomalous cases and to the case where R is any principal ideal ring or unique factorization ring (joint work with M. Axtell and J. Stickles), as well as when R is a PID and $n > 2$ (joint work with D. Bachman and A. McQueen). (Received August 19, 2015)

1113-13-155 **Eric Edo** and **Drew Lewis*** (dlewis@ua.edu), Department of Mathematics, University of Alabama, Campus Box 870350, Tuscaloosa, AL 35487. *Cotame automorphisms of polynomial rings.* Preliminary report.

An automorphism of the polynomial ring $\mathbb{C}[x_1, \ldots, x_n]$ is called tame if it is generated by affine and elementary (i.e. those that fix $n-1$ variables) automorphisms. The subgroup of tame automorphisms is a well studied object; however, the notion of *cotame automorphisms*, automorphisms which together with the affine subgroup generate the entire tame subgroup, is a relatively new area of research. Surprisingly, many automorphisms are cotame. In this part-survey talk, we will go through the short history of this problem of identifying cotame automorphisms, including a new result proving the existence of automorphisms which are tame but not cotame. (Received August 19, 2015)

1113-13-172 **Arindam Banerjee** and **Luis Nunez-Betancourt*** (lcn8m@virginia.edu). *Graph Connectivity and Binomial Edge Ideals.* Preliminary report.

We study the quotient of a polynomial ring R by a binomial edge ideal $\mathcal{J}_G$ associated to a simple graph G. Specifically, we give a relation between the depth of $R/\mathcal{J}_G$ and the vertex-connectivity of G. We also compute the graph toughness of G, when $R/\mathcal{J}_G$ is a Cohen-Macaulay ring. (Received August 20, 2015)

1113-13-189 **Gregory J Morre*** (morre@math.unm.edu). *Standard Closure Operations for Rings of Small Dimension.*

We will discuss the cardinality of the set of standard closure operations on rings of small dimension. (Received August 21, 2015)

1113-13-202 **Arindam Banerjee***, Purdue University, west lafayette, IN 47906. *Powers of Edge Ideal.*

Homological algebra of powers of edge ideals has been an active field of research for past few decades. In this talk we shall discuss some recent developments and some open questions. (Received August 21, 2015)

1113-13-205 **Jinjia Li*** (j0li0027@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40245. *Some observations on F-threshold.* Preliminary report.

Let R be a commutative Noetherian ring in characteristic p. For a pair of ideals a, I of R such that $a \subseteq \sqrt{I}$, one can define the F-threshold as the limit of $\max\{t | a^t \nsubseteq I^{[p^e]}\}/p^e$ as $e \to \infty$, provided the limit exists. We will discuss some new properties of this invariant, and its connections with other numerical invariants in Commutative Algebra. (Received August 21, 2015)

1113-13-255 **Nathan Fieldsteel*** (fieldst2@illinois.edu), Department of Mathematics, 1409 W Green Street, Urbana, IL 61801. *Zero-Divisors-Cup-Length of Orlik-Solomon Algebras.* Preliminary report.

To any arrangement of n complex affine hyperplanes we associate the Orlik-Solomon algebra A, a combinatorially determined $\mathbb{C}$-algebra. The Orlik-Solomon algebra is a quotient of an exterior algebra by an ideal generated by products of linear forms, and is naturally identified with the singular cohomology of the complement of the arrangement with its usual cup product. The zero-divisors-cup-length of A, denoted $\mathrm{zcl}(A)$, is the degree of nilpotency of the kernel of $A \otimes_{\mathbb{C}} A \to A$, the cup product map. $\mathrm{zcl}(A)$ is a lower bound for certain topological invariants of the complement of the arrangement. We present a combinatorial formula for the zero-divisors-cup-length of Orlik-Solomon algebras. (Received August 24, 2015)

1113-13-265 **Ashley K. Wheeler*** (ashleykw@uark.edu), Department of Mathematical Sciences, University of Arkansas, Fayetteville, AR 72701. *Ideals Generated by Principal Minors.* Preliminary report.

A minor of a square matrix is *principal* means its column and row indices are the same. Given a polynomial ring in the entries of a generic square matrix X, over a field, we study the ideals $\mathfrak{P}_t$ generated by principal minors of

a fixed size t. For any size generic matrix, $\mathfrak{P}_2$ is prime and defines a normal complete intersection with rational singularities (in characteristic $p \neq 0$). If X is size $n \geq 4$, then the ideals $\mathfrak{P}_{n-1}$ have two minimal primes; when $n = 4$, $\mathfrak{P}_{n-1}$ is reduced and both minimal primes have height 4. (Received August 24, 2015)

15 ► Linear and multilinear algebra; matrix theory

1113-15-82 **Andrew Vince*** (avince@ufl.edu), Gainesville, FL 32611, and **Michael Barnley**. *The Eigenvalue Problem for an Iterated Function System.*

For an interated functions system $\mathcal{F} = \{\mathbb{R}^n;\ f_1, f_2, f_3, \dots\}$, the Hutchinson operator $F : \mathbb{H} \to \mathbb{H}$ is defined on the space $\mathbb{H}$ of nonempty compact subsets of $\mathbb{R}^n$ by

$$F(B) = \bigcup_{f \in \mathcal{F}} f(B).$$

We formulate and discuss an analog of the classical eigenvalue problem, namely to find a nonzero $\lambda \in \mathbb{R}$ and a nonempty compact subset X of $\mathbb{R}^n$ such that

$$F(X) = \lambda X.$$

(Received August 12, 2015)

1113-15-110 **Kelly Pearson*** (kpearson@murraystate.edu), Mathematics Department, Faculty Hall, Murray State University, Murray, KY 42071. *Spectral hypergraph theory of the adjacency tensor and matroids.*

We define a matroid from an m-uniform hypergraph. Spectral properties of the adjacency tensor which can be deduced from the matroid are investigated. In particular, relationships between the coordinates of eigenvectors are revealed in terms of circuits of the matroid. It is expected that these relationships will lead to a better initial input vector on the interior of the positive cone for numerical calculations of Z-eigenvalues using the SS-HOPM method and for H-eigenvalues when using the NQZ method. (Received August 14, 2015)

1113-15-299 **Prakash Ghimire*** (pzg0011@auburn.edu), Mathematics/ Statistics Dept, Auburn University, 218 Parker Hall, auburn, AL 36849-5310, and **Huajun Huang**. *Derivations of the Lie algebra of dominant upper triangular ladder matrices.*

We give an explicit description of the derivation algebra of Lie algebra M_L associate with a dominant upper triangular ladder L over a field of characteristics not equal to two. Some properties of these Lie algebras and their derivation algebras are discovered. (Received August 25, 2015)

20 ► Group theory and generalizations

1113-20-133 **Songhao Li*** (sli@math.wustl.edu). *Blow-up construction of Lie groupoids.*

We introduce the elementary modification of Lie algebroids and the corresponding blow-up construction of Lie groupoids. (Received August 17, 2015)

1113-20-191 **Sheila Sundaram*** (shsund@comcast.net). *On some S_n-submodules induced from centraliser subgroups.* Preliminary report.

We study the conjugacy action of the symmetric group on itself, and some related representations. We show that these representations are induced from centraliser subgroups, and that their Frobenius characteristics have elegant descriptions. They are also related to the representation afforded by the Whitney homology of the partition lattice. (Received August 21, 2015)

22 ► Topological groups, Lie groups

1113-22-101 **Dorette Pronk*** (pronkd@dal.ca), Department of Mathematics and Statistics, Dalhousie University, Halifax, NS B3H 4R2, Canada, and **Laura Scull**. *Mapping Groupoids for Orbispaces.*

We consider orbispaces as modeled by étale topological groupoids with a proper diagonal (i.e., combined source and target map). When we consider the category of topological groupoids with topological functors and natural transformations represented by appropriate continuous functions, there is a notion of mapping groupoid which we denote by $\mathrm{GMap}(G, H)$ for any two topological groupoids G and H, which again has a topological structure.

However, for the category of orbifolds, we want to consider generalized maps obtained by formally inverting Morita equivalences; these are built out of the topological functors, but are more complicated structures. We will discuss the groupoid $\mathrm{OMap}(G, H)$ which models generalized maps and 2-cells between them. We will present this groupoid as a pseudo colimit of groupoids of the form $\mathrm{OMap}(G', H)$ for a chosen small family of groupoids G' which are Morita equivalent to G. This presentation allows us to show that the resulting groupoid $\mathrm{OMap}(G, H)$ is again an orbispace groupoid. We will illustrate this with several examples. This is joint work with Laura Scull. (Received August 13, 2015)

26 ► Real functions

1113-26-100 **Pieter C Allaart*** (allaart@unt.edu), Mathematics Department, University of North Texas, 1155 Union Cir #311430, Denton, TX 76203-5017. *The infinite derivatives of Okamoto's functions and β-expansions.*

Okamoto's family $\{F_a : 0 < a < 1\}$ of self-affine functions includes the classical Cantor function ($a = 1/2$) as well as the continuous but nowhere differentiable functions of Perkins ($a = 5/6$) and Bourbaki/Katsuura ($a = 2/3$). The most interesting behavior, as far as differentiability is concerned, takes place in the paramater interval $1/2 < a < 2/3$. This talk will focus on the set $D_\infty(a)$ of points where F_a has an infinite derivative. The theory of expansions of real numbers in non-integer bases (so called β-expansions) turns out to play a vital and unexpected role in determining the size of $D_\infty(a)$. Both the golden ratio and the Thue-Morse sequence will pop up naturally in the investigation. (Received August 13, 2015)

28 ► Measure and integration

1113-28-6 **Palle E.T. Jorgensen*** (palle-jorgensen@uiowa.edu), Palle Jorgensen, Math MLH, Iowa City, IA 52242. *Fractal boundaries arising from infinite networks.*

We study Cantor spaces which arise as limits of infinite discrete models; specifically infinite weighted graphs. Examples include electrical networks with resistors; the network Laplacian plays a role; from it we get harmonic functions, and harmonic analysis. The Cantor spaces we study serve as boundaries; for example, Poisson boundaries, Shilov boundaries, Martin boundaries, path-space boundaries, and metric boundaries. The metric we consider is called the resistance-metric. In the talk we outline new results in these areas, and their interconnections. (Received February 03, 2015)

1113-28-49 **Joseph Rosenblatt*** (joserose@iupui.edu), Department of Mathematical Sciences, 402 N. Blackford St., Indianapolis, IN 46202-3216. *Characterizing convergence via jump inequalities.* Preliminary report.

Many convergent stochastic processes satisfy strong quantitative estimates for their jumps i.e. quantitative Cauchy conditions. Examples include ergodic averages, martingales, and Fourier series. These quantitative jump inequalities are proved by deriving strong inequalities for series that measure the variational behavior of the process. These results on the variational behavior of the process are often difficult to derive. However, we know that some forms of these strong estimates for the variational behavior are equivalent to quantitative jump inequalities. This suggests that we try to show that for a wide class of stochastic process their almost everywhere convergence is actually equivalent to there being a quantitative jump inequality. (Received August 05, 2015)

30 ► Functions of a complex variable

1113-30-12 **Maxim Derevyagin*** (mderevya@olemiss.com). *On the locally uniform convergence of Pade approximants for a class of meromorphic functions.*

Padé approximation is a very useful tool for a variety of computational needs. Usually, one uses the Padé approximation method when it is necessary to extract information about singularities of a meromorphic function provided that a power series representation of this function centered at some point of the complex plane is known. In fact, if the Padé approximation method can be applied then it gives approximants, which are rational functions, and these approximants converge to a given function very quickly. Moreover, the poles of the obtained rational functions give the idea about singularities of the original meromorphic function. Thus, one of the main questions in the theory of Padé approximation is to characterize classes of meromorphic functions for which Padé approximation works. In the present talk, we will discuss a new class of meromorphic functions for which Padé

approximants converge locally uniformly. This new class contains previously known classes that were proposed by Markoff, Gonchar, and Rakhmanov. (Received March 10, 2015)

31 ► Potential theory

1113-31-218 **Doug Hardin*** (doug.hardin@vanderbilt.edu), Dept of Mathematics, Vanderbilt University, Nashville, TN 37240. *Discrete minimum energy problems on rectifiable and fractal sets.*

We consider 'ground state' point configurations on a compact metric space that minimize a weighted inverse power law energy functional. We review classical and recent results concerning asymptotic geometrical properties of such configurations as the number of points goes to infinity and compare and contrast what is known for the cases that the compact set is rectifiable set (non-fractal case) with the general case that it is a fractal set. (Received August 23, 2015)

1113-31-234 **Joel M Cohen** and **Flavia Colonna*** (fcolonna@gmu.edu), Dept. of Mathematical Sciences, George Mason University, 4400 University Drive, Fairfax, VA 22030, and **Massimo A Picardello** and **David H Singman**. *Bergman spaces and Carleson measures on homogeneous trees.*

Hastings studied Carleson measures for non-negative subharmonic functions on the polydisk and characterized them by a certain geometric condition relative to Lebesgue measure σ. Cima & Wogen and Luecking proved analogous results for weighted Bergman spaces on the unit ball and other open subsets of $\mathbb{C}^n$. We consider a similar problem on a homogeneous tree, and study how the characterization and properties of Carleson measures for various function spaces depend on the choice of reference measure σ. (Received August 23, 2015)

34 ► Ordinary differential equations

1113-34-18 **Sougata Dhar*** (dhar@math.niu.edu), 810 Kimberly Dr. Apt 212, DeKalb, IL 60115, and **Qingkai Kong**. *Lyapunov-type inequalities for third-order linear differential equations.*

We obtain new Lyapunov-type inequalities for the third-order linear differential equation. Our work provides the sharpest results in the literature. Based on the above, we further establish new Lyapunov-type inequalities for more general third-order linear differential equations. Moreover, by combining these inequalities with the "uniqueness implies existence" theorems by several authors, we establish the uniqueness and hence existence-uniqueness for several classes of boundary value problems for third-order linear equations. (Received May 26, 2015)

1113-34-75 **Jeffrey Thomas Neugebauer***, jeffrey.neugebauer@eku.edu, and **Murat Adivar**, **Muhammad N. Islam** and **H. Can Koyuncuoglu**. *Periodic solutions of q-Volterra integral equations.*

We study the periodicity properties of functions that arise in quantum calculus. First, a linkage between two existing periodicity notions is established. Second, the existence of periodic solutions of a q-Volterra integral equation, which is a general integral form of a first order $q-$difference equation, is obtained. At the end, some examples are provided. (Received August 11, 2015)

1113-34-243 **Alexandra Smirnova**, **Maia Martcheva** and **Hui Liu*** (huil09482@gmail.com). *On Generalized Cross Validation for Regularization Parameter Selection in the Model of Plasmodium falciparum Malaria.*

We study advantages and limitations of the Generalized Cross Validation (GCV) approach for selecting a regularization parameter in the case of a partially stochastic linear irregular operator equation. The research has been motivated by an inverse problem in epidemiology, where the goal was to reconstruct a time dependent treatment recovery rate for Plasmodium falciparum, the most dangerous form of malaria. Initial numerical simulations gave rise to a theoretical analysis of the expected value of the GCV function and the efficiency of the GCV method for different noise levels. It was shown that, as opposed to L-curve, the GCV does not necessarily generate a systematic error in the value of the regularization parameter for Tikhonov's stabilizing algorithm. (Received August 24, 2015)

1113-34-252 **Xiaolong He*** (xhe92@math.gatech.edu), 686 Cherry St, Atlanta, GA 30332, and **Rafael de la Llave** (rll6@math.gatech.edu), 686 Cherry st, Atlanta, GA 30332. *Construction of quasi-periodic solutions to state-dependent delay differential equations.*

The existence of quasi-periodic solutions for state-dependent delay differential equations is investigated by using the parameterization method, which is different from the usual way-working on the solution manifold. Under the assumption of finite-times differentiability of functions and exponential dichotomy, the existence and smoothness of quasi-periodic solutions are investigated by using contraction arguments. Meanwhile, we show that there are Lindstedt series under some nondegeneracy conditions for the analytic case. In particular, a KAM theory is developed to seek analytic quasi-periodic solutions, which gets involving the theory of foliation-preserving torus mapping. Moreover, we prove that the set of parameters which guarantee the existence of analytic quasi-periodic solutions is of full measure. All of these results are given in an a-posterior form. Namely, given a approximate solution satisfying some non-degeneracy conditions, there is a true solution nearby. (Received August 24, 2015)

35 ► Partial differential equations

1113-35-17 **Michael Renardy*** (mrenardy@math.vt.edu), 225 Stanger St., Blacksburg, VA 24061-0123. *From the maximum principle to inverting the future.*

We prove that a C0-semigroup of operators exp(At) satisfies backward uniqueness if the resolvent of A exists on a ray in the left half plane and satisfies a bound of subexponential growth. The proof of this result is based on the Phragmen-Lindelöf theorem.

The result can be applied to PDE systems which in a sense perturb problems for which backward uniqueness does not hold. Examples include the linearized compressible Navier-Stokes equations in one space dimension and the wave equation with absorbing boundary condition in several space dimensions, under the assumption that the boundary has positive mean curvature. (Received May 12, 2015)

1113-35-20 **Antonio Vitolo*** (vitolo@unisa.it), Dipartimento di Matematica, Universita' di Salerno, via Giovanni Paolo II, 132, 84084 Fisciano, Salerno, Italy. *ABP Maximum principle and Hölder estimates for degenerate elliptic operators.*

Due to a recent result by Imbert, the Alexandroff-Bakelman-Pucci estimate (ABP) continues to hold for viscosity solutions of degenerate elliptic operators which are uniformly elliptic for "large" gradients. We extend this ABP estimate to possibly unbounded cylindrical domains of Cabré type, for viscosity solutions of both singular and degenerate elliptic equations, generalizing previous results. Moreover, we also refine the estimates in order to obtain the global Holder continuity of solutions in cylindrical domains suitably strengthening the measure-geometric condition of Cabré. (Received June 29, 2015)

1113-35-23 **Steven Derochers*** (sjderoch@ncsu.edu), 1211 Ridge Trace Dr. Apt 207, Raleigh, NC 27606. *On the Semigroup Generator for the Total Linearization of a Hydro-Elasticity Model.* Preliminary report.

In this talk, we will investigate a fluid structure system involving coupled flow. Due to the coupling, a nonstandard means to eliminate the pressure term is required. This method makes use of specific extensions into the solid domain. It also prompts the convenient use of a finite element method to obtain a numerical approximation of a solution. (Received June 02, 2015)

1113-35-33 **P Jameson Graber*** (pjg140130@utdallas.edu), 800 West Campbell Road, SM30, Richardson, TX 75080, and **Joseph L Shomberg**. *Attractors for Strongly Damped Wave Equations with Nonlinear Hyperbolic Dynamic Boundary Conditions.*

We establish the well-posedness of a strongly damped semilinear wave equation equipped with nonlinear hyperbolic dynamic boundary conditions. Results are carried out with the presence of a parameter distinguishing whether the underlying operator is analytic, $\alpha > 0$, or only of Gevrey class, $\alpha = 0$. In both settings, we establish the existence of a global attractor and a weak exponential attractor under minimal assumptions on the nonlinear terms. The weak exponential attractor is a finite dimensional compact set in the weak energy phase space. Here, the existence of a weak exponential attractor insures the corresponding global attractors also possess finite fractal dimension in the weak topology; moreover, the dimension is independent of the perturbation parameter. The final result concerns the upper-semicontinuity of the family of global attractors as $\alpha \to 0$. (Received July 24, 2015)

1113-35-45 **Alain Miranville*** (miranv@math.univ-poitiers.fr), Mathematics department - SP2MI, 86962 Chasseneuil, France. *The Cahn-Hilliard equation and some of its variants.*

Our aim in this talk is to present and discuss the Cahn-Hilliard equation in phase separation, as well as some of its variants. Such variants have applications, e.g., in biology or in image inpainting. (Received August 03, 2015)

1113-35-57 **Pei Pei*** (peipe@earlham.edu), **Mohammad Rammaha** (mrammaha1@unl.edu) and **Daniel Toundykov** (dtoundykov@unl.edu). *Weak solutions and blow-up for wave equations of p-Laplacian type with supercritical sources.*

This paper investigates a quasilinear wave equation with Kelvin-Voigt damping, $u_{tt} - \Delta_p u - \Delta u_t = f(u)$, in a bounded domain $\Omega \subset \mathbb{R}^3$ and subject to Dirichlét boundary conditions. The operator Δ_p, $2 < p < 3$, denotes the classical p-Laplacian. The nonlinear term $f(u)$ is a source feedback that is allowed to have a *supercritical* exponent, in the sense that the associated Nemytskii operator is not locally Lipschitz from $\mathrm{W}_0^{1,p}(\Omega)$ into $L^2(\Omega)$. Under suitable assumptions on the parameters, we prove existence of local weak solutions, which can be extended globally provided the damping term dominates the source in an appropriate sense. Moreover, a blow-up result is proved for solutions with negative initial total energy. (Received August 06, 2015)

1113-35-60 **Irena Lasiecka**, **Michael Pokojovy** and **Xiang Wan*** (xiangwan@virginia.edu). *Global Wellposedness and Uniform Stability of a Quasilinear Thermo-elastic PDE system.* Preliminary report.

We consider a nonlinear thermoelastic system defined on a bounded domain $\Omega \subset \mathbb{R}^n, n = 2$ or 3:

$$\begin{cases} w_{tt} - \gamma \Delta w_{tt} + \Delta^2 w + \alpha \Delta((\Delta w)^3) = \Delta\theta \\ \theta_t - \Delta\theta = -\Delta w_t \end{cases} \tag{1}$$

for $\gamma \geq 0$ with the boundary conditions imposed on $\Gamma = \partial\Omega$ corresponding to the simply supported plate. The main goal of this talk is to discuss the wellposedness of suitable solutions to the system defined above.

I will first introduce the background of this model, and then briefly talk about the work on the case $\gamma = 0$. Our main challenge is to consider the case when $\gamma > 0$, of which the first equation (elasticity) is of hyperbolic — rather than of parabolic type. From a mathematical point of view, the most important message is that the *analyticity* and *maximal regularity* of the associated linear system are *gone*. We will show how to choose suitable topologies to overcome this difficulty.

This is a joint work with Irena Lasiecka, University of Memphis, and Michael Pokojovy, University of Konstanz. Germany. (Received August 07, 2015)

1113-35-61 **Jerry L. Bona** and **Fred B. Weissler*** (weissler@math.univ-paris13.fr). *Finite time blowup and global existence for complex-valued solutions of the Korteweg-de Vries equation with periodic boundary conditions.* Preliminary report.

We consider complex-valued solutions to the Korteweg-de Vries equation $u_t + u_{xxx} + (u^2)_x = 0$ with periodic boundary conditions, specifically solutions with only positive Fourier modes present. For such solutions we give sufficient conditions for finite time blow up, and sufficient conditions for global existence. For example, with initial value $u_0(x) = ae^{ix}$, we show that if $|a| > 6$, then the resulting solution blows up in finite time. On the other hand, if $|a| < 1/2e\pi$, then the resulting solution is global, and time-periodic as well. (Received August 07, 2015)

1113-35-70 **Jerry Bona*** (bona@math.uic.edu), Dept Math, Statistics & Computer Science, University of Illinois at Chicago, 851 S. Morgan Street MC 249, Chicago, IL 60607, and **Chun-Hsiung Hsia** (willhsia@math.ntu.edu.tw), Institute of Applied Mathematical Sciences, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei City, 10607, Taiwan. *Nonlinear Waves on Trees.* Preliminary report.

We will discuss nonlinear, dispersive wave equations defined on tree-like spatial domains. Problems of this nature have arisen as a crude, mathematical model of the human arterial system. We will sketch the derivation and discuss recent work on the long-time well-posedness of such models. (Received August 10, 2015)

1113-35-71 **Michael Victor Klibanov*** (mklibanv@uncc.edu), Department of Mathematics and Statistics, Charlotte, NC 28223. *Inverse scattering problems without the phase information.*

Inverse scattering problems without the phase information arise in imaging of nanostructures and biological cells. Sizes are of hundreds of nanometers, i.e. about 0.1 micron. Indeed, in these cases the wavelength must be of 1

micron or less. This means that the phase of the complex valued wave field cannot be measured, whereas only its modulus can be measured.

The governing PDE is the generalized Helmholtz equation. In the case of quantum scattering this is the Schrodinger equation. The inverse problem consists in determining the unknown coefficient of that PDE given measurements of the modulus of its solution. Unlike this, in the standard inverse scattering problem the whole complex valued wave field is measured.

In 2014 the author has published three (3) papers where uniqueness theorems were proven for that problem. However, proofs were not constructive. Thus, in 2015 the author jointly with V.G. Romanov has published/submitted five (5) papers where reconstruction procedures were proposed.

These results will be presented. In addition, some numerical reconstructions will be presented as well. (Received August 11, 2015)

1113-35-72 **Kazuo Yamazaki*** (kyamazaki@math.wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164-3113. *Recent developments on the micropolar and magneto-micropolar fluid systems: deterministic and stochastic perspectives.*

We review recent developments on the magnetohydrodynamics and its related systems such as the Navier-Stokes equations, Boussinesq system, magnetohydrodynamics-Benard problem, and in particular the micropolar and magneto-micropolar fluid systems. The topics include, depending on the time, the global regularity issue in the deterministic case, well-posedness, ergodicity and large deviation principle in the stochastic case. (Received August 11, 2015)

1113-35-73 **Thinh Kieu*** (thinh.kieu@ung.edu), 2514 Education Way Apt#2514, Oakwood, GA 30566, and **Luan Hoang** (luan.hoang@ttu.edu), Lubbock, TX. *Global estimates for generalized Forchheimer flows of slightly compressible fluids in porous media.*

we consider the generalized Forchheimer flows for slightly compressible fluids and study the initial boundary value problem for the resulting degenerate parabolic equation for pressure with the time-dependent Dirichlet boundary condition. The estimates up to the boundary and for all time are derived for the L^∞-norm of the pressure, its gradient and time derivative. Large-time estimates are established to be independent of the initial data. Thanks to the special structure of the pressure's nonlinear equation, the global gradient estimates are obtained in a relatively simple way, avoiding complicated calculations and a prior requirement of Hölder estimates. (Received August 11, 2015)

1113-35-74 **Victor Isakov*** (victor.isakov@wichita.edu), Dept. of Mathematics, Statistics, and Phys., Wichita State University, Wichita, KS 67260-0033. *On increasing stability in the inverse source and conductivity problems.*

We overview recent results of the speaker partly jointly with J. Cheng, S. Lu (Fudan Univ.), R.-Y. Lai (Univ. of Washington, Seattle), and J.-N. Wang (Taiwan Nation. Univ) concerning improving stability in inverse scattering/source problems for the Helmholtz equation and recovery of the conductivity coefficient in the stationary Maxwell system when frequency in growing. Stability estimates and ideas of their proofs as well as some numerical evidence will be presented. Some of these results are published and some are to be published soon. (Received August 11, 2015)

1113-35-76 **Julia Anderson-Lee***, 396 Carver Hall, Ames, IA 50014, and **Scott Hansen** (shansen@iastate.edu). *Model of Rocking Structures: A Mathematical Approach.*

The study of seismic engineering is extremely interesting not only from an engineering perspective but also within other disciplines which have applications in engineering and modeling of dynamical systems. In particular, rocking systems–made popular as a research area by G.W. Housner with his paper regarding modeling the displacement of block-shaped structures —involve interesting mathematics in the area of coupled partial differential equations. In this talk, a coupled system of partial differential equations incorporating the strain energy of the block, and internal longitudinal vibrations is presented. Then, using only the internal vibrations and the angle of rocking, a coefficient of restitution is formulated. These results are used to construct the expected motion of the block and compared to the motion of the block predicted by Housner. (Received August 11, 2015)

1113-35-83 **Oleg Yu Imanuvilov*** (oleg@math.colostate.edu), 101 Weber Building, Department of Mathematics, CSU, Fort Collins, CO 80523. *On Calderón's problem for the system of elliptic equations.*

We consider the Calderón problem in the case of partial Dirichlet-to-Neumann map for the system of elliptic equations in a bounded two dimensional domain. The main result of the manuscript is as follows: If two

systems of elliptic operators generate the same partial Dirichlet-to-Neumann map the coefficients can be uniquely determined up to the gauge equivalence. (Received August 12, 2015)

1113-35-85 **Jing Zhang*** (jizhang@vsu.edu), 506 Green Garden Circle, Chester, VA 23836. *Min-Max Game Problem for Elastic and Visco-Elastic Fluid Structure Interactions.* Preliminary report.

We present the features of min-max problem for a linear fluid-structure interaction model in both elastic and visco-elastic cases, with control and disturbance exercised at the interface between the two media. The saddle point solutions are expressed in a pointwise feedback form, which involves a Riccati operator satisfying a suitable non-standard Riccati equation. (Received August 12, 2015)

1113-35-91 **Loc Hoang Nguyen*** (lnguye50@uncc.edu), **Ammari**, **Garnier** and **Seppecher**. *Reconstruction and stability in acoustic-optic imaging for absorption maps.*

The aim of this talk is to study a reconstruction scheme and a stability result for recovering absorption distributions from internal acoustic-optic data. Such data can be obtained by using acoustic waves. Both analytic and numerical results are reported. (Received August 13, 2015)

1113-35-92 **Heng Li*** (h0li0018@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Jianrong Zhou**. *Direct and inverse problem for the parabolic equation with initial value and moving boundaries.*

In this paper, we deal with dual problem of a class of non-classical parabolic equations in which the boundaries are moving instead of fixed values, which arise from Ductal carcinoma in situ (DCIS). In the direct problem part, on using the several transformation and heat potential theory, we established the integral form of solution and proved the existence and uniqueness of solution. Then we consider the inverse problem of finding the control parameter of known moving boundaries, which means determining the potential function of model from incisional biopsy information in the view of DCIS. Algorithm and numerical simulation for both problems are included to demonstrate the validity and applicability of solutions. (Received August 13, 2015)

1113-35-95 **Martin Adler*** (maad@fa.uni-tuebingen.de), Auf der Morgenstelle 10, 72076 Tübingen, Germany. *On perturbations of generators of analytic semigroups.*

This is joint work with Miriam Bombieri and Klaus-Jochen Engel.

In a recent paper we presented an operator theoretic approach towards the Weiss-Staffans perturbation result for generators of strongly continuous semigroups. If the unperturbed semigroup is analytic, we replace the various "admissibility" conditions by simpler assumptions on the domain and range of the operators involved. The power of our main result consists in a systematic treatment of various classes of PDE's as shown by discussing a delayed reaction diffusion equation in one space variable. (Received August 13, 2015)

1113-35-96 **Marius V Ionescu*** (ionescu@usna.edu), United States Naval Academy, Department of Mathematics, 572C Holloway Road, Chauvenet Hall, Annapolis, MD 21402, and **Luke G Rogers** and **Kasso Okoudjou**. *Asymptotics of eigenvalue clusters for generalized Schrödinger operators.*

A generalized Schrödinger operator with continuous potential χ on the Sierpinksi gasket is an operator of the form $H = p(-\Delta)+[\chi]$, where $p : (0,\infty) \to \mathbb{R}$ is a measurable function. In this talk we present some results on the asymptotic behavior of spectra of generalized Schrödinger operators with continuous potentials and continuous p, generalizing some results of Okoudjou and Strichartz. Our proof is based on the the study of the asymptotics of the trace of continuous functions of pseudo-differential operators. Our results are the fractal analogue of results first observed by Weinstein and Guillemin for Schrödinger operators on compact Riemannian manifolds. This talk is based on joint work with Kasso Okoudjou and Luke Rogers. (Received August 13, 2015)

1113-35-107 **Irena M Lasiecka*** (lasiecka@memphis.edu), Department of Mathematical Sciences, University of Memphis, Dunn 373, Memphis, TN 38120, and **Xiaojun Wang**, Department of Mathematics, Stillwater, OK. *Uniform stability for Moore-Gibson-Thompson (MGT) equation with memory arising in High Frequency Ultrasound (HIFU).*

We consider MGT equation arising in modeling of High Frequency Ultrasound technology. The model accounts for a finite speed of propagation of acoustic waves which results from the application of Catteneo's Law rather than the usual Fourrier 's Law in describing heat conduction. This leads to a third order in time equation with a heat relaxation parameter $\tau > 0$. In addition to the heat flux relaxation, molecular relaxation is accounted for. The latter results in adding memory term with a dynamic relaxation kernel described by a rather general

decreasing function $g(t)$. Questions related to well-posedness and uniform stability of the resulting third order dynamics with a memory are discussed. .

In particular, it will be shown that the dynamics can be uniformly stabilized through molecular relaxation only and without any mechanical dissipation. Quantitative description of stability is given by providing optimal decay rates for the energy where the latter reflect the rates of decay of molecular relaxation. (Received August 14, 2015)

1113-35-113 **Muhammad Usman*** (musman1@udayton.edu), 300 College Park, Dayton, OH 45469-2316. *A perturbation method to study the stability of travelling wave solutions of a class of nonlinear partial differential equations.*

In this talk some results on bifurcations in steady state solutions of a class of nonlinear dispersive wave equation and for a damped externally excited Kuramoto-Sivashinsky type Equation will be presented. Using an asymptotic perturbation method stability of solutions will be discussed. We consider the primary resonance by defining the detuning parameter. External-excitation and frequency-response curves are shown to exhibit jump and hysteresis phenomena for the models. (Received August 15, 2015)

1113-35-121 **Roberto Triggiani*** (rtrggani@memphis.edu) and **Irena Lasiecka**. *Stabilization to an equilibrium of the 2d-, 3d- Navier-Stokes equations by 'tangential' feedback controls with arbitrarily small support.*

Uniform stabilization in the neighborhood of an unstable equilibrium of the Navier-Stokes equations is considered. It is shown that in 2 and 3 dimensions such equilibrium can be stabilized by purely tangential action of feedback boundary and interior control. The support of such feedback controls can be arbitrary small-but needs to be localized in a boundary layer. In contrast with prior literature, this result is proved without any assumptions imposed on the spectral properties of the Oseen's operator. This is joint work with I.Lasiecka. (Received August 16, 2015)

1113-35-122 **Roberto Triggiani*** (rtrggani@memphis.edu), **George Avalos** and **Irean Lasiecka**. *Fluid-structure interaction: Optimal Polynomial decay rate via microlocal analysis.*

We shall focus initially on a simplified model of heat-structure interaction proposed in the literature; later to be replaced by a corresponding fluid-structure interaction (linearized Navier-Stokes equation involving the pressure). We consider the problem of decay of the solution when the initial condition is in the domain of the generator (a problem referred to as rational or polynomial stability). Recent literature provides results with decay rate $\alpha = 1/6$, next $\alpha = 1/2$, finally $\alpha = (1 - \epsilon)$, all these efforts involving a t-domain analysis. It was advanced that $\alpha = 1$ gives the optimal decay rate. This paper returns to a prior effort of two of the authors where the rate $\alpha = 1/2$ was obtained by basing the strategy this time on a frequency domain λ-approach, technically executed via semigroup theory/functional analytic and elliptic theory techniques. We now prove that in fact the decay rate $\alpha = 1$ is obtained, by crucially using a micro-local analysis argument to estimate a critical term involving two boundary traces. This is joint work with G.Avalos and I.Lasiecka. (Received August 16, 2015)

1113-35-144 **Marian Bocea***, Loyola University Chicago, Department of Mathematics and Statistics, 1032 W. Sheridan Road, Chicago, IL 60660. *Duality for the L^∞ Optimal Transport Problem.*

I will discuss a duality theory for the the Monge-Kantorovich optimal mass transport problem in L^∞, where one seeks to minimize cost functionals acting on probability measures with prescribed marginals. Several formulations of the dual problem can be obtained using techniques from quasiconvex analysis and partial differential equations. Joint work with Nick Barron and Robert Jensen (Loyola University Chicago). (Received August 18, 2015)

1113-35-148 **Alfonso Castro*** (castro@g.hmc.edu), Mathematics, Harvey Mudd College, Claremont, CA 91711, and **Ivan Ventura**. *Existence of augmented Morse index 3 solution for a semilinear boundary value problem.* Preliminary report.

Let Ω be a bounded region in $\mathbb{R}^N$. Let $f : \mathbb{R} \to \mathbb{R}$ be a differentiable function such that $f(0) = f'(0) = 0$, $f'(t) > f(t)/t$ for $t \neq 0$, and there exists $A > 0$ and $p \in (1, (N+2)/(N-2)$ such that $|f'(t)| \leq A(|t|^p + 1)$ for all $t \in \mathbb{R}$. The boundary value problem $\Delta u + f(u) = 0$ in Ω, $u = 0$ on the boundary of Ω has two Morse index 1 solutions and a Morse index 2 solution that changes sign exactly once. We prove that when a sublevel of the functional $J(u) = \int_\Omega \|(\nabla u\| - 2F(u))dx$, $F(u) = \int_0^u f(s)ds$, on the *equator of the Nehari Manifold* has nontrivial topology, an augmented Morse index 3 solutions exists. We provide examples of regions Ω for which this assumption applies. (Received August 18, 2015)

1113-35-164 **Peter Bates**, **Giorgio Fusco** and **Jiayin Jin*** (jin@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Invariant Manifolds of Multi Interior Spike States for the Cahn-Hilliard Equation.*

We construct invariant manifolds of interior multi-spike states for the nonlinear Cahn-Hilliard equation and then investigate the dynamics on it. An equation for the motion of the spikes is derived. It turns out that the dynamics of interior spikes has a global character and each spike interacts with all the others and with the boundary. Moreover, we show that the speed of the interior spikes is super slow, which indicates the long time existence of dynamical multi-spike solutions in both positive and negative time. This result is obtained through the application of a companion abstract result concerning the existence of truly invariant manifolds with boundary when one has only approximately invariant manifolds. (Received August 19, 2015)

1113-35-169 **Guillermo Reyes*** (guillermo.reyes@usc.edu), guillermo.reyes@usc.edu. *Equipartition of energy in operator-damped abstract wave equations.*

In this talk I will present some recent results, obtained in collaboration with J. A. Goldstein on the asymptotic equipartition of energy for damped abstract wave equations of the form

$$u_{tt} + 2F(S)u_t + S^2u = 0,$$

where S is a strictly positive selfadjoint operator and the damping operator $F(S)$ is "small" in a sense to be precised. Namely, we prove that the ratio of suitably modified kinetic and potential energies, $\tilde{K}(t)/\tilde{P}(t)$, tends to 1 as $t \to \infty$ for all nonzero solutions $u(t)$ of the equation. Some examples involving PDEs, as well as pseudo-differential equations, are given.

I plan to devote some time to introduce the subject of equipartition, as well as to present some previous results concerning the undamped case and the scalar-damped one as motivations. (Received August 20, 2015)

1113-35-173 **Yongjin Lu*** (ylu@vsu.edu). *Asymptotic and uniform stability of weak solutions to a nonlinear fluid-structure interaction model.*

Fluid-structure interaction modeling the dynamics of a structure submerged or surrounding viscous non-compressible fluid has wide applications ranging from aerospace engineering, civil engineering, medicine and environmental sciences, etc. In our study, we consider models where the elastic body exhibits small but rapid oscillations so that the dynamics is governed by a PDE system coupling Navier-Stokes equation with a wave equation. We will discuss the asymptotic and uniform stability of weak solutions to this nonlinear coupled system near either a trivial or nontrivial equilibrium via boundary and interface feedback controls. The result depends on the strength of the controls and the geometry of the interface. (Received August 20, 2015)

1113-35-180 **Shitao Liu*** (liul@clemson.edu) and **Lauri Oksanen**. *A Lipschitz stable reconstruction formula for the wave speed from boundary measurements.*

We consider the problem of reconstructing a wave speed in a bounded domain from acoustic boundary measurements modeled by the hyperbolic Dirichlet-to-Neumann map. We introduce a reconstruction formula that is based on the Boundary Control method and also incorporates features from the complex geometric optics solutions approach. Moreover, we show that the reconstruction formula is locally Lipschitz stable for a low frequency component of the wave speed under suitable geometrical and controllability assumptions. (Received August 21, 2015)

1113-35-181 **George Avalos*** (gavalos@math.unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588. *Rational Decay Rates for Solutions of a Structural Acoustics PDE model with no Additional "Hard Wall" Dissipation.*

A rate of rational decay is obtained for solutions of a PDE model which has been used in the literature to describe structural acoustic flows. This structural acoustics PDE consists partly of a wave equation which is invoked to model the interior acoustic flow within a given cavity. Moreover, a structurally damped elastic equation is invoked to describe time-evolving displacements along the flexible portion of the cavity walls. The coupling between these two distinct dynamics will occur across a boundary interface. We obtain the uniform decay rate of this structural acoustic PDE without incorporating any boundary dissipative feedback mechanisms on the inactive portion of the boundary. By way of deriving this stability result, necessary a priori inequalities for a certain static structural acoustics PDE model are generated, thereby allowing for an application of a recently derived resolvent criterion for rational decay. (Received August 21, 2015)

1113-35-184 **Catherine Lebiedzik*** (ar6554@wayne.edu). *Uniform Decay Rates for a full Von Karman System of Dynamic Thermoelasticity with Free Boundary Conditions.*

We consider a full Von Karman system accounting for in-plane acceleration and nonlinear thermal effects. Our model features free boundary conditions and an internal damping term on the in-plane displacement. We will discuss wellposedness of regular and weak solutions, and obtain uniform decay rates for the energy function. (Received August 21, 2015)

1113-35-186 **Yuri A. Melnikov***, 519 Brandywine Drive, Murfreesboro, TN 37129, and **Volodymyr N. Borodin**. *Recover of missing data for boundary-value problems simulating potential fields in thin shell structures.*

A specific class of inverse problems is targeted aiming at the restoration of missing governing data in statements of boundary-value problems that simulate potentials fields induced in thin-walled structures of irregular configuration. The latter could represent either single shell fragments or assemblies of fragments each of which is made of a homogeneous isotropic conductive material. Fragments of considered assemblies might either be weakened with apertures or contain some inclusions made of foreign materials. The targeted inverse problems are treated by the method of successive approximations at each iteration of which a corresponding direct problem is tackled by a Green's function modification of one of the versions of the classical boundary integral equation method. Required for that Green's functions for governing differential equations are analytically constructed prior to the actual computer work. This creates a reliable background for fast and accurate solution of targeted inverse problems. (Received August 21, 2015)

1113-35-192 **Michael Pokojovy*** (michael.pokojovy@uni-konstanz.de), Dept. of Mathematics and Statistics, University of Konstanz, 78457 Konstanz, Germany, and **J. Marcus Jobe** (jobejm@miamioh.edu), Information Systems and Analytics Dept., Farmer School of Business, Miami University, Oxford, OH 45056. *On Distributed Systems with Noisy Observations.*

Let X be a separable Hilbert space and let the linear operator A generate a C_0-semigroup on X. Within the framework of linear control theory, the observation problem on a finite time horizon $T > 0$ typically reads as

$$\dot{z}(t) = Az(t) \text{ for } t \in (0,T), \quad z(0) = x,$$
$$w(t) = Cz(t) \text{ in } (0,T)$$

for some observation operator C.

In this talk, we assume the observation variable w to be 1D and consider a noisy system given by

$$\dot{z}(t) = Az(t) \text{ for } t \in (0,T), \quad z(0) = x,$$
$$w(t_k) = Cz(t_k) + \varepsilon(t_k) \text{ for } k = 1, \dots, n,$$

where $t_k = Tk/n$ and $\varepsilon(t_k)$'s are i.i.d. univariate r.v. with mean 0 and variance $\sigma^2 > 0$. Note that the system is now observed over a discrete set of time periods.

Assuming the deterministic system is exactly observable at time T, we use the taut string estimator from nonparametric statistics to construct an estimate $\hat{x}_n$ for the initial state x based on noisy observations and prove $\hat{x}_n$ converges in appropriate sense to the actual initial state x reconstructed from the original deterministic system at the optimal rate of $n^{-1/2}$. (Received August 21, 2015)

1113-35-195 **Henry C Simpson*** (hsimpson@math.utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 37996. *The Complementing Condition for Elliptic Estimates in Elasticity.* Preliminary report.

We examine the static equations of elasticity on a bounded domain in R^2 or R^3. We consider boundary-value problems consisting of a system of elliptic partial differential equations with first-order traction boundary conditions. Central to corresponding elliptic estimates of ADN is the complementing condition. This is an algebraic requirement between the linearized differential equation and boundary operator (keeping highest-order derivatives), and it is necessary and sufficient for the validity of the estimates. We also look at the closely related Agmon's condition pertaining to spectral properties of the operators. For isotropic elasticity in R^2 we present closed-form expressions characterizing these conditions in terms of coefficients in the equations. We also consider certain cases in R^3. (Received August 21, 2015)

1113-35-200 **Joseph L Shomberg*** (jshomber@providence.edu), Providence College, 1 Cunningham Square, 212 Howley Hall, Providence, RI 02918. *Well-posedness and asymptotic behavior for non-isothermal viscous nonlocal Cahn-Hilliard equations.* Preliminary report.

We examine a variation of the phase separation model of spinodal decomposition governed by the non-isothermal viscous Cahn-Hilliard equation. Here, we employ a variant motivated by the work of Giacomin and Lebowitz

(1996-98) where the gradient term in the free energy functional is replaced with a nonlocal version. The nonlocal term accounts for long-range interactions which arise from a more satisfactory derivation of the Cahn-Hilliard equation based on statistical mechanics. Well-posedness results are obtained via a Faedo-Galerkin approximation method for regular (nonsingular) potentials. The asymptotic behavior of the solutions to the nonlocal Cahn-Hilliard equation is also examined. In particular, we show the existence of a bounded absorbing set and a global attractor. We also examine the regularity properties of the weak solutions and the global attractor. (Received August 21, 2015)

1113-35-203 **Minh Tuan Kha***, Department of Mathematics, Texas A&M University, 3368 TAMU, College Station, TX 77843, and **Peter Kuchment** and **Andrew Raich**. *Green's function asymptotics near the internal edges of spectra of periodic elliptic operators. Spectral gap interior.* Preliminary report.

Precise asymptotics known for the Green function of the Laplacian have found their analogs for bounded below periodic elliptic operators of the second-order below the bottom of the spectrum. Due to the band-gap structure of the spectra of such operators, the question arises whether similar results can be obtained near the edges of spectral gaps. In this talk, we will discuss the Green's function asymptotics for "generic" periodic elliptic operators of second-order in dimension $d \geq 2$, when the gap edge occurs at a high symmetry point of the Brillouin zone. (Received August 21, 2015)

1113-35-214 **Jerry Bona*** (bona@math.uic.edu), University of Illinois at Chicago, Dept Math., Statistics and Computer Sci., 851 S. Morgan Street MC 249, Chicago, IL 60607, and **Chun-Hsiung Hsia**. *Nonlinear, Dispersive Evolution Equations on Trees.*

The propagation of pressure waves in the mammalian arterial system and of surface waves on branching rivers and streams can be approximated by coupled systems of evolution equations. Cascaval derived Korteweg-de Vries type equations to model a pressure wave in a single, elastic tube. This work was extended later by Cascaval and one of the present authors to allow for branching tubes, so providing a crude model of arterial blood flow. A local well-posedness theory was mounted for this coupled system. Here, we discuss a global theory that complements the earlier local results. (Received August 22, 2015)

1113-35-219 **Turker Ozsari*** (tozsari@gmail.com), Department of Mathematics, Izmir Institute of Technology, 35430 Urla, Izmir, Turkey. *Semilinear Schrödinger equations with nonlinear interior and boundary sources on the half-line.*

In this talk, we present some recent results concerning the initial-boundary value problem for semilinear Schrödinger equations on the half-line with nonlinear interior and boundary sources. We first discuss the local and global well-posedness in the fractional Sobolev spaces. Secondly, we study the interaction between the interior and boundary sources. We give a certain set of conditions which yields blow-up solutions at the energy level. In addition to the blow-up property, we also discuss the energy decay and the critical exponent for the same model (Received August 23, 2015)

1113-35-220 **Laurence Cherfils*** (laurence.cherfils@univ-lr.fr), Université de La Rochelle, laboratoire MIA, Avenue Michel Crépeau, 17690 La Rochelle, France, **Hussein Fakih** (hussein.fakih@math.univ-poitiers.fr), Université de Poitiers, Laboratoire LMA, Boulevard Marie et Pierre Curie, SP2MI, Futuroscope, 86962 Chasseneuil, France, and **Alain Miranville** (alain.miranville@math.univ-poitiers.fr), Université de Poitiers, Laboratoire LMA, Boulevard Marie et Pierre Curie, SP2MI, Futuroscope, 86962 Chasseneuil, France. *On the Bertozzi-Esedoglu-Gillette-Cahn-Hilliard equation for image inpainting.*

A generalization of the Cahn-Hilliard equation with a fidelity term was initially introduced in 2007 by A. Bertozzi & al. for binary image inpainting. We are interested in the study of the asymptotic behavior, in terms of finite dimensional attractors, of the dynamical system associated with this problem. A major difficulty here is that we no longer have the conservation of mass, i. e. of the spacial average of the order parameter, as it was the case in the classical Cahn-Hilliard equation. We also propose and study some improvements of the model in order to deal with multicolor image inpainting and with grayscale image inpainting. We finally give numerical simulations which confirm the efficiency of these different models. (Received August 23, 2015)

1113-35-225 **Madalina Petcu*** (madalina.petcu@math.univ-poitiers.fr), Téléport 2 - BP 30179, Boulevard Marie et Pierre Curie, 86962 Futuroscope Chasseneuil Cedex, 86962 Poitiers, France, and **Laurence Cherfils** (laurence.chefils@univ-lr.fr), Laboratoire MIA, Avenue Michel Crepeau, 17042 La Rochelle, France. *On the viscous Cahn-Hilliard-Navier-Stokes equations with dynamic boundary conditions.*

In this talk we study the viscous Cahn-Hilliard-Navier-Stokes model, endowed with dynamic boundary conditions, from the theoretical and numerical point of view. We start by deducing results on the existence, uniqueness and regularity of the solutions for the continuous problem. Then we propose a space semi-discrete finite element approximation of the model and we study the stability and the convergence of the approximate scheme. We also prove the stability and convergence of a fully discretized scheme, obtained using the semi-implicit Euler scheme applied to the space semi-discretization proposed previously. Numerical simulations are also presented to illustrate the theoretical results. (Received August 23, 2015)

1113-35-226 **Yongzhi Steve Xu*** (ysxu0001@louisville.edu), Professor Yongzhi Xu, Department of Mathematics, University of Louisville, Louisville, KY 40292, **Heng Li** (heng.li@louisville.edu), Heng Li, Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Jianrong Zhou** (zhoujianrong2012@163.com), Jianrong Zhou, Department of Mathematics, Foshan University, Foshan, Guangdong 528000, Peoples Rep of China. *Inverse problem for a parabolic equation with time-dependent boundaries.*

In this talk we discuss problems of a class of non-classical parabolic equations in which the boundaries are time-dependent function, which arise from a mathematical model of Ductal Carcinoma In Situ(DCIS). We use some transformation and heat potential theory to establish the integral form of solution and proved the existence and uniqueness of solution. Then we consider the inverse problem of determining the potential function of model from moving boundary information, which related to the mammography screening of DCIS. Algorithm and numerical simulation are presented to demonstrate the validity and applicability of solutions. (Received August 25, 2015)

1113-35-228 **Ning Ju*** (nju@okstate.edu), 401 Mathematical Sciences, Oklahoma State University, Stillwater, OK 74078. *Long time behavior of the solutions to the Primitive Equations for Oceans.*

The system of 3D Primitive Equations is a fundamental mathematical model for the large scale fluid flows occurring in the ocean and atmosphere. Recently, global well-posedness of the system was established and long-time dynamics of the solutions was well studied. In this talk, recent progress and new results for the long-time dynamics of the solutions of the system will be presented. (Received August 23, 2015)

1113-35-237 **Rafael de la Llave*** (rll6@math.gatech.edu) and **Yannick Sire**. *An a-posteriori KAM theorem that applies even to some ill posed equations.*

We formulate the existence of quasi-periodic solutions for an evolutionary equation as the existence of solutions to a functional equation for a parametrization of the solutions. We present an abstract theorem that shows that if there are approximate solutions of this functional equation that satisfy some non-degeneracy conditions, then, there are true solutions close by. We present applications to the Boussinesq equation and the Boussinesq system. The method also leads to efficient algorithms. (Received August 24, 2015)

1113-35-251 **George Avalos*** (gavalos@math.unl.edu), Department of Mathematics, Lincoln, NE 68542. *Concerning an Applied Analysis of Fluid-Structure Interactive PDE Models.*

In this talk we will present qualitative results for a partial differential equation (PDE) system which models a fluid-structure PDE of longstanding interest within the mathematical literature. The coupled PDE model under discussion involves a Stokes or Navier-Stokes system, which evolves on a three dimensional domain, interacting with a fourth order plate equation which evolves on a flat portion of said fluid domain. Among other technical difficulties we note that, inasmuch as the fluid velocity does not vanish on all of the boundary, the associated pressure variable cannot be eliminated via the classic Leray Projector. We will discuss current wellposedness work for the fully nonlinear model; i.e., the fluid component of the dynamics is governed by the Navier-Stokes, rather than the Stokes equations. (Received August 24, 2015)

1113-35-267 **Lorena Bociu*** (lvbociu@ncsu.edu). *Sensitivity Analysis and Control in the Lamina Cribrosa.*

In this talk we will discuss sensitivity analysis with respect to important biological parameters (Lame coefficients, intra-ocular pressure and retrolaminar tissue pressure) for a poroelastic model describing the lamina cribrosa in the eye. It is believed that the biomechanics of the lamina cribrosa plays an important role in the retinal ganglion

cell loss in glaucoma. Our goal is to reveal which parameters are most influential and need to be controlled in order to prevent the development of glaucoma. (Received August 24, 2015)

1113-35-272 **Justin T Webster*** (websterj@cofc.edu), 66 GEORGE ST, Charleston, SC 29424, and **Pelin G Geredeli**, Ankara. *Nonlinear Plates with Boundary Dissipation: Contrasting Berger versus von Karman.*

The dynamics of the nonlinear Berger plate, in the absence of rotational inertia are considered. We consider boundary damping in free plate boundary conditions, and hinged boundary conditions—where the structure of the nonlinearity gives rise to complicating boundary terms in the analysis (not found for von Karman dynamics).

In the case of dissipation acting through free boundary conditions, we obtain well-posedness through the use of highly nonlinear boundary damping (to accommodate non-dissipative, nonlinear terms in the energy relation).

We also show the existence of a compact global attractor for the dynamics in the presence of hinged boundary dissipation (assuming a star-shaped, star-complemented condition). We explicitly construct the absorbing set for the dynamics by employing energy methods that exploit the specific structure of the Berger nonlinearity. We critically utilize sharp trace results for the Euler-Bernoulli plate.

Our results provide a parallel mathematical commentary to Berger versus von Karman modeling: we discuss the validity and applicability of the Berger approximation, which we believe to be of broad value across engineering and applied mathematics communities. (Received August 24, 2015)

1113-35-278 **Chiu-Yen Kao**, **Alexander Kurganov**, **Zhuolin Qu** and **Ying Wang*** (wang@math.ou.edu). *A Fast Explicit Operator Splitting Method for Modified Buckley-Leverett Equations.*

In this talk, I will discuss a fast explicit operator splitting method to solve the modified Buckley-Leverett equations which include a third-order mixed derivatives term resulting from the dynamic effects in the pressure difference between the two phases. The method splits the original equation into two equations, one with a nonlinear convective term and the other one with high-order linear terms so that appropriate numerical methods can be applied to each of the split equations: The high-order linear equation is numerically solved using a pseudo-spectral method, while the nonlinear convective equation is integrated using the Godunov-type central-upwind scheme. A variety of numerical examples in both one and two space dimensions show that the solutions may have many different saturation profiles depending on the initial conditions, diffusion parameter, and the third-order mixed derivatives parameter. The results are consistent with the study of traveling wave solutions and their bifurcation diagrams. This is a joint work with C.-Y. Kao, A. Kurganov, and Z.-L. Qu. (Received August 24, 2015)

1113-35-282 **Daniel Toundykov*** (dtoundykov@unl.edu), Lincoln, NE , and **Jean-Paul Zolesio** (jean-paul.zolesio@inria.fr), Sophia-Antipolis, France. *Control through moving boundary.* Preliminary report.

I will discuss some stabilization results for PDEs on moving domains. A system can be controlled by adjusting the velocity of the boundary of the underlying physical domain. Numerical simulations will be presented. (Received August 24, 2015)

1113-35-285 **Christopher G Lefler***, cgl9b@virginia.edu, and **Marcelo Cavalcanti**, **Wellington Correa** and **Irena Lasiecka**. *Well-posedness and Uniform Stability for Nonlinear Schrödinger Equations with Dynamic/Wentzell Boundary Conditions.*

The Shrödinger equation with a defocusing nonlinear term and dynamic boundary conditions defined on a smooth boundary of a bounded domain $\Omega \in R^N, N = 2, 3$ is considered. Local wellposedness of strong H^2 solutions is established. In the case $N = 2$ local solutions are shown to be global. In addition, existence of weak H^1 solutions in dimensions $N = 2, N = 3$ is also shown. The energy corresponding to weak solutions are shown to satisfy uniform decay rates under appropriate monotonicity conditions imposed on the nonlinear terms appearing in the dynamic boundary conditions. The proof of wellposedness is critically based on converting the equation into a Wentzell boundary value problem associated with Shrödinger dynamics. The analysis of this later problem with inhomegenous boundary data allows us to build a theory suitable for the treatment of the dynamic boundary conditions. (Received August 25, 2015)

1113-35-297 **Sedar Ngoma*** (nzb0015@auburn.edu), Department of Mathematics and Statistics, 221 Parker Hall, Auburn University, Auburn, AL 36849, and **Dmitry Glotov**, **A. J Meir** and **Willis E Hames**. *An inverse time-dependent source problem for the two dimensional parabolic equation with integral overdetermination.*

An inverse time-dependent source problem for the heat equation in two dimensions with integral overdetermination is considered. Existence and uniqueness of a weak solution of the inverse problem are proved. Numerical studies using the finite element method in space combined with the implicit backward Euler in time are presented and discussed. The errors and convergence rates are also reported. (Received August 25, 2015)

1113-35-300 **Ludovic Goudenège*** (goudenege@math.cnrs.fr), Grande Voie des Vignes, 92295 Chatenay-Malabry, France. *Phase field model of Cahn-Hilliard type for coating process.*

A coating process is a complex phenomenon. In order to simulate it, we need at least two equations. One for the dynamic of the fluid and one for the interface between the different species. We will present a phase field model of Cahn-Hilliard type coupled with the Navier-Stokes equations. In particular we extend the model to take into account the dynamic of surfactant. The main difficulty is to control the physical effects induced by this new dynamics. Moreover this is a particularly challenging situation where the density ratio is close to 1000 and the viscosity ratio is close to 100. We will present theoretical and numerical results. (Received August 25, 2015)

1113-35-303 **Yuri A. Antipov** (antipov@math.lsu.edu) and **Ashar Ghulam*** (aghula2@lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Method of the Riemann-Hilbert problem for the Helmholtz equation in a semi-strip.*

The Helmholtz equation in a semi-infinite strip subject to the boundary conditions $[U_j(\partial/\partial\tau)\partial/\partial n + \mu_j]u = f_j$ on side j ($j = 1, 2, 3$), is analyzed. Here, $\partial/\partial\tau$ and $\partial/\partial n$ are the tangential and normal derivatives, U_j are order-m_j differential operators with constant coefficients, μ_j are constants, and f_j are given functions. The problem is transformed into an order-2 vector Riemann-Hilbert boundary value problem of the theory of analytic functions. It is shown that if the polynomials $U_j(s)$ have only even powers of s, then the vector Riemann-Hilbert problem admits a closed-form solution. The particular case when $U_j(s)$ are constants is analyzed in detail. In this case the representation formulas for the solution are reducible to the ones obtained by the finite integral transformation and solution of the associated Sturm-Liouville problem. Both methods ultimately require determining roots of the same transcendental equation. They are found by quadratures on applying the Burniston-Siewert method and solving a certain Riemann-Hilbert problem on two segments. (Received August 25, 2015)

1113-35-308 **Patrick Guidotti*** (gpatrick@math.uci.edu), 340 Rowland Hall, Department of Mathematics, Irvine, CA 92697. *Well-posedness and Stability of Equilibria for a Droplet Equation.*

In this talk the classical well-posedness of a simple droplet model will be analyzed. Its equilibria will be characterized and their stability established. The model consists of a moving boundary value problem which will be reduced to a nonlocal geometric evolution (for the domain alone). Well-posedness is obtained by analyzing the properties of the relevant linearization, whereas stability follows from an explicit characterization of the linearization and from the introduction of a convenient coordinate system for the geometric evolution. (Received August 25, 2015)

1113-35-310 **Patrick Guidotti*** (gpatrick@math.uci.edu), 340 Rowland Hall, Department of Mathematics, Irvine, CA 92697. *Numerical Analysis in a Box.*

In this talk a method will be described to simulate boundary value problems on general domains contained in a periodic bounding box on a regular grid discretization of the latter. The procedure will mimic analytical considerations and make the structure of the kernels involved apparent along with a natural way to handle them numerically. (Received August 25, 2015)

1113-35-316 **Gisele Ruiz Goldstein*** (ggoldste@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38138. *The Ubiquitous Presence of Dynamic Boundary Conditions in Science.*

Dynamic boundary conditions play an essential role in acurately modeling complex physical interactions on the boundary. In this lecture we explain the role of dynamic boundary conditions in modeling diffusion processes, wave propagation, and problems in materials science. The connection between dynamic boundary conditions and Wentzell boundary conditions will be explained, and rigorous mathematical results related to these boundary conditions will be presented. (Received August 25, 2015)

37 ► Dynamical systems and ergodic theory

1113-37-27 **Robert L. Devaney*** (bob@bu.edu), Math Dept., 111 Cummington Mall, Boston University, Boston, MA 02215. *Mandelpinski Structures in the Parameter Planes of Rational Maps.*

In this talk we shall describe three different types of Mandelpinski structures that arise in the parameter planes of singularly perturbed complex maps, namely Mandelpinski necklaces, spokes, and mazes. Each of these objects consists of a collection of infinitely many different curves arranged in a particular manner along which are located a large number of (usually infinitely many) Mandelbrot sets and Sierpinski holes in alternating fashion. Here a Sierpinski hole is a disk in the parameter plane from which any parameter has a corresponding Julia set that is a Sierpinski curve, i.e., is homeomorphic to the Sierpinski carpet fractal. (Received July 06, 2015)

1113-37-44 **Hiroki Sumi*** (sumi@math.sci.osaka-u.ac.jp), 1-1, Machikaneyama, Toyonaka, Osaka 560-0043, Japan. *Complex Analogues of the Takagi Functions in Random Complex Dynamics.*

We consider random dynamical systems of holomorphic maps on the Riemann sphere. We study the function T of probability of tending to one minimal set. We show that under a generic condition, T is continuous on the Riemann sphere. Also, we show if the system is generated by finitely many holomorphic maps, T is real analytic with respect to the probability parameter. Under certain conditions, T is a complex analogue of the Lebesgue's singular functions or the devil's staircase, and the partial derivative C of T with respect to the probabilty parameter is a complex analogue of the Takagi function, which is continuous but nowhere differentiable on [0,1]. Namely, these functions T and C are continuous on the Riemann sphere and varies precisely on the Julia set of the associated semigroup of holomorphic maps, which is a thin fractal set. References: [1] J. Jaerisch and H. Sumi, Multifractal formalism for expanding rational semigroups and random complex dynamical systems, Nonlinearity 28 (2015) 2913-2938. [2] H. Sumi, Random complex dynamics and semigroups of holomorphic maps, Proc. London Math. Soc. (2011) 102(1), 50–112. [3] H. Sumi, Cooperation principle, stability and bifurcation in random complex dynamics, Adv. Math., 245 (2013) 137–181. (Received August 03, 2015)

1113-37-48 **Jessica Dyer**, **Steven Hurder** and **Olga Lukina*** (lukina@uic.edu), 322 SEO (M/C 249), University of Illinois at Chicago, 851 S. Morgan St., Chicago, IL 60607. *The discriminant invariant of Cantor group actions.*

In this talk, we consider minimal equicontinuous actions of non-abelian groups on Cantor sets. Such an action may be classified as regular, weakly regular or irregular by the properties of its automorphism group. We introduce an invariant, called the discriminant function, which assigns to each point of a Cantor set a profinite group. The cardinality of the group does not depend on the point and is related to the type of the action. We give new examples of minimal actions of the Heisenberg group for which the invariant is not trivial. (Received August 04, 2015)

1113-37-52 **Johannes Jaerisch*** (jaerisch@riko.shimane-u.ac.jp), Matsue, Japan, and **Hiroki Sumi**, Osaka, Japan. *Hölder regularity of the complex analogues of the Takagi function.*

Recently, H. Sumi introduced complex analogues of the Takagi function, which play a role in the iteration of rational maps on the Riemann sphere $\hat{\mathbb{C}}$ and random complex dynamical systems. We investigate the Hölder regularity of a complex analogue C of the Takagi function. Under certain assumptions, by employing methods from ergodic theory, we obtain new results about the set of points in which C satisfies a local Hölder condition with a prescribed Hölder exponent. In particular, we determine the set of points $z \in \hat{\mathbb{C}}$ for which C is not locally constant in a neighbourhood of z. This is a joint work with H. Sumi. (Received August 05, 2015)

1113-37-53 **Yunping Jiang*** (yunping.jiang@qc.cuny.edu), Department of Mathematics, Queens College of CUNY, 65-30 Kissena Blvd, Flushing, NY 11367. *Asymptotic Geometry of Non-Linear Family of Cantor sets.*

In this talk, I will discuss asymptotic geometry of families of Cantor sets arisen from asymptotic first kind of Fuchsian groups and from asymptotic non-hyperbolic families. We will concentrate on asymptotic scaling property and asymptotic dimension property. (Received August 05, 2015)

1113-37-134 **Vasilis Chousionis** and **Jeremy T Tyson*** (tyson@math.uiuc.edu), 1409 West Green Street, Urbana, IL 61801, and **Mariusz Urbanski**. *Conformal graph directed Markov systems in Carnot groups of Iwasawa type.*

We develop a theory of conformal iterated function systems (IFS) and graph directed Markov systems (GDMS) in nilpotent stratified Lie groups equipped with a sub-Riemannian metric (a.k.a. Carnot groups). Our theory

extends known results for self-similar IFS in Carnot groups to the case of infinite alphabets. It applies also to nonlinear conformal GDMS in Carnot groups. Of particular interest are the Carnot groups of Iwasawa type, which arise as local models for the boundaries at infinity of the classical rank one symmetric spaces. This class of Carnot groups includes the usual Heisenberg group as well as its quaternionic and octonionic counterparts. The group of conformal self-maps of an Iwasawa group is rather rich, for instance, it is two-point transitive with nontrivial stabilizer subgroups. We develop a thermodynamic formalism for Iwasawa conformal GDMS and, under suitable hypotheses, identify the Hausdorff dimension of the limit set as the unique zero of the pressure function. We investigate when the Hausdorff or packing measures of the limit set in its natural dimension is positive and finite. As an application, we estimate dimensions of limit sets arising from Heisenberg continued fractions. This talk is based on joint work with Vasilis Chousionis and Mariusz Urbański. (Received August 17, 2015)

1113-37-135 **Jeannette Janssen** and **Anthony Quas***, Mathematics and Statistics, University of Victoria, Victoria, BC V8W 3R4, Canada, and **Reem Yassawi**. *A dichotomy for random adic transformations.*

A class of dynamical systems is obtained by taking the so-called adic transformations of an ordered Bratteli diagram. These adic transformations may be extended to homeomorphisms if there are unique maximal and minimal paths. Herman, Putnam and Skau showed that these transformations provide models of any Cantor minimal dynamical system.

Given an unordered Bratteli diagram, we study the dynamical systems obtained by endowing the diagram with a random order. We relate the question of unique maximal and minimal paths to a model in population genetics and establish a dichotomy for the number of maximal and minimal paths: if the levels of the diagram grow too slowly, there is almost surely a unique maximal and minimal path; if they grow too fast, there are almost surely uncountably many maximal and minimal paths. (Received August 17, 2015)

1113-37-138 **Wenbo Sun*** (math@math.northwestern.edu), 2033 Sheridan Road, Evanston, IL 60208. *Structure theorem for multiplicative functions of Gaussian integers and its applications.*

In this talk, we present a structure theorem for multiplicative functions of Gaussian integers. Roughly speaking, we show that every multiplicative function of Gaussian integers can be written as the sum of an "almost periodic" function, a function with small Gowers norm, and an error term. We will also explain its connection with ergodic theory and give a combinatorial application of it. (Received August 18, 2015)

1113-37-143 **Bibiana Iaffei**, **Andrew Parrish*** (ajnparrish@gmail.com) and **Joseph Rosenblatt**. *Maximal Functions With and Without Cancellation.*

Given a measure-preserving transformation, T, acting on a probability space $(X, \mathcal{B}, m)$, define a maximal function

$$Mf = \sup_N \frac{1}{N} \sum_{n=0}^{N-1} f \circ T^n(x).$$

The traditional ergodic maximal function is then $M|f|$. In 1976, Roger Jones showed that there are functions for which $Mf \in L^1(X)$ while $M|f| \notin L^1(X)$.

In this talk, we will discuss several issues surrounding maximal functions that allow for cancellation, including how this manifests for other operators, how common this difference in behavior is, in a categorical sense, and situations (along specific sequences) in which no such discrepancy occurs. (Received August 18, 2015)

1113-37-161 **Dogan Comez*** (dogan.comez@ndsu.edu), Department of Mathematics, Dept. #2750, PO Box 6050, Fargo, ND 58108-6050. *Discrete ergodic Hilbert transform along moving averages sequences.* Preliminary report.

This presentation is on the existence and non-existence of the discrete ergodic Hilbert transform (deHt) along sequences of integers, in particular moving averages sequences. Observing that deHt along moving averages sequences does not exist in general, we investigate classes of measure preserving transformations for which the existence hold. These results are also extended to the setting of a class of superadditive processes. (Received August 19, 2015)

1113-37-170 **Sarah Frick** and **Karl Petersen*** (petersen@math.unc.edu), Department of Mathematics, CB 3250 Phillips Hall, UNC, Chapel Hill, NC 27599, and **Sandi Shields**. *The Pascal adic system with arbitrary ordering is essentially expansive and topologically weakly mixing.*

We consider arbitrary orderings of the edges entering each vertex of the (downward directed) Pascal graph. Each ordering determines an adic (Bratteli-Vershik) system, with a transformation that is defined on most of the space

of infinite paths that begin at the root. We prove that for every ordering the coding of orbits according to the partition of the path space determined by the first three edges is essentially faithful, meaning that it is one-to-one on a set of paths that has full measure for every fully supported invariant probability measure. We also show that for every k the subshift that arises from coding orbits according to the first k edges is topologically weakly mixing. (Received August 20, 2015)

1113-37-188 **S. Eigen** (s.eigen@neu.edu), Boston, MA 02115, and **A. B. Hajian**, **Y. Ito** and **V. S. Prasad*** (vidhu_prasad@uml.edu), Dept. of Mathematical Sciences, University of Massachusetts Lowell, 1 University Avenue, Lowell, MA 01824. *Special Weakly Wandering sequences in ergodic theory and tilings of the integers.* Preliminary report.

We consider a class of sequences of integers, for an ergodic infinite measure preserving transformation, called special weakly wandering sequences. These sequences (unexpectedly) give rise to tilings of the integers. This connection between ergodic theory and tilings leads to a purely combinatorial result about hereditary tilings of the integers. We consider special weakly wandering sequences for the case of simple random walk on the integers. (Received August 21, 2015)

1113-37-199 **Vitaly Bergelson**, Department of Mathematics, 231 West 18th Avenue, Columbus, OH 43210, and **Donald Robertson*** (robertson@math.utah.edu), Department of Mathematics, 155 S 1400 E, Salt Lake City, 84112. *Intersective Polynomials and Recurrence.*

In this talk I will describe recent progress made with V. Bergelson on recurrence and multiple recurrence for $\mathbb{Z}^d$ actions along intersective polynomials - polynomials having a common root modulo any congruence. Specifically, I will describe new collections of intersective polynomials for which multiple recurrence is known to hold, and a strengthening of the structure of single recurrence times along an intersective polynomial. (Received August 23, 2015)

1113-37-206 **Sergey Kryzhevich*** (kryzhevicz@gmail.com), University of Texas at Dallas, 800, W.Campbell Rd., Department of Mathematical Sciences, Richardson, TX 75080, and **Danila Cherkashin** (matelk@mail.ru), Saint-Petersburg State University, Faculty of Mathematics and Mechanics, Saint-Petersburg, 198503, Russia. *Weak shadowing in topological dynamics.*

We study several weak forms of shadowing for generic homeomorphisms that do not have hyperbolicity or any similar property.

Theorem 1. *For any $\varepsilon > 0$ there exists a $d > 0$ such that for any d – pseudotrajectory x_k there exists a subsequence $\{k_n\}$ and a trajectory y_k such that $\rho(x_{k_n}, y_{k_n}) < \varepsilon$.*

Let $W \subset C^0(X \to X)$ be the set of all homeomorphisms such that for any $\varepsilon > 0$ there exists a $d > 0$ such that for any d pseudotrajectory $\{x_k\}$ there exist points $y^1, \dots, y_N$ $(N = N(\{x_k\}, \varepsilon))$ such that x_k is ε close to one of points $T^k(y^i)$ for all $k \in \mathbb{N}$.

Let Q be the set of all homeomorphisms of X such that for any $\varepsilon > 0$ there exists a finite ε net whose iterations are ε nets.

Theorem 2. *Let T be a homeomorphism of a compact metric space X, $CR(X,T)$ be the set of all chain recurrent points, $M(X,T)$ is the set of all minimal points. Then $T \in W$ iff $M(X,T)$ is dense in $CR(X,T)$. This condition is C^0 and C^1 generic. It implies that restriction of T to $CR(X,T)$ belongs to Q. Also, there is a Borel probability invariant measure supported on all $CR(X,T)$.* (Received August 22, 2015)

1113-37-207 **John T. Griesmer*** (jtgriesmer@gmail.com). *Rigidity, Recurrence, and Popular Differences.*

A sequence $(a_n)_{n\in\mathbb{N}}$ is a *rigidity sequence* for a probability measure preserving system (X, μ, T) if $\lim_{n\to\infty} \mu(A \triangle T^{a_n} A) = 0$ for every measurable $A \subseteq X$. If $(a_n)_{n\in\mathbb{N}}$ is a rigidity sequence for a weak mixing system, then the set of values $\{a_n : n \in \mathbb{N}\}$ has upper Banach density 0, so rigidity sequences for weak mixing systems are small in the sense of density.

We construct some rigidity sequences which are large in several other ways and we deduce some classical results in ergodic Ramsey theory and harmonic analysis as corollaries. In particular, we reprove a result of A. Forrest: there is a set of recurrence which is not a set of strong recurrence. (Received August 22, 2015)

1113-37-209 **Rich Stankewitz*** (rstankewitz@bsu.edu), Ball State Univeristy, and **Hiroki Sumi** (sumi@math.sci.osaka-u.ac.jp), Osaka University. *Mobius Semigroup Julia sets and Random Backward Iteration.* Preliminary report.

We extend a result regarding the Random Backward Iteration algorithm for drawing Julia sets (known to work for certain rational semigroups containing a non-Möbius element) to a class of Möbius semigroups which includes certain settings not yet been dealt with in the literature, namely, when the Julia set is not a thick attractor in the sense given in a paper by Fried, Marotta, and Stankewitz. (Received August 22, 2015)

1113-37-213 **Drew D. Ash***, drew.ash@du.edu. *Topological Speedups.*

Given a dynamical system (X,T) one can define a speedup of (X,T) as another dynamical system $S : X \to X$ where $S = T^{p(\cdot)}$ for some $p : X \to \mathbb{Z}^+$. In 1985 Arnoux, Ornstein, and Weiss showed that given a pair of measure theoretic dynamical systems, one is isomorphic to a speedup of the other under the very mild condition that both transformations are aperiodic. In this talk, I will give the setting and relevant definitions for what we mean by a topological speedup; then we will discuss a characterization theorem for speedups of minimal Cantor systems. This theorem is both a topological analog of the Arounx-Ornstein-Weiss result and a sort of "one-sided" version of a theorem of Giordano-Putnam-Skau on topological orbit equivalence. Finally, I will discuss on-going joint work with Lori Alvin and Nic Ormes on bounded speedups, i.e., speedups where the function p is bounded and therefore continuous. (Received August 22, 2015)

1113-37-222 **Elizabeth Sattler***, elizabeth.sattler.1@ndsu.edu. *Fractal dimensions of subfractals induced by sofic subshifts.* Preliminary report.

In this talk, we will consider subfractals of hyperbolic iterated function systems which satisfy the open set condition. The subfractals will consist of points associated with infinite strings from a sofic subshift on the symbolic space. We will use a topological pressure function to find bounds for the Hausdorff and upper box dimensions of the subfractals. (Received August 23, 2015)

1113-37-235 **Steven Hurder*** (hurder@uic.edu), University of Illinois at Chicago, Department of Math (m/c 249), 322 SEO, 851 S. Morgan Street, Chicago, IL 60607. *Entropy of the Kuperberg pseudogroup.* Preliminary report.

The purpose of this talk is to describe some novel aspects of the dynamics of the Kuperberg pseudogroup. Krystyna Kuperberg showed that the smooth Seifert Conjecture is false, by constructing smooth aperiodic plugs in 3-dimensions, which can be used to construct smooth aperiodic flows on any compact 3-manifold. The flows in these aperiodic plugs have a unique minimal set. In the paper "The dynamics of generic Kuperberg flows" by Hurder and Rechtman, we analyze the dynamics and topology of these minimal sets. A key tool is the introduction of the Kuperberg pseudogroup, defined by the return maps of the flow to a section, where the section is allowed to have tangencies to the flow, and thus the pseudogroup generators have singularities. While the usual entropy of an smooth aperiodic flow must always vanish, the "slow entropy" need not, and we discuss why the slow entropy does not vanish for the Kuperberg pseudogroup, and also is not zero for the flow. (Received August 23, 2015)

1113-37-236 **Terry Soo*** (tsoo@ku.edu). *A monotone isomorphism theorem.*

In the simple case of a Bernoulli shift on two symbols, zero and one, by permuting the symbols, it is obvious that any two equal entropy shifts are isomorphic. We show that the isomorphism can be realized by a factor that maps a binary sequence to another that is coordinatewise smaller than or equal to the original sequence. (Received August 23, 2015)

1113-37-259 **Vitaly Bergelson** and **Joel Moreira*** (moreira.6@osu.edu). *Actions of the affine semigroup of certain rings and $\{x+y, xy\}$ patterns.*

A famous open problem in Ramsey theory states that any finite partition/coloring of the natural numbers $\mathbb{N}$ yields infinitely many monochromatic patterns of the form $\{x+y, xy\}$. Using a version of Furstenberg's correspondence principle, an analogue of this problem, with $\mathbb{N}$ replaced with a countable field, can be approached using ergodic theoretical techniques. We use a modification of this approach, with the more classical Cesàro limits replaced with limits along certain ultrafilters, to prove, in particular, that for any finite coloring of the set of rational numbers $\mathbb{Q}$ there infinitely many monochromatic configurations of the form $\{x+n, xn\}$ with $x \in \mathbb{Q}$ and $n \in \mathbb{N}$. This talk is based on joint work with Vitaly Bergelson. (Received August 24, 2015)

1113-37-269 **Florian Rupp*** (florian.rupp@gutech.edu.om), German University of Technology in Oman, Department of Mathematics and Science, PO Box 1816, Athaibah PC 130, Muscat, Oman. *Towards the Approximation of Stochastic Lyapunov Functions.*

Based on the deterministic radial basis interpolation method and the sums of square decomposition we discuss the construction of Lyapunov functions for asymptotically stable equilibria in dynamical systems generated by random and stochastic differential equations. (Received August 24, 2015)

1113-37-273 **Mikel de Viana***, School of Mathematics, Georgia Institute of Technology, 686 Cherry Street, Atlanta, GA 30332, and **Rafael de la Llave**. *Construction of whiskered invariant tori for fibered holomorphic dynamics via reducibility and almost reducibility.*

We consider fibered holomorphic dynamics generated by the skew product

$$F : \mathbb{C}^n \times \mathbb{T}^d \longrightarrow \mathbb{C}^n \times \mathbb{T}^d$$

$$F(z, \theta) = (f(z, \theta), \theta + \omega)$$

which has as base the irrational translation T_ω on the torus $\mathbb{T}^d$.

F has no fixed point nor a periodic orbit: The invariant object that organizes the dynamics is an invariant torus $K : \mathbb{T}^d \to \mathbb{C}^n$. Given an approximately invariant torus K_0, we construct an invariant torus K. The main technique is a KAM iteration in a-posteriori format.

The asymptotic properties of the derivative cocycle

$$A_{K_0}(\theta) := Df(K_0(\theta), \theta),$$

will play a crucial role. We assume that A_{K_0} is whiskered: There exists a splitting of $\mathbb{C}^n$ in stable, unstable and central directions which are approximately invariant under A_{K_0}. In the central directions, we use the ideas of reducibility or almost-reducibility for A_{K_0}. Here we also encounter the lack-of-parameters problem, which we solve using an idea due to Moser. (Received August 24, 2015)

1113-37-292 **Mrinal K Roychowdhury*** (mrinal.roychowdhury@utrgv.edu), Dept of Mathematics, 1201 West University Drive, Edinburg, TX 78539. *Quantization for probability distributions.*

The representation of a given quantity with less information is often referred to as 'quantization' and it is an important subject in information theory. The aim of quantization for probability measures is to approximate a continuous probability measure with discrete probability measure with finite support. I will talk about it. (Received August 25, 2015)

1113-37-302 **Scott Sutherland*** (scott@math.stonybrook.edu), Stony Brook University, Stony Brook, NY , and **Artem Dudko**. *On the Measure of the Feigenbaum Julia Set.* Preliminary report.

We discuss a computer-assisted proof that the Julia set of the Feigenbaum map

$$z \mapsto z^2 - 1.4011551890\cdots,$$

which is the limit of period-doubling renormalization in the quadratic family, has zero measure. (Received August 25, 2015)

1113-37-314 **Tamara Kucherenko*** (tkucherenko@ccny.cuny.edu) and **Christian Wolf**. *Localized pressure and equilibrium states.*

We introduce the notion of localized topological pressure for continuous maps on compact metric spaces and establish a local version of the variational principle for several classes of systems and potentials. Going further, we study localized equilibrium states and show that even in the case of subshifts of finite type and Hölder continuous potentials, there are several new phenomena that do not occur in the theory of classical equilibrium states. In particular, ergodic localized equilibrium states for Hölder continuous potentials are not unique. It is even possible to have infinitely many. (Received August 25, 2015)

39 ► Difference and functional equations

1113-39-37 **E Cabral Balreira*** (ebalreir@trinity.edu), One Trinity Place, Department of Mathematics, San Antonio, TX 78212. *Global Stability of Higher Dimensional Monotone Maps.* Preliminary report.

We discuss a new notion of monotonicity for maps on $\mathbb{R}^k$ called normal monotonicity. This notion extend the classical definition of competitive planar maps and geometrically captures the dynamics of a competitive system in higher dimensions. Namely, a map $F : \mathbb{R}^k \to \mathbb{R}^k$ is monotone at p if for any hypersurface Γ containing $\mathbf{p}$ with

$\eta_\Gamma(\mathbf{p}) > 0$, we have $\eta_{F(\Gamma)}(F(\mathbf{p})) > 0$. Here η denotes the normal vector at a hypersurface. The main result is that under this new idea, we can establish global stability for monotone maps beyond planar maps. We illustrate our ideas in the three dimensional Leslie-Gower and Ricker Competition maps. (Received July 29, 2015)

1113-39-40 **Michael A. Radin*** (michael.radin@rit.edu), Rochester Institute of Technology, School of Mathematical Sciences, College of Science, Rochester, NY 14623, and **Inese Bula** (inese.bula@lu.lv), University of Latvia, Institute of Mathematics & Computer Science, Zellu 8, Rufa, Latvia. *Periodic orbits of a neuron model with periodic internal decay rate.* Preliminary report.

In this paper we will study a non-autonomous piecewise linear difference equation which describes a discrete version of a single neuron model with a periodic internal decay rate. We will investigate the periodic behavior of solutions relative to the periodic internal decay rate. Furthermore,we will show that only even ordered periodic cycles can exist and show their stability character. (Received July 30, 2015)

1113-39-54 **Sabrina H Streipert*** (shsbrf@mst.edu), 400 West, 12th Street, Rolla Building, Rolla, MO 65409, and **Martin Bohner**. *The Beverton–Holt equation with periodic coefficients.*

We study the Beverton–Holt difference equation with periodic carrying capacity and periodic inherent growth rate. For this equation, we present proofs of the first Cushing–Henson conjecture (there exists a unique periodic solution that is globally attractive) and the generalized second Cushing–Henson conjecture (the weighted average of the unique periodic solution is less than the weighted average of the carrying capacity). (Received August 05, 2015)

1113-39-81 **Turhan Koprubasi*** (tkoprubasi@kastamonu.edu.tr), 1325 Waterford Oak Drive #305, Orlando, FL 32828, and **Ram N Mohapatra** (ram.mohapatra@ucf.edu), 3927 Muzante Ct., Orlando, FL 32817. *SPECTRAL ANALYSIS OF A SYSTEM OF NON-SELFADJOINT DIFFERENCE EQUATIONS WITH QUADRATIC SPECTRAL PARAMETER IN BOUNDARY CONDITION.*

We consider the system of difference equations satisfying some boundary conditions. Problems of this kind arise in the solution of Dirac equation. For this problem we obtain Jost solution, Jost function, eigenvalues and spectral singularities. (Received August 12, 2015)

1113-39-141 **Nika Lazaryan*** (lazaryans@vcu.edu), Richmond, VA , and **Hassan Sedaghat**, Richmond, VA. *Extinction, periodicity and multistability in a planar Ricker model of stage-structured populations.*

We study the dynamics of a second-order difference equation that is derived from a planar Ricker model of two-stage biological populations. We obtain general results for boundedness and convergence to zero (extinction) in the case when the equation is nonautonomous. We then analyze a special case for the autonomous equation that exhibits multistable periodic and non-periodic behavior in the positive quadrant of the plane. (Received August 18, 2015)

1113-39-165 **Eddy A Kwessi*** (ekwess@trinity.edu), 1 Trinity Place, San Antonio, TX 78212, **Laila Assas**, , Saudi Arabia, **Saber Elaydi**, 1 Trinity Place, San Antonio, TX 78212, **Brian Dennis**, Moscow, and **George Livadiotis**, San Antonio, TX. *Stochastic Modified Beverton-Holt model with Allee effect II:the Cushing-Henson Conjecture.*

We consider a single-species stochastic modified Beverton- Holt model with Allee effects caused by predator saturation. We prove that, under some conditions on the parameters, there exists a Markov operator that is asymptotically stable. A stochastic version of the Cushing-Henson conjecture on attenuance and resonance is investigated. (Received August 20, 2015)

1113-39-224 **Candace M. Kent*** (cmkent@vcu.edu), 3510 Hanover Avenue, Richmond, VA 23221. *Piecewise-Defined Difference Equations with Every Solution Eventually Periodic: Open Problem.*

We consider piecewise-defined autonomous and nonautonomous difference equations of the form

$$x_{n+1} = f_n(x_n, x_{n-1}, \ldots, x_{n-k}),\ n = 0, 1, \ldots,$$

where $k \in 0, 1, \ldots$, f_n is piecewise defined and $f_n : D^{k+1} \to D$, $D \subset \mathbf{R}$, whose behavior of solutions is such that every solution is eventually periodic. We ask, "Why?" in most circumstances and "Why not?" in a few cases. This behavior of having every solution in D eventually periodic may occur in one of the following two settings:

(i) certain conditions on the parameters of the equation are present;

(ii) under all conditions on parameters of the equation.

We dedicate this talk to E.A. Grove and G. Ladas of the University of Rhode Island who asked the same question but specifically with regard to reciprocal max-type difference equations. (Received August 23, 2015)

1113-39-247 **Elvan Akin*** (akine@mst.edu), Missouri S&T, Department of Mathematics and Statistics, 400 W 12th Street, Rolla, MO 65409, and **Taher Hassan**, **Ozkan Ozturk** and **Ismail Ugur Tiryaki**. *On Nonoscillatory Solutions of Three-Dimensional Dynamic Systems.*

In this article, we obtain the existence of nonoscillatory solutions of three dimensional systems of first order dynamic equations and classify such solutions based on their signs. (Received August 24, 2015)

1113-39-248 **Ozkan Ozturk*** (oo976@mst.edu), Missouri University of Science and Technology, 202 Rolla Building, 400 West 12th Street, Rolla, MO 65409, and **Elvan Akin**, Missouri University of Science and Technology, 202 Rolla Building, 400 West 12th Street, Rolla, MO 65409. *Classification of Non-oscillatory Solutions of Dynamical Systems on Time scales.*

We classify the non-oscillatory solutions of the system of dynamic equations on time scales and show the existence and nonexistence of solutions by using Knaster and Schauder fixed point theorems and certain integrals. We also show examples in order to highlight our main results. (Received August 24, 2015)

1113-39-289 **Harold M Hastings***, hhastings@simons-rock.edu, and **Michael Radin** and **Tamas Wiandt**. *Induced Allee effect, generalized Ornstein-Uhlenbeck dynamics and scaling, and sustainability in a stochastic environment.*

We consider the problem of planning for sustainable harvesting of a fishery in a fluctuating environment, We find that harvesting policies can cause an induced Allee effect in logistic and similar fishery growth models. As a result, fluctuations then yield underlying generalized Onstein-Uhlenbeck dynamics, under which expected survival time (first-passage time to extinction) can depend sensitively upon key model parameters, especially harvest rates. (Received August 25, 2015)

1113-39-313 **Youssef Naim Raffoul*** (yraffoul1@udayton.edu), University of Dayton, Department of Mathematics, 300 College Park, Dayton, OH 5469-2316. *Existence Of Bounded Solutions For Almost Linear Volterra Difference Equations Using Fixed Point Theory and Lyapunov Functionals.* Preliminary report.

We obtain sufficient conditions for the boundedness of solutions of the almost linear Volterra difference equation using Krasnoselskii's fixed point theorem. Also, we will display a Lyapunov functional that yield boundedness of solution and compare both methods. (Received August 25, 2015)

41 ► Approximations and expansions

1113-41-8 **George Anastassiou** (ganastss@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152, and **Merve Kester*** (mkester@memphis.edu), University of Memphis, Department of Mathematical Sciences, Memphis, TN 38152. *Uniform Approximation with Rates by Multivariate Generalized Discrete Singular Operators.* Preliminary report.

Here we establish the uniform approximation properties of multivariate generalized discrete versions of Picard, Gauss-Weierstrass, and Poisson-Cauchy singular operators over R to N, N greater equal 1. We treat both the unitary and non-unitary cases of the operators above. We give quantitatively the pointwise and uniform convergences of these operators to the unit operator by involving the multivariate higher order modulus of smoothness. (Received February 12, 2015)

1113-41-9 **George Anastassiou*** (ganastss@gmail.com), Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152. *Approximations by Multivariate Perturbed Neural Network Operators.* Preliminary report.

This article deals with the determination of the rate of convergence to the unit of each of three newly introduced here multivariate perturbed normalized neural network operators of one hidden layer. These are given through the multivariate modulus of continuity of the involved multivariate function or its high order partial derivatives and that appears in the right-hand side of the associated multivariate Jackson type inequalities. The multivariate activation function is very general, especially it can derive from any multivariate sigmoid or multivariate bell-shaped function. The right hand sides of our convergence inequalities do not depend on the activation function. The sample functionals are of multivariate Stancu, Kantorovich and Quadrature types. We give applications for the first partial derivatives of the involved function. (Received February 13, 2015)

1113-41-11 **Angel San Antolin*** (angel.sanantolin@ua.es), Departamento de Analisis Matematico, Universidad de Alicante, 03080 Alicante, Alicante, Spain, and **P. Cifuentes** and **M. Soto-Bajo**. *Anisotropic Dilations of Shift-Invariant Subspaces and Approximation Properties in $L^2(\mathbb{R}^d)$.*

Let A be an expansive linear map in $\mathbb{R}^d$. Approximation properties of shift-invariant subspaces of $L^2(\mathbb{R}^d)$ when they are dilated by integer powers of A are studied. Shift-invariant subspaces providing approximation order α or density order α associated to A are characterized. These characterizations impose certain restrictions on the behavior of the spectral function at the origin expressed in terms of the concept of point of approximate continuity. The notions of approximation order and density order associated to an isotropic dilation turn out to coincide with the classical ones introduced by de Boor, DeVore and Ron. This is no longer true when A is anisotropic. In this case the A-dilated shift-invariant subspaces approximate the anisotropic Sobolev space associated to A and α. Our main results are also new when S is generated by translates of a single function. The obtained results are illustrated by some examples. (Received March 05, 2015)

1113-41-16 **boris shekhtman*** (shekhtma@usf.edu), department of mathematics and statistics, USF, Tampa, FL 33620. *On one class of Hermite projectors.*

We conjecture that every ideal projector on the space of polynomials of several variables is Hermite, i.e., a limit of Lagrange interpolation projectors. We prove the above result under one additional assumption that generators of the ideal kerP have no roots at infinity. (Received May 04, 2015)

1113-41-108 **Ram N Moahpatra*** (ram.mohapatra@ucf.edu), Mathematics Department, University of Central Florida, Mathematical Sciences Building, Room # 412, Orlando, FL 32816. *Approximation of Data by Sinc function and application to designing of correlation filter.*

Data can be approximated by polynomials, entire functions, splines, wavelets and regression functions. The main aim of this talk is to look at certain date that can be best recognised by using correlation filters. We shall discuss the approximation properties for Sinc function and show through numerical evidence how sinc function serves well in our case. The work is still at its developmental phase.We will discuss the problems that have not been resolved also. (Received August 17, 2015)

1113-41-124 **Srinivasa Siva Rama Krishna Rao Taduri*** (srin@fulbrightmail.org), Visiting Fulbright Scholar, Department of Mathematical Sciences, University of Memphis, memphis, TN 38152. *Coproximinality in spaces of Bochner integrable functions.*

In this talk we use a new way of applying von Neumann's selection theorem for obtaining best coapproximation. For a coproximinal closed subspace Y of a Banach space X, we show that if Y is constrained in a weakly compactly generated dual space, then the space of Y-valued Bochner integrable functions is coproximinal in the space of X-valued Bochner integrable functions. This extends a result of Haddadi et. al., proved when Y is reflexive. (Received August 17, 2015)

1113-41-317 **Leslaw Skrzypek*** (skrzypek@usf.edu), Tampa, FL 33559. *Projections in Banach Spaces.*

We will discuss the relations between minimal, orthogonal and radial projections in classical ℓ_p^n spaces. Further we will discuss recent advances in finding maximal minimal projections. (Received August 25, 2015)

42 ► Fourier analysis

1113-42-10 **Angel San Antolín** and **Richard A Zalik*** (zalikri@auburn.edu). *Some smooth compactly supported tight wavelet frames with vanishing moments.*

Let $A \in \mathbb{R}^{d\times d}$, $d \geq 1$ be a dilation matrix with integral entries and $|\det A| = 2$. We construct several families of compactly supported Parseval framelets associated to A having any desired number of vanishing moments. The first family has a single generator and its construction is based on refinable functions associated to Daubechies low pass filters and a theorem of Bownik. For the construction of the second family we adapt methods employed by Chui He and Petukhov for dyadic dilations to any dilation matrix A. The third family has the additional property that we can find members of that family having any desired degree of regularity. Its construction involves some compactly supported refinable functions, the Oblique Extension Principle and a slight generalization of a theorem of Lai and Stöckler. (Received February 19, 2015)

1113-42-114 **Marius Junge** and **Tao Mei*** (tao_mei@baylor.edu), Baylor University, Waco, TX 46701, and **Javier Parcet**. *Operator UMD property and Hörmander-Mikhlin Multipliers.*
It is generally believed that every Hörmander-Mikhlin fourier multiplier extends to a bounded map on X-valued L^p spaces for any UMD Banach space X and $1 < p < \infty$. We prove that this is true if one can put an operator space structure on X such that X becomes an operator UMD space. The key ingredient of our argument is that every Hörmander-Mikhlin fourier multiplier is a Littlewood-Paley average of Riesz transforms associated with 1-cocycles. Joint work with M. Junge and J. Parcet. (Received August 16, 2015)

1113-42-187 **Neil Lyall*** (lyall@uga.edu). *Embedding simplices in sets of positive upper density.*
We will discuss some results pertaining to the embedding of simplices in subsets of $\mathbb{R}^d$ of positive upper density. Time permitting we will also discuss the analogous problem for subsets of $\mathbb{Z}^d$. (Received August 21, 2015)

45 ► Integral equations

1113-45-22 **D. P. Dwiggins*** (ddwiggns@memphis.edu), Dept Mathematical Sciences, 373 Dunn Hall, Memphis, TN 38152. *Bivariate Convolution and a Bivariate Version of the Laplace Transform.*
A Volterra integral equation uses a bivariate function as the kernel of the integral operator, and associated with each kernel is a bivariate function called the resolvent. The resolvent equation, relating the kernel and resolvent, can be expressed using the operation of bivariate convolution, and this leads to a formal series solution for the resolvent. In the case where the kernel is of convolution type, the resulting convolution equation is solved using the method of Laplace transforms. We seek to handle the non-convolution case by generalizing the Laplace transform to one acting on bivariate functions. The question now is how bivariate convolution works under this transform, and whether this approach will lend new insight into the behavior of solutions to the integral equation. (Received June 01, 2015)

1113-45-35 **Petronela Radu**, **Daniel Toundykov** and **Jeremy Trageser*** (s-jtrages1@math.unl.edu). *A nonlocal biharmonic operator and its connection with the classical analogue.*
We consider a nonlocal operator as a natural generalization to the biharmonic operator that arises in thin plate theory. The operator is built in the nonlocal calculus framework and connects with the recent theory of peridynamics. This framework enables us to consider non-smooth approximations to fourth-order elliptic boundary value problems. For these systems we introduce nonlocal formulations of the clamped and hinged boundary conditions that are well-defined even for irregular domains. We will also explore results on existence and uniqueness of solutions to these nonlocal problems and demonstrate their L^2-strong convergence to functions in $W^{1,2}$ as the nonlocal interaction horizon goes to zero. For regular domains we identify these limits as the weak solutions of the corresponding classical elliptic boundary value problems. (Received July 28, 2015)

1113-45-150 **Leigh C. Becker*** (lbecker@cbu.edu), Department of Mathematics, 650 E. Parkway S., Memphis, TN 38104. *Solutions of Complementary Resolvent and Fractional Differential Equations.*
This is a study of the solutions of both the scalar resolvent equation

$$R(t) = \lambda t^{q-1} - \lambda \int_0^t (t-s)^{q-1} R(s)\, ds, \tag{R_λ}$$

where $\lambda > 0$ and $q \in (0,1)$, and of the initial value problem

$$D^q x(t) = -\lambda \Gamma(q) x(t), \quad \lim_{t \to 0^+} t^{1-q} x(t) = \lambda, \tag{F_λ}$$

where the fractional differential equation is of Riemann-Liouville type. First, *a priori* bounds on potential solutions of (R_λ) are established. Then, for given $\lambda > 0$ and $q \in (0,1)$, it is proved with Banach's contraction mapping principle that a unique continuous solution of (R_λ) exists on a short interval. Using the *a priori* bounds, Schaefer's fixed point theorem, and a "uniqueness of continuation" result, it is shown that this solution—the *resolvent*—exists and is unique on the entire interval $(0, \infty)$. Important properties of the resolvent are also obtained. It is also shown that the resolvent is also the unique continuous solution of (F_λ). Finally, a closed-form formula for the resolvent expressed in terms of the two-parameter Mittag-Leffler function is derived. (Received August 18, 2015)

1113-45-182 **M N Islam*** (mislam1@udayton.edu), M. N. Islam, Department of Mathematics, University of Dayton, Dayton, OH 45469-2316. *Asymptotically Periodic Solutions of Volterra Integral Equations.* Preliminary report.

Abstract. Existence of asymptotically periodic solutions of a nonlinear Volterra integral equation is studied in this paper. In the process, the existence of periodic solutions of an associated nonlinear integral equation with infinite delay is obtained. Schauder's fixed point theorem has been used in the analysis. (Received August 21, 2015)

46 ► Functional analysis

1113-46-13 **Chenxu Wen*** (chenxu.wen@vanderbilt.edu), Department of Mathematics, 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240. *Maximal amenability and disjointness for the radial masa.*

The study of the inclusion of amenable subalgebras inside II_1 factors leads to many important notions in the theory such as regularity, singularity, solidity, etc.

Popa showed the first concrete examples of maximal amenable subalgebras inside a II_1 factor. Subsequent work on maximal amenable subalgebras has mostly revolved around a property due to Popa, called the asymptotic orthogonal property (AOP). Only recently, a new approach via the study of centralizers was developed by Boutonnet and Carderi.

We show a stronger version of AOP which implies the "disjointness property" that any distinct maximal amenable subalgebra cannot have diffuse intersection with the radial masa. This confirms partially a conjecture of Jesse Peterson. (Received April 11, 2015)

1113-46-26 **Alexander Koldobsky*** (koldobskiya@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Slicing inequalities for subspaces of L_p.*

The slicing problem asks whether there exists an absolute constant c so that every origin-symmetric convex body of volume one in any dimension has a central hyperplane section with $(n-1)$-dimensional volume greater than c. We give an affirmative answer for the case of k-intersection bodies, or the unit balls of normed spaces that embed isometrically in L_{-k}. The result holds in the setting of arbitrary measures in place of volume. Other results of this kind include unconditional convex bodies, bodies whose duals have bonded volume ratio, slicing inequalities for sections of proportional dimensions. The original problem is still open, with best-to-date estimate $c \sim n^{-1/4}$ due to Klartag, who improved an earlier result of Bourgain. (Received June 25, 2015)

1113-46-32 **Paul Skoufranis*** (pskoufra@math.tamu.edu). *Problems involving Majorization in II_1 Factors.*

A notion of majorization for n-tuples of complex numbers plays an interesting role in a diverse collection of problems in linear algebra. When applied to the n-tuple eigenvalue lists of self-adjoint matrices, several fascinating operator theoretic results can be obtain. One example of this that has received much attention in recent years is the Schur-Horn Theorem, which classifies the possible diagonal n-tuples of a self-adjoint matrix based on its eigenvalues.

In this talk, we will discuss the notion of majorization of self-adjoint operators in II_1 factors and its applications. In particular, we will discuss the Schur-Horn Theorem in II_1 factors (due to Ravichandran), a classification of possible diagonals of operators in II_1 factors based on singular values (joint work with Matt Kennedy), and other applications of majorization in II_1 factors (joint work with Ken Dykema). (Received July 23, 2015)

1113-46-46 **S. J. Dilworth**, **Denka Kutzarova*** (denka@math.uiuc.edu), **Gilles Lancien** and **N. L. Randrianarivony**. *Equivalent norms with the property (β) of Rolewicz.*

We extend to the non separable setting many characterizations of the Banach spaces admitting an equivalent norm with the property (β) of Rolewicz. These characterizations involve in particular the Szlenk index and asymptotically uniformly smooth or convex norms. This allows to extend easily to the non separable case some recent results from the non linear geometry of Banach spaces. (Received August 03, 2015)

1113-46-62 **Erin Griesenauer** and **Paul S. Muhly*** (paul-muhly@uiowa.edu), Department of Mathematics, University of iowa, Iowa City, IA 52242, and **Baruch Solel**. *Groupoid Methods in Free Analysis.* Preliminary report.

In this talk, we will discuss recent work of ours concerning the representation of algebras of free analytic as algebras of cross sections of certain holomorphic matrix bundles. Our representation leads to many questions of

a groupoid-theoretic nature that are mostly unanswered. We will attempt to describe some of these. (Received August 07, 2015)

1113-46-67 **Michael Hartglass*** (michael.hartglass@ucr.edu), University of California, Riverside, 900 University Ave., Surge hall 233, Riverside, CA 92521. *A free graph algebra and atomless loops.*

I will investigate a canonical free product (C* or von Neumann) algebra associated to a weighted undirected graph, which was initially considered by Guionnet, Jones, and Shlyakhtenko. For the von Neumann algebra, the condition for factorality will be will be described explicitly, as will the conditions for simplicity and unique trace for the C*-algebra. Along the lines of recent work by Shlyakhtenko and Skoufranis, as well as Mai, Speicher, and Weber, I will show that certain self-adjoint polynomials in the generators of this algebra have no atoms in their spectral measure. Applications to random matrix theory and planar algebras will be discussed. (Received August 10, 2015)

1113-46-69 **Remi Boutonnet** (rboutonnet@ucsd.edu), Department of Mathematics, University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92093, **Ionut Chifan*** (ionut-chifan@uiowa.edu), Department of Mathematics, University of Iowa, 14 MacLean Hall, Iowa City, IA 52242, and **Adrian Ioana** (aioana@ucsd.edu), Department of Mathematics, University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92093. *II_1 facors with non-isomorphic ultrapowers.*

In this talk we will show that there exist uncountably many separable II_1 factors whose ultrapowers (with respect to arbitrary ultrafilters) are non-isomorphic. In fact, it will be proved that the families of non-isomorphic II_1 factors originally introduced by Dusa McDuff in the late sixties are such examples. This entails the existence of a continuum of non-elementarily equivalent II_1 factors, thus settling a well-known open problem in the continuous model theory of operator algebras. This is based on joint work with Remi Boutonnet and Adrian Ioana. (Received August 10, 2015)

1113-46-78 **Vaughan F.R. Jones*** (vaughan.f.jones@vanderbilt.edu), Mathematics department, Vanderbilt University, Nashville, TN 37240. *Do all subfactors come from conformal field theory?*

In the 1990's Haagerup discovered a new subfactor of finite index $\frac{5+\sqrt{13}}{2}$. Many other finite index, finite depth subfactors are now known and many of them can be obtained from algebras of local observables in conformal quantum field theory. Evans and Gannon suggest that this should also be the case for the Haagerup and we present a toy model which produces these subfactors from local algebras but falls short of the smoothness requirements of a quantum field theory. As a spinoff of the program we obtain families of unitary representations of Thompson's groups F and T and a new way to construct all knots and links from these groups. (Received August 17, 2015)

1113-46-84 **Melissa Shabazz** and **Maria Tjani*** (mtjani@uark.edu). *Isometries among composition operators on Besov type spaces.*

Given $p > 1$, $\alpha > -1$, let $B_{p,\alpha}$ denote the Besov type space of analytic functions on the unit disk $\mathbb{D}$. Allen, Heller and Pons have shown that the isometries among composition operators on certain Besov spaces, $B_{p,p-2}$, are induced by rotations. We extend this to all Besov spaces and in fact to all Besov type spaces $B_{p,\alpha}$. We show that in every Besov type space, except on $B_{2,0}$, rotations are the only symbols inducing isometries. We show that this is the case in every weighted Dirichlet space $\mathcal{D}_\alpha$, $\alpha \neq 0$ as well. (Received August 12, 2015)

1113-46-88 **Malgorzata Marta Czerwinska***, m.czerwinska@unf.edu, and **Anna Kaminska**, kaminska@memphis.edu. *Banach envelopes in symmetric spaces of measurable operators.*

Let $\mathcal{M}$ be a non-atomic, semifinite von Neumann algebra with a faithful, normal, σ-finite trace τ and E be a quasi-normed symmetric function space on $[0, \tau(1))$. The quasi-normed space $E(\mathcal{M}, \tau)$ 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 quasi-norm $\|x\|_{E(\mathcal{M},\tau)} = \|\mu(x)\|_E$.

We show that the Banach envelope $E(\mathcal{M}, \tau)^\frown$ of $E(\mathcal{M}, \tau)$ is equal to $\widehat{E}(\mathcal{M}, \tau)$, where $\widehat{E}$ is a Banach envelope of a quasi-normed symmetric function space E. The analogous result follows for the unitary matrix spaces. It is a joint work with Anna Kamińska from the University of Memphis. (Received August 13, 2015)

1113-46-89 **Sudeshna Basu*** (sudeshna66@gmail.com), Department of Mathematics, George Washington University, Washington DC, DC 20052. *On Small Combination of Slices in Banach Spaces.*

Small Combination of Slices (SCS) in the unit ball of a Banach space was first introduced by Ghoussoub,Godefory ,Maurey and Scachermeyer and subsequently analysed in detail by Scachermeyer and in Rosenthal. In this work, we introduce BSCSP a generalization of dentability in terms of SCS. We study certain stability results for w^*BSCSP leading to a discussion on SCSP in the context of ideals in Banach Spaces. We prove that w^*-BSCSP is stable under c_0-sums. We further prove that w^*-BSCSP can be lifted from an M -ideal to the whole Banach Space and vice versa. We prove similar results for strict ideals and U-subspaces of a Banach space. We also study the local version, namely, Small Combination of Slices Points(SCSP) in the context of ideals in Banach spaces. (Received August 13, 2015)

1113-46-94 **Noah Snyder*** (nsnyder@gmail.com). *The maximal atlas, Brauer-Picard groupoids, and subfactors.*

The maximal atlas describes all ways that you can build a larger factor over N out of a fixed collection of N-N bimodules. The Brauer-Picard groupoid is a certain categorical quotient of the maximal atlas with extra algebraic structure. I will explain both of these ideas, and go through several illustrating examples. I'll end by briefly discussing a new application of these techniques, in joint work with Grossman-Izumi, to give a new more symmetric construction of the Asaeda-Haagerup subfactor. (Received August 13, 2015)

1113-46-99 **Qingying Bu*** (qbu@olemiss.edu), **Donghai Ji** and **Ngai-Ching Wong**. *Weak Sequential Completeness of Spaces of Homogeneous Polynomials.*

Let $\mathcal{P}_w({}^nE;F)$ be the space of all continuous n-homogeneous polynomials from a Banach space E into another F, that are weakly continuous on bounded sets. We give sufficient conditions for the weak sequential completeness of $\mathcal{P}_w({}^nE;F)$. These sufficient conditions are also necessary if both E^* and F have the bounded compact approximation property. We also show that the weak sequential completeness and the reflexivity of $\mathcal{P}_w({}^nE;F)$ are equivalent whenever both E and F are reflexive. (Received August 13, 2015)

1113-46-104 **Mikhail I. Ostrovskii*** (ostrovsm@stjohns.edu), Department of Mathematics and Comp.Sci., St. John's University, 8000 Utopia PKWY, Queens, NY 11439, and **Beata Randrianantoanina**. *Metric spaces admitting low-distortion embeddings into all n-dimensional Banach spaces.*

For a fixed $K \gg 1$ and $n \in \mathbb{N}$, $n \gg 1$, we study metric spaces which admit embeddings with distortion $\leq K$ into each n-dimensional Banach space. Classical examples include spaces embeddable into $\log n$-dimensional Euclidean spaces, and equilateral spaces.

We prove that good embeddability properties are preserved under the operation of metric composition of metric spaces. In particular, we prove that n-point ultrametrics can be embedded with uniformly bounded distortions into arbitrary Banach spaces of dimension $\log n$.

The main result of the talk is a new example of a family of finite metric spaces which are not metric compositions of classical examples and which do embed with uniformly bounded distortion into any Banach space of dimension n. This partially answers a question of Gideon Schechtman. (Received August 13, 2015)

1113-46-106 **F Albiac**, **J L Ansorena**, **S J Dilworth*** (dilworth@math.sc.edu) and **Denka Kutzarova**. *Uniqueness of Greedy Bases in Banach Spaces.*

Greedy bases are the bases for which the Thresholding Greedy Algorithm produces the best n-term approximation up to a multiplicative constant. According to a theorem of Konyagin and Temlyakov, greedy bases are characterized as being unconditional and democratic. The latter is a symmetry condition on the basis which is weaker than being subsymmetric. The spaces c_0, ℓ_1, and ℓ_2 are the only Banach spaces with a unique seminormalized unconditional basis up to basis equivalence. We present new examples of Banach spaces with a unique greedy basis. These examples are certain Orlicz and Marcinkiewicz sequencespaces. (Received August 14, 2015)

1113-46-115 **Han Ju Lee*** (hjlee.math@gmail.com), Seoul, 100-715, South Korea. *The Bishop-Phelps-Bollobás property for numerical radius.*

There have been many researches about the Bishop-Phelps theorem for numerical radius. That is, it is a study about the denseness of numerical radius attaining operators in the space of bounded linear operators on a Banach space. Recently, the notion of the Bishop-Phelps-Bollobás property for numerical radius has been introduced and it was shown that L_1 and $C(K)$ spaces have this property. We show that some classical Banach spaces (e.g. L_p, $1 < p < \infty$) have this property. We also give some examples where the set of numerical radius attaining

operators is dense in the space of bounded linear operators, however it does not have the Bishop-Phelps-Bollobás property for numerical radius. (Received August 16, 2015)

1113-46-118 **Richard M Aron*** (aron@math.kent.edu), Richard M. Aron, Department of Mathematics, Kent State University, Kent, OH 44242, **Javier Falco Benavent** (franjfal@gmail.com), Javier Falco Benavent, Department of Mathematics, Kent State University, Kent, OH 44242, **Domingo Garcia**, Departamento de Analisis Matematico, Universidad de Valencia, Dr. Moliner, 50, 46100 Burjassot, Spain, and **Manuel Maestre**, Departamento de Analisis Matematico, Universidad de Valencia, Dr. Moliner, 50, 46100 Burjassot, Spain. *Analytic structure in Fibers.* Preliminary report.

Let B_X be the open unit ball of a complex Banach space X. Denote by $\mathcal{H}^\infty(B_X)$ the Banach algebra of bounded analytic functions $f : B_X \to \mathbb{C}$, endowed with the sup-norm. Our interest is in the *maximal ideal space* $\mathcal{M}(\mathcal{H}^\infty(B_X)) :\equiv$

$$\{\varphi : \mathcal{H}^\infty(B_X) \to \mathbb{C} \mid \varphi \text{ is a } (\text{non} - \text{trivial}, \text{ continuous}) \text{ homomorphism}\}.$$

After reviewing the classical situation (when $X = \mathbb{C}$ so that $\mathcal{H}^\infty(B_{\mathbb{C}})$ is just the standard $\mathcal{H}^\infty$), we will discuss properties of the natural fibering $\pi : \mathcal{M}(\mathcal{H}^\infty(B_X)) \to \overline{B_{X^{**}}}$. We will examine fibers $\pi^{-1}(z)$ for points $z \in \overline{B_{X^{**}}}$, and we will specialize to two cases: $X = c_0$ and $X = \mathbb{C}^2$, where some intriguing basic questions have arisen. This is a preliminary report on joint work with J. Falcó (Kent) and D. García and M. Maestre (Valencia). (Received August 16, 2015)

1113-46-126 **Jean N. Renault*** (jean.renault@univ-orleans.fr), Dept of Math, University of Orléans, 45067 Orléans, France. *Semigroups, higher rank graphs and groupoids.* Preliminary report.

I will present a survey of some recent work on semigroups, higher rank graphs and C*-algebras associated to them. Some constructions are limited to special classes of semigroups (for example Ore semigroups or quasi-lattice ordered semigroups). I will show that the introduction of suitable groupoids of germs provides a general framework for these constructions and that the main problem is the identification of these groupoids. (Received August 17, 2015)

1113-46-129 **Petr Hajek** and **Thomas Schlumprecht*** (schlump@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77845, and **Andras Zsak**. *On a generalization of Theorem of Zippin.* Preliminary report.

In 1977, Zippin observed that for any $\varepsilon > 0$ and for any Banach space X with separable dual there is a Banach space Z, an isometric embedding $i : X \to Z$, an ordinal $\alpha \leq \omega^{Sz(X,\varepsilon/2)+\omega}$, and a subspace Y of Z, which is isometrically isomorphic to $C[0, \alpha]$, so that for any $z \in i(X)$ there is a $y \in Y$ with $\|z - y\| < \varepsilon$.

We will give a new proof of this result which also extends to non separable cases. (Received August 17, 2015)

1113-46-146 **Corey M Jones*** (corey.m.jones@vanderbilt.edu). *Analytical Properties for Tensor Categories.*

Popa introduced analytical properties including amenability, the Haagerup property, and property (T) for finite index inclusions of II_1 factors $N \subseteq M$, generalizing the notions familiar from the theory of discrete groups. Recently, Popa and Vaes provided a characterization of these definitions in the more algebraic setting of rigid C^*-tensor categories. Soon after their work, several different points of view on this topic have emerged. In this talk we discuss how these properties have natural interpretations from the point of view of the annular representation theory introduced by Jones, and we discuss applications of this viewpoint, namely that quantum G_2 categories have property (T). (Received August 18, 2015)

1113-46-149 **J. W. Neuberger*** (jwn@unt.edu), UNT, Dept. Mathematics, 1155 Union Circle #311430, Denton, TX 76203-5017. *A Linear Condition Determining Local or Global Existence for a Nonlinear Semigroup of Transformations.*

Suppose X is a complete separable metric space and T is a strongly continuous semigroup of transformations on X. There are two notions of a generator for T, call the first one B, the conventional generator and the second one A, the Lie Generator. Roughly,

- $B = \{(x, y) \in X^2; |y = \lim_{t\to 0+} \frac{1}{t}(T(t)x - x)$;
- $A = \{(f, g) \in L(X)^2 | g(x) = \lim_{t\to 0+} \frac{1}{t}(f(T(t)x) - f(x)), x \in X$.

where L denotes the set of bounded continuous real functions on X. Theorem. The semigroup T exists globally in time if and only if A has a positive eigenvalue. (Received August 18, 2015)

1113-46-162 **Zhengwei Liu*** (zhengweiliu@fas.harvard.edu). *Skein theory for subfactors.*

We talk about the classification and construction of subfactors. We provide a universal skein theory to construct small index subfactors and a different type skein relation, called Yang-Baxter relation, to construct new subfactors with large index. (Received August 19, 2015)

1113-46-177 **Takeshi Miura*** (miura@math.sc.niigata-u.ac.jp), Department of Mathematics, Faculty of Science, Niigata University, Japan. *Surjective isometries on $C^1[0,1]$.*

Let $C^1[0,1]$ be the Banach space of all continuously differentiable complex valued functions on the unit interval $[0,1]$ with the norm $\|f\|_C = \sup\{|f(x)| + |f'(x)| : x \in [0,1]\}$. We give characterizations of surjective isometries, which need not be linear, on $C^1[0,1]$ with respect to the norm $\|\cdot\|_C$. (Received August 21, 2015)

1113-46-178 **Abdullah Bin Abu Baker*** (abdullahmath@gmail.com), Department of Applied Sciences, Indian Institute of Information Technology, Allahabad, 211012, India. *Generalized 3-circular projections for unitary congruence invariant norms.*

A projection P_0 on a complex Banach space is generalized 3-circular if its linear combination with two projections P_1, P_2 having coefficients λ_1, λ_2 respectively is a surjective isometry, where λ_1, λ_2 are distinct unit modulus complex numbers different from 1, and $P_0 \oplus P_1 \oplus P_2 = I$. Such projections are always contractive. In this paper we prove structure theorems for generalized 3-circular projections acting on the spaces of all $n \times n$ symmetric and skew-symmetric matrices over $\mathbb{C}$, when these spaces are equipped with unitary congruence invariant norms. (Received August 21, 2015)

1113-46-185 **Alexander Kumjian*** (alex@unr.edu), Dept of Mathematics & Statistics, University of Nevada, MS084, Reno, NV 89557. *Applications of the Stabilization Theorem to twisted higher rank graph C^*-algebras.* Preliminary report.

In joint work with Marius Ionescu, Aidan Sims and Dana Williams, we prove that a saturated Fell bundle over a groupoid is Morita equivalent to the action of the groupoid on a C^*-bundle. Under mild hypotheses, we apply the theorem to characterize the primitive ideal space of a twisted higher rank graph C^*-algebra. (Received August 21, 2015)

1113-46-197 **Valentin Deaconu*** (vdeaconu@unr.edu), Department of Math & Stat, University of Nevada, Reno, NV 89557. *Groupoid actions on graphs and C^*-correspondences.* Preliminary report.

Let the groupoid G act on a C^*-correspondence $\mathcal{H}$ over the C^*-algebra A. By the universal property G acts on the Cuntz-Pimsner algebra $\mathcal{O}_{\mathcal{H}}$ which becomes a $C_0(G^0)$-algebra. We study the crossed product $\mathcal{O}_{\mathcal{H}} \rtimes G$ and the fixed point algebra $\mathcal{O}_{\mathcal{H}}^G$. Using intertwiners, we define the Doplicher-Roberts algebra $\mathcal{O}_\rho$ of a representation ρ of a groupoid G on $\mathcal{H}$ and prove that under certain conditions $\mathcal{O}_{\mathcal{H}}^G$ is isomorphic to $\mathcal{O}_\rho$.

Suppose G has finite unit space and finite isotropy. If G acts on a discrete and locally finite graph E, we prove that the crossed product $C^*(E) \rtimes G$ is isomorphic to the C^*-algebra of a graph of C^*-correspondences and stably isomorphic to a locally finite graph algebra. We illustrate with some examples. (Received August 21, 2015)

1113-46-198 **Douglas Farenick**, **Mitja Mastnak** and **Alexey I Popov***, alexey.popov@uleth.ca. *Isometries of the Toeplitz matrix algebra.*

We study the structure of linear isometries defined on the algebra A of upper-triangular Toeplitz matrices. We use a range of ideas in algebra, operator theory and linear algebra to show that every linear isometry T from A to $M_n(C)$ is of the form T(A)=UAV where U and V are two unitary matrices. This implies, in particular, that every such an isometry is a complete isometry and that a unital linear isometry $A \to M_n(C)$ is necessarily an algebra homomorphism. (Received August 21, 2015)

1113-46-201 **Remus Nicoara*** (nicoara@math.utk.edu), 227 Ayres Hall, 1403 Circle Drive, Knoxville, TN 37996-1320. *Deformations of group-type commuting squares and Hadamard matrices.*

Let G be a finite group and denote by $\mathfrak{C}_G$ the commuting square associated to G. We introduce the defect $d(G)$ of the group G, as an upper bound for the number of linearly independent directions in which $\mathfrak{C}_G$ can be continuously deformed in the class of commuting squares. We show that this bound is actually attained, by constructing $d(G)$ analytic families of commuting squares containing $\mathfrak{C}_G$.

When $G = \mathbb{Z}_n$, $d(\mathbb{Z}_n)$ can be interpreted as the dimension of an enveloping tangent space of the real algebraic manifold of $n \times n$ complex Hadamard matrices, at the Fourier matrix F_n. We obtain $d(\mathbb{Z}_n)$ families of complex Hadamard matrices containing the Fourier matrix F_n, and of linearly independent directions of convergence. We

then use analytic tools to prove a non-equivalence result for some of these matrices. Part of this presentation is based on joint work with Joseph White. (Received August 21, 2015)

1113-46-210 **Marius Junge** and **Bogdan T Udrea*** (bogdanteodor-udrea@uiowa.edu), 14 MacLean Hall, Iowa City, IA 52242-1419. *Generalized q-gaussian von Neumann algebras with coefficients and their structural properties.*

For every sequence of symmetric independent copies (π_j, B, A, D), every subset $1 \in S = S^* \subset A$ and every separable Hilbert space H we define the associated generalized q-gaussian von Neumann algebra $\Gamma_q(B, S \otimes H)$ with coefficients in B. We then prove that under suitable technical assumptions the von Neumann algebra $M = \Gamma_q(B, S \otimes H)$ is strongly solid over B, i.e. for every von Neumann subalgebra $\mathcal{A} \subset M$ which is amenable over B, either a corner of $\mathcal{A}$ embedds into B inside M in the sense of Popa, or the von Neumann algebra generated by the normalizer of $\mathcal{A}$ in M is amenable relative to B inside M. Time permitting, we will also talk about other structural properties of these algebras, such as solidity, embedability into R^ω and absence of non-trivial central sequences. This is joint work with Marius Junge (University of Illinois at Urbana-Champaign). (Received August 22, 2015)

1113-46-211 **Damian Kubiak*** (dkubiak@tntech.edu), Mathematics Department, Tennessee Technological University, 110 University Drive Box 5054, Cookeville, TN 38505. *Diameter two properties in the Musielak-Orlicz spaces.*

We say that a Banach space has the slice diameter two property if every slice of the unit ball has diameter 2. A Banach space has the strong diameter two property if every convex combination of slices of the unit ball has diameter 2. We study these properties in the Musielak-Orlicz spaces. (Received August 22, 2015)

1113-46-227 **Hyung-Joon Tag*** (htag@memphis.edu), Department of mathematical sciences, 373 Dunn hall, University of Memphis, Memphis, TN 38152, and **Anna Kamińska** (kaminska@memphis.edu), Department of mathematical sciences, 373 Dunn hall, University of Memphis, Memphis, TN 38152. *Diameter of weak neighborhoods and the Radon-Nikodým property in Orlicz-Lorentz spaces.*

Given an Orlicz convex function φ and a positive weight w, we present criteria of diameter two property and of Radon-Nikodým property in the Orlicz-Lorentz function and sequence spaces, $\Lambda_{\varphi,w}$ and $\lambda_{\varphi,w}$, respectively. We show that in the spaces $\Lambda_{\varphi,w}$ or $\lambda_{\varphi,w}$ equipped with the Luxemburg norm, the diameter of any relatively weakly subset of the unit ball in these spaces is two if and only if φ does not satisfy the appropriate growth condition Δ_2, while they do have the Radon-Nikodým property if and only if φ satisfies the appropriate condition Δ_2. This paper is a joint work with Anna Kamińska. (Received August 23, 2015)

1113-46-229 **Elizabeth Gillaspy***, Department of Mathematics, University of Colorado - Boulder, Campus Box 395, Boulder, CO 80309-0395, and **Alexander Kumjian**. *Cohomology for categories, k-graphs, and groupoids.*

Kumjian, Pask, and Sims have recently studied several cohomology theories for higher-rank graphs. Higher-rank graphs, or k-graphs, are small categories which give rise to both C^*-algebras and groupoids in a natural way. In their paper "On twisted higher-rank graph C^*-algebras," Kumjian, Pask, and Sims establish the existence of a homomorphism from the categorical 2-cohomology $H^2(\Lambda, A)$ of a k-graph Λ to the continuous cocycle 2-cohomology $H^2_c(\mathcal{G}_\Lambda, A)$ of the associated groupoid. However, this homomorphism is not natural and does not easily generalize to a homomorphism $H^n(\Lambda, A) \to H^n_c(\mathcal{G}_\Lambda, A)$ for $n \neq 2$.

In this talk, we will discuss joint work with Alex Kumjian in which we use the theory of cohomology for small categories to construct a homomorphism $H^n(\Lambda, A) \to H^n_c(\mathcal{G}_\Lambda, A)$ for any $n \geq 0$. In order to define our homomorphism, we use a certain relative projective resolution of the trivial $\mathcal{G}_\Lambda$-sheaf $\underline{\mathbb{Z}}$, which we believe may be of independent interest. Time permitting, we will also discuss the connection between our homomorphism and that established by Kumjian, Pask, and Sims. (Received August 23, 2015)

1113-46-233 **Ken Dykema*** (kjd@tamu.edu), **Fedor Sukochev** and **Dmitriy Zanin**. *Haagerup–Schultz projections and upper triangular forms for some unbounded operators affiliated to finite von Neumann algebras.*

Building on remarkable results of Haagerup and Schultz in the bounded case, we exhibit invariant subspaces for certain operators affiliated to a finite von Neumann algebra, that decompose Brown's spectral distribution measure. In turn, we use these to construct upper triangular forms for such operators. These results have applications to singular "Dimmer" traces on modules of affiliated operators. (Received August 23, 2015)

1113-46-238 **Pete Casazza**, **Daniel Freeman*** (dfreema7@slu.edu) and **Richard Lynch**. *Weaving bases and frames for Banach spaces.*

Suppose $(x_i^0)_{i=1}^\infty$ and $(x_i^1)_{i=1}^\infty$ are two bases for a Banach space X. We say that the bases are woven if for every $\sigma \in \{0,1\}^{\mathbb{N}}$ we have that $(x_i^{\sigma(i)})_{i=1}^\infty$ is also a basis for X. We present multiple theorems on woven unconditional bases and frames, and we give some surprising examples of woven conditional bases. (Received August 24, 2015)

1113-46-245 **Arnaud Brothier***, Vanderbilt University, Department of Mathematics, 1326 Stevenson Center, Nashville, TN 37240. *Approximation properties for subfactors.*

I will discuss about various approximation properties such as amenability, weak amenability, and the Haagerup property. Those properties have been originally defined for groups and later on for C*-algebras and von Neumann algebras. I will explain how they can be define for subfactors and more generally for rigid C*-tensor categories. Then I will present examples of subfactors that have a prescribe approximation property. (Received August 24, 2015)

1113-46-246 **Ian L. Charlesworth*** (ilc@math.ucla.edu) and **Dimitri Shlyakhtenko**. *Regularity of polynomials in non-commuting random variables.*

Given an n-tuple of non-commuting random variables $y_1, \ldots, y_n$ and a polynomial P in n indeterminates, we examine how the spectral distribution of $y = P(y_1, \ldots, y_n)$ is effected by certain assumptions on the variables and the polynomial P. We show that assuming the existence of a dual system to $y_1, \ldots, y_n$, the spectral measure of y cannot be singular with respect to Lebesgue measure, and if P is assumed to be homogeneous, the spectral measure of y is Lebesgue absolutely continuous. (Received August 24, 2015)

1113-46-249 **Ben Wallis*** (z1019463@students.niu.edu), Dekalb, IL 60115, and **Gleb Sirotkin**. *Closed ideals in $\mathcal{L}(X)$ and $\mathcal{L}(X^*)$ when X contains certain copies of ℓ_p and c_0.*

Let X denote a Banach space, and let $\mathcal{L}(X)$ denote the space of continuous linear operators acting on X. An ideal of $\mathcal{L}(X)$ is a linear subspace $\mathcal{J}$ of $\mathcal{L}(X)$ which is closed under composition with arbitrary operators in $\mathcal{L}(X)$, i.e. such that if $A, B \in \mathcal{L}(X)$ and $T \in \mathcal{J}$ then $BTA \in \mathcal{J}$. It is called closed if it is closed in the norm topology of $\mathcal{L}(X)$. We show that there are uncountably many closed ideals in $\mathcal{L}(\ell_p \oplus \ell_q)$ for $1 \leq p < q \leq \infty$, and in $\mathcal{L}(\ell_p \oplus c_0)$ for $1 \leq p < 2$. This finishes answering a longstanding question of Pietsch (1978). Additional results are obtained for Rosenthal's X_p spaces and Woo's $X_{p,r}$ generalizations thereof. This is joint work with Gleb Sirotkin. (Received August 24, 2015)

1113-46-253 **Gerard Buskes*** (mmbuskes@olemiss.edu), Department of Mathematics, University of Mississippi, University, MS 38677. *Real and complex Banach lattices and vector lattices of polynomials.*

We present results for real and complex AM- and AL-spaces of polynomials on Banach lattices (joint work with Q. Bu) and for polynomials on complex vector lattices (joint work with C. Schwanke). (Received August 24, 2015)

1113-46-258 **Timur Oikhberg*** (oikhberg@illinois.edu), **Garth Dales**, **Niels Laustsen**, **Martino Lupini** and **Vladimir Troitsky**. *Multinorms: new developments (joint work with G. Dales, N. Laustsen, M. Lupini, and V. Troitsky).*

A p-multinormed space ($1 \leq p \leq \infty$) is a pair consisting of a Banach space X, and a left tensorial cross norm on $\ell_p \otimes X$ ("left tensorial" means that, for any $u \in B(\ell_p)$, we have $\|u \otimes I_X\| \leq \|u\|$). The study of p-multinorms originates in an attempt, in the 1990s, to describe subspaces of Banach lattices. More recently, Dales, Daws, Pham, and Ramsden used multinorms to show that $L_p(G)$ is injective as a left $L_1(G)$ module if an only if the locally compact group G is amenable. In this talk, we survey some recent results on p-multinormed spaces, such as local reflexivity, injective and projective objects, and representation as subspaces, quotients, or subquotients of Banach lattices. (Received August 24, 2015)

1113-46-260 **Marius V Ionescu*** (ionescu@usna.edu), United States Naval Academy, Department of Mathematics, 572C Holloway Road, Chauvenet Hall, Annapolis, MD 21402, and **Alex Kumjian**, **Dana P Williams** and **Aidan Sims**. *A Stabilization Theorem for Fell bundles over Groupoids.*

We prove that a saturated second countable Fell bundle over a second countable Hausdorff locally compact groupoid is equivalent to a groupoid dynamical system. Therefore the full (reduced) C^*-algebra of a Fell bundle is Morita equivalent to the full (reduced) C^*-algebra of a groupoid dynamical system. Our results generalize previous work of Alex Kumjian and Paul S. Muhly. As an application of our results, we describe the lattice

of ideals of the C^*-algebra of a continuous Fell bundle using the corresponding results that Renault proved for groupoid dynamical systems. We also characterize the simplicity of C^*-algebras of continuous Fell bundles in terms of the minimality of the action of the groupoid on the primitive ideal space of the C^*-algebra over its unit space. This talk is based on joint work with Alex Kumjian, Dana P. Williams, and Aidan Sims. (Received August 24, 2015)

1113-46-270 **Ionut Chifan**, **Rolando de Santiago** and **Thomas Sinclair*** (tsincla@purdue.edu). *W*-rigidity for products of hyperbolic groups.*

Two groups are said to be W*-equivalent if they give rise to isomorphic von Neumann algebras. We show that if $\Gamma = \Gamma_1 \times \cdots \times \Gamma_n$ is a direct product of $n \geq 2$ hyperbolic ICC groups which is W*-equivalent to Λ, then Λ decomposes as an n-fold direct product as well. This strengthens Ozawa and Popa's unique prime decomposition theorem by removing all assumptions on the target group Λ. This is part two of two talks on this result; the first part will be given by Rolando de Santiago. This is joint work with Ionut Chifan and Rolando de Santiago. (Received August 24, 2015)

1113-46-271 **Farhad Jafari*** (fjafari@uwyo.edu), 1000 E University Ave, P O Box 3036, Laramie, WY 82070-3036. *Sparse moment sequences and multi sequences.*

While many fundamental results in analysis have their foundation in the study of moment problems, the study of sparse moment sequences in one and several variables is relatively recent. In one variable, it is well known that a sequence is a (Hamburger) moment sequence if and only if it is positive definite. It is easy to show that sparse subsequences are generated by sub algebras of polynomials. In several variables, positive definite multi sequences are moment sequences if functions of the form $\theta_j(x) = (1 + x_j^2)^{-1}$ are added to the algebra. In this talk we show that sparse moment multi sequences are generated by adding functions of the form $(1+x_j^{2d_j})^{-1}$ to the algebra. A general theorem relating subsequences of multi sequences to the algebras of functions generating these sequences will be given.

This is joint work with Saroj Aryal and Hayoung Choi. (Received August 24, 2015)

1113-46-274 **S Kaliszewski*** (kaliszewski@asu.edu), **M B Landstad** and **J Quigg**. *Coaction Functors and Exact Large Ideals of Fourier-Stieltjes Algebras.* Preliminary report.

We use functors on a category of coactions to understand the crossed-product functors that have been recently introduced by Baum, Guentner and Willett in relation to the Baum-Connes conjecture. The most important coaction functors are the ones induced by "large" ideals of a Fourier-Stieltjes algebra $B(G)$. The intersection of two large ideals of $B(G)$ for which the associated coaction functors (and hence the associated crossed-product functors) are exact, is also exact. (Received August 24, 2015)

1113-46-276 **S. J. Dilworth**, **Denka Kutzarova** and **N. Lovasoa Randrianarivony***, nrandria@slu.edu, and **J. P. Revalksi** and **N. V. Zhivkov**. *Asymptotic Midpoint Uniform Convexity.*

We introduce a new geometric property of real Banach spaces, namely Asymptotic Midpoint Uniform Convexity, and compare it to other geometric properties of Banach spaces. (Received August 24, 2015)

1113-46-290 **Dana P Williams*** (dana.williams@dartmouth.edu), 6188 Kemeny Hall, Hanover, NH 03755. *Haar Systems on Equivalent Groupoids.*

For second countable locally compact Hausdorff groupoids, the property of possessing a Haar system is preserved by equivalence. (Received August 25, 2015)

1113-46-291 **Luke G Rogers*** (luke.rogers@uconn.edu). *Magnetic operators on resistance spaces.*

A quantum particle confined to a fractal substrate and subject to the influence of a magnetic field should be modeled by a magnetic operator based on a fractal Laplacian. In joint work with Michael Hinz, we consider sufficient conditions for the existence of a self-adjoint magnetic operator in the case that the substrate is a resistance space in the sense of Kigami, and identify some properties regarding local exactness and gauge invariance. Within this framework we then consider the special case of the Sierpinski Gasket, and identify some properties of the spectrum of the magnetic operator when the magnetic field is locally exact. The latter results are from a collaboration with Jessica Hyde, Jesse Muller, Daniel Kelleher and Luis Seda. (Received August 25, 2015)

1113-46-293 **Arlan Ramsay***, ramsay@euclid.colorado.edu. *Convolution on Groupoids Revisited, Again.*

Because groupoids are used in a variety of contexts, it is at least conceivable that there could be a variety of useful ways to handle convolution. The aim of this talk is to examine some of the less commonly used of the

known ways to handle convolution, and consider possible contexts in which they might have some advantage relative to other ways. (Received August 25, 2015)

1113-46-295 **Judith A. Packer*** (packer@euclid.colorado.edu), Department of Mathematics, Campus Box 395, University of Colorado, Boulder, CO 80309-0395. *Wavelets for higher-rank graph C*-algebras.* Preliminary report.

This talk will give an overview of a procedure for constructing a system of functions termed "wavelets" on a Hilbert space associated to a finite, higher rank graph C*-algebra, where We emphasize the case where the k-graph in question is strongly connected and aperiodic. This work generalizes some results of M. Marcolli and A. Paolucci for the finite directed graph case, and is joint with C. Farsi, E. Gillaspy, and S. Kang. (Received August 25, 2015)

1113-46-304 **Alan Wiggins*** (adwiggin@umich.edu), Department of Mathematics & Statistics, 2014 CASL Building, 4901 Evergreen Road, Dearborn, MI 48128. *Perturbation Problems for Subfactors.* Preliminary report.

Given two separable II_1 factors M and N that are close in the Hausdorff distance, we examine which properties of finite-index subfactors may be transferred from one to the other. This is joint work with Dave Penneys and Stuart White. (Received August 25, 2015)

1113-46-306 **Laura Anderson** and **Beata Randrianantoanina*** (randrib@miamioh.edu). *Maximal equilateral sets in finite dimensional Petty spaces.* Preliminary report.

A subset S of a normed space $(X, \|\cdot\|)$ is called equilateral if the distance between any two points of S is the same. We denote by $e(X)$ the largest size of an equilateral set in X. There has been a lot of work to estimate the value of $e(X)$ for various spaces, but many questions remain open. In particular, a conjucture that $e(\ell_p^n) = n+1$, for all $2 < p < \infty$, is open. In 1977 Petty proved that if $\dim X \geq 3$ then any equilateral set in X of size 3 can be extended to an equilateral set of size 4. Petty also showed that the space $\mathbb{R}^n$ with the norm

$$\|(x_1, \ldots, x_n)\|_{Petty} := |x_1| + \Big(\sum_{i=2}^{n} |x_i|^2\Big)^{\frac{1}{2}}$$

contains a maximal equilateral set S of size 4, that is the set S cannot be extended to a larger equilateral set. Note that the space $(\mathbb{R}^n, \|\cdot\|_{Petty})$ also contains an equilateral set of size $(n+1)$. In 2004 Swanepoel asked what is the value of $e(\mathbb{R}^n, \|\cdot\|_{Petty})$. In this talk I will describe possible sizes of maximal equilateral sets in $(\mathbb{R}^n, \|\cdot\|_{Petty})$. In particular, we show that $e(\mathbb{R}^n, \|\cdot\|_{Petty}) \geq n+2$, for $3 \leq n \leq 10$.

Joint work with Laura Anderson. (Received August 25, 2015)

1113-46-311 **Pavlos Motakis*** (pavlos@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843. *On the structure of separable $\mathcal{L}_\infty$-spaces.*

In 1980 J. Bourgain and F. Delbaen introduced a construction method, used to obtain $\mathcal{L}_\infty$-spaces not containing c_0. A large variety of $\mathcal{L}_\infty$-spaces has been constructed with this method, such an example is the Argyros-Haydon space, the first Banach space satisfying the scalar-plus-compact property. Based on the aforementioned construction, we give a general definition of a Bourgain-Delbaen space and prove that every separable $\mathcal{L}_\infty$-space is isomorphic to such a space. We use this general approach to obtain Bourgain-Delbaen spaces as quotients of simpler Bourgain-Delbaen spaces. This is analogous to the use of an unconditional norming set as the frame for an HI construction. We also mention some recent examples of $\mathcal{L}_\infty$-spaces, such as an asymptotic c_0 $\mathcal{L}_\infty$-space not containing c_0 and a space with the scalar-plus-compact property having no reflexive subspaces.
This lecture is based on joint work with S. A. Argyros and I. Gasparis. (Received August 25, 2015)

47 ► Operator theory

1113-47-19 **Andras Batkai*** (batkai@uni-wuppertal.de), Gaussstr. 20, 42119 Wuppertal, Germany. *Operator splitting for delay equations.*

We investigate operator splitting methods for a special class of nonlinear partial differential equations with delay. Using results from the theory of nonlinear contraction semigroups in Hilbert spaces, we explain the convergence of the splitting procedure. The order of convergence is also investigated in detail along with numerical comparisons. (Received May 29, 2015)

1113-47-31 **Yuri Latushkin*** (latushkiny@missouri.edu). *The Morse and Maslov indices.*
In this talk I will review recent results on relations between the Morse and Maslov indices for partial differential operators. The Morse index counts the number of unstable eigenvalues of the operator while the Malsov index is the signed number of intersections counting multiplicity of a path in the set of Lagrangian plane with a given plane. This talk is based on several joint projects with M. Beck, G. Cox, C. Jones, R. Marangell, A. Sukhtayev and S. Sukhtaiev (Received July 21, 2015)

1113-47-36 **Pamela Gorkin*** (pgorkin@bucknell.edu), Department of Mathematics, Lewisburg, PA 17837, and **Brett Wick** (wick@math.wustl.edu), Department of Mathematics, St. Louis, MO 63130. *Thin sequences, model spaces, and Douglas algebras.*
Let (z_n) be a sequence in the open unit disk and T_p an operator taking an H^p function f to the sequence $(f(z_n)(1-|z_n|)^{1/p})$. Shapiro and Shields found conditions for the sequence to be interpolating; e.g, the range $T_p(H^p)$ equals the sequence space ℓ^p and the condition is Carleson's condition:

$$\inf_k \prod_{n\neq k} \left| \frac{z_k - z_n}{1-\overline{z}_n z_k} \right| \geq \delta > 0.$$

We consider interpolating sequences for model spaces, $K_\Theta := H^2 \ominus \theta H^2$, associated with an inner function θ. If we have a sequence for which the restriction of T_2 maps K_θ onto ℓ^2, then T_2 will map H^2 onto ℓ^2. For which sequences can we be sure that if $T_2 : H^2 \to \ell^2$ is surjective, then the restriction $T_2 : K_\theta \to \ell^2$ is surjective?

We answer this for the class of *thin sequences* – interpolating sequences for which $\lim_{k\to\infty} \prod_{j;j\neq k} \left| \frac{z_j - z_k}{1-\overline{z_j} z_k} \right| = 1$. The answer depends on the sequence and the inner function. We also consider the same question for H^∞ and subalgebras of L^∞ that properly contain H^∞. (Received July 29, 2015)

1113-47-41 **Nadia J Gal*** (nadiagal@math.miami.edu), University of Miami, Department of Mathematics, Ungar Bldg. 515, Coral Gables, FM 33146. *The isometric equivalence problem: a survey.* Preliminary report.
In this talk, I will consider some of the results in the joint work with Professor James Jamison. Most of them cover the isometric equivalence problem of certain operators on different Banach spaces. Most recent ones include characterizing the generalized bi-circular projections on the space A1,p(X). (Received July 31, 2015)

1113-47-47 **Balint Farkas*** (farkas@uni-wuppertal.de), Bergische Universität Wuppertal, Faculty of Mathematics und Natural Sciences, Gaussstrasse 20, 42119 Wuppertal, Germany. *The periodic decomposition problem for one-parameter semigroups.*
Given commuting power-bounded linear operators $T_1, \dots, T_n$ on a Banach space the periodic decomposition problem, orginally due to I.Z. Ruzsa, asks whether and under which conditions the equality $\ker(T_1 - I) \cdots (T_n - I) = \ker(T_1 - I) + \cdots + \ker(T_n - I)$ holds true. In this talk we consider the case when $T_j = T(t_j)$, $t_j > 0$, $j = 1, \dots, n$ for some (strongly continuous) one-parameter semigroup $(T(t))_{t\geq 0}$. We also look at a generalization of the periodic decomposition problem when instead of the cyclic semigroups $\{T_j^n : n \in \mathbb{N}\}$ more general semigroups of bounded linear operators are considered. (Received August 03, 2015)

1113-47-77 **Osamu Hatori*** (hatori@math.sc.niigata-u.ac.jp), Department of Mathematics, Faculty of Science, Niigata University, 8050 Ikarashi 2-no-chou, Nishi-ku, Niigata City, 950-2181, Japan. *An application of a Mazur Ulam theorem on generalized gyrovector spaces.*
A generalized gyrovector space is an exotic normed vector space, which is a generalization of the gyrovector space defined by A.A.Ungar. We apply a Mazur Ulam theorem for the gyrometric preserving maps between GGV's to describe isometries between the convex cones of positive invertible elements of unital C^*-algebras. (Received August 12, 2015)

1113-47-80 **Isabelle Chalendar*** (chalendar@math.univ-lyon1.fr), Institut Camille Jordan, Batiment Jean Braconnier, 43 bld du 11/11/1918, 69622 Villeurbanne, France. *Truncated Toeplitz Operators.*
According to Beurling theorem, a coinvariant subspace of $H^2 = H^2(\mathbb{D})$ is a closed subspace of H^2 of the form $H^2 \cap (\Theta H^2)^\perp$, where Θ is an inner function, that is, a holomorphic and bounded function on the open unit disc D whose radial limits are of modulus one almost everywhere on the unit circle.

Compressions of Toeplitz operators to coinvariant subspaces of H^2 are called *truncated Toeplitz operators*. We study several questions related to these operators. The first, raised by Sarason, is whether boundedness of the operator implies the existence of a bounded symbol; the second is the Reproducing Kernel Thesis. We also study sufficient conditions for the compactness. (Received August 12, 2015)

1113-47-87 **Anna Skripka***, Department of Mathematics and Statistics, University of New Mexico, 400 Yale Blvd NE, MSC01 1115, Albuquerque, NM 87110. *Approximation of operator functions.*

We will discuss conditions for existence of good approximations of operator functions that are analogous to Taylor approximations of scalar functions. (Received August 12, 2015)

1113-47-102 **Eva A. Gallardo-Gutierrez*** (eva.gallardo@mat.ucm.es), Dpto. Analisis Matematico, Fac. Matematicas, Universidad Complutense de Madrid, Plaza de Ciencias 3, 28040 Madrid, Spain. *An extension of a Theorem of Domar on invariant subspaces.*

A remarkable theorem of Domar asserts that the lattice of the invariant subspaces of the right shift semigroup $\{S_\tau\}_{\tau\geq 0}$ in $L^2(\mathbb{R}_+, w(t)dt)$ consists of just the *"standard invariant subspaces"* whenever w is a positive continuous function in $\mathbb{R}_+$ such that

(1) $\log w$ is concave in $[c,\infty)$ for some $c \geq 0$,

(2) $\lim_{t\to\infty} \dfrac{-\log w(t)}{t} = \infty$, and $\lim_{t\to\infty} \dfrac{\log|\log w(t)| - \log t}{\sqrt{\log t}} = \infty$.

We prove an extension of Domar's Theorem to a wider class of weights w not necessary fulfilling condition (1); which answers a question posed by Domar in *Extensions of the Titchmarsh convolution theorem with application in the theory of invariant subspaces*, Proc. London Math. Soc. **46** (1983), 288–300.

(Joint work with Jonathan Partington and Daniel Rodríguez). (Received August 13, 2015)

1113-47-125 **M. G. Cabrera-Padilla**, **J. A. Chavez-Dominguez**, **Antonio Jimenez-Vargas** and **Moises Villegas-Vallecillos*** (moises.villegas@uca.es), Facultad de Ciencias, Campus Universitario de Puerto Real, 11510 Puerto Real, Cadiz, Spain. *Lipschitz tensor product.* Preliminary report.

Inspired by ideas of Schatten in his celebrated monograph [*A theory of cross-spaces*, 1950], we introduce the notion of a Lipschitz tensor product $X \boxtimes E$ of a pointed metric space X and a Banach space E as a certain linear subspace of the algebraic dual of $\mathrm{Lip}_0(X, E^*)$, where $\mathrm{Lip}_0(X, E^*)$ denotes the space of Lipschitz functions from X to E^*.

We show that the Lipschitz injective norm ε, the Lipschitz projective norm π and the Lipschitz p-nuclear norm d_p $(1 \leq p \leq \infty)$ are uniform dualizable Lipschitz cross-norms on $X \boxtimes E$ and study their properties.

On the other hand, for a Lipschitz cross-norm α on $X \boxtimes E$, we introduce the notion of α-Lipschitz operators from X into E^* and prove that the space $\mathrm{Lip}_\alpha(X, E^*)$ of such Lipschitz operators under the α-Lipschitz norm Lip_α is isometrically isomorphic to the dual space of $X \boxtimes_\alpha E$.

In addition, if p' denotes the conjugate index of p, we show that $\mathrm{Lip}_{d_p}(X, E^*)$ is justly the space of all Lipschitz p'-summing operators from X to E^* (introduced by Farmer and Johnson) and therefore such space can be identified with $(X \boxtimes_{d_p} E)^*$. (Received August 17, 2015)

1113-47-145 **Sivaram K Narayan*** (sivaram.narayan@cmich.edu), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859. *Commutators of Composition Operators.*

In this talk we will survey the results on when a commutator of composition operators (or weighted composition operators) acting on spaces of analytic functions is compact. (Received August 18, 2015)

1113-47-147 **Rudi Weikard*** (rudi@math.uab.edu). *Spectral Theory for Schrödinger Operators with Operator-Valued Potentials.*

We study initial value problems and spectral theory for Schrödinger Operators with Operator-Valued Potentials on the half-line and the full-line. Specifically, we treat Weyl–Titchmarsh theory, Green's function structure, eigenfunction expansions, diagonalization, and a version of the spectral theorem.

This is joint work with F. Gesztesy (Missouri) and M. Zinchenko (New Mexico). (Received August 18, 2015)

1113-47-151 **Aleksej Turnsek*** (aleksej.turnsek@fmf.uni-lj.si), University of Ljubljana, 1000 Ljubljana, Slovenia. *Circular two-sided multiplications.*

We will consider circular and strongly circular two-sided multiplications $\phi(X) = AXB$ acting on $\mathcal{B}(\mathcal{H})$ or on minimal norm ideals of $\mathcal{B}(\mathcal{H})$. We will prove that strong circularity of ϕ implies circularity of A or of B. If A and B are irreducible and ϕ is acting on some minimal norm ideal different from the Hilbert-Schmidt class, then ϕ is strongly circular if and only if A or B is strongly circular. These results partially answer a question posed by F. Botelho, J. Jamison, B. Zheng, *Circular operators on minimal norm ideals of* $\mathcal{B}(\mathcal{H})$, Linear Multilinear Algebra 61 (2013), no. 10, 1339–1347. (Received August 19, 2015)

1113-47-153 **Ajit Iqbal Singh*** (ajitis@gmail.com), 102, Din Apartments, Plot No. 7, Sector 4, Dwarka, New Delhi, 110075, India. *Perseverance with preservers of properties of operators with emphasis on Quantum entanglement.*

We begin with completely positive maps that preserve positivity of operators even when the space interacts with environment. We will present such maps on matrix algebras or block matrix algebras that preserve identity, trace, rank, separability, entanglement, positivity under partial transpose. Finally, we will display Quantum dynamical systems that may preserve to begin with but may stop to preserve such properties as we go along as well as those with opposite scenario. (Received August 19, 2015)

1113-47-171 **Carl C. Cowen*** (ccowen@math.iupui.edu). *More Universal Operators Commuting with a Compact Operator.*

A bounded operator U on the Hardy space H^2 is called a *universal operator in the sense of Rota* if for each bounded operator A on H^2, there is a closed invariant subspace M for U and a non-zero number λ so that the restriction of U to M is similar to λA, that is, $UX = \lambda XA$ for a unitary X taking H^2 onto M. In 2013, Eva Gallardo and the speaker proved the existence of an analytic Toeplitz operator whose adjoint is a universal operator that commutes with an injective compact operator with dense range.

In fact, there is a very large class of analytic Toeplitz operators whose adjoints are universal operators in the sense of Rota and commute with interesting compact operators. These ideas provide a possible path to the proof of the invariant subspace theorem:
If every closed, infinite dimensional, invariant subspace for the adjoint of an analytic Toeplitz operator on H^2 that is universal in the sense of Rota has a non-trivial intersection with some invariant subspace of T_z^*, then every bounded linear operator on a separable Hilbert space of dimension two or more has a non-trivial closed invariant subspace.

This talk is based on joint work of Eva Gallardo and the speaker. (Received August 20, 2015)

1113-47-174 **Dijana Ilisevic*** (ilisevic@math.hr), Department of Mathematics, University of Zagreb, Bijenicka 30, 10000 Zagreb, Croatia. *Generalized Bicircular and Generalized Tricircular Projections.*

Let X be a complex Banach space and let $P\colon X \to X$ be a linear projection, that is, a linear mapping with the property $P^2 = P$. A projection P is called a generalized bicircular projection if the mapping $P + \lambda(I - P)$ is an isometry for some modulus one complex number $\lambda \neq 1$. The notion of a generalized tricircular projection naturally arises when a combination of two mutually orthogonal projections P and $I - P$ is replaced with a combination of three projections P, Q, R satisfying $P \oplus Q \oplus R = I$. The aim of this talk is to describe the structure of these mappings on certain spaces of operators. (Received August 20, 2015)

1113-47-221 **Lajos Molnar*** (molnarl@math.u-szeged.hu), Aradi vertanuk tere 1., Szeged, 6720, Hungary. *Linear bijections on von Neumann factors commuting with λ-Aluthge transform.*

We present a characterization of *-isomorphisms of certain operator algebras in terms of their relation to generalized Aluthge transforms.

We prove that a bijective linear transformation between von Neumann factors which commutes with a λ-Aluthge transform is necessarily a nonzero scalar multiple of an algebra *-isomorphism in the case of algebras which are not of type I_2. As for type I_2 factors, i.e., in the particular case of the algebra of 2 by 2 complex matrices, we also present a complete description of those transformations which is a bit different. Namely, nonzero scalar multiples of algebra *-antiisomorphisms perturbed by the negative of the trace functional times the identity also show up.

This is a joint work with F. Botelho and G. Nagy.

The presenter is supported by the "Lendület" Program (LP2012-46/2012) of the Hungarian Academy of Sciences. (Received August 23, 2015)

1113-47-230 **claudio h morales*** (morales@math.uah.edu), Department of Mathematics, University of Alabama in Huntsville, Huntsville, AL 35899. *Monotone Operator Theory and the solution of a Hammerstein Equation.* Preliminary report.

Let H be a Hilbert space, and let A from H into H be a monotone operator. We will present several results for monotone operators, including the solution of a Hammerstein equation under some monotonicity assumptions on the operators. Also some related results will be discussed, where the so-called coercive condition will be assumed. (Received August 23, 2015)

1113-47-240 **Toshikazu Abe*** (abebin08@gmail.com), Dairokuminamigaokasou 15, 1-360-4 Daigakuminami, Nishi-ku, Niigata, Niigata 950-2111, Japan. *A Mazur-Ulam theorem for the generalized gyrovector spaces.*

In special relativity, the Einstein velocity addition is non-commutative and non-associative. It does not have a group structure and hence does not have a linear space structure. However, it has a gyrocommutative gyrogroup structure and is called the Einstein gyrogroup. The concept of gyrocommutative gyrogroups is a generalization of the concept of commutative groups. Some gyrocommutative gyrogroups giving rise to gyrovector spaces. The concept of gyrovector spaces is a generalization of the concept of inner product spaces.

The celebrated Mazur-Ulam theorem states that a surjective isometry between real normed spaces is a real linear isomorphism follwed by translations. This asserts that a bijection between real normed spaces which preserves the metric structure also preserves the algebraic structure automatically.

In this talk, we define the concept of generalized gyrovector spaces (in short, GGV's). It is a common generalization of the concept of gyrovector spaces and of real normed spaces. A typical example of GGV's is the positive definite cone of a unital C^*-algebra. We give a generalization of the Mazur-Ulam theorem for GGV's. (Received August 24, 2015)

1113-47-242 **Scott A. Atkinson*** (saa6uy@virginia.edu). *Convex Sets Associated to C*-Algebras.*

Given a separable C*-algebra $\mathfrak{A}$, we can associate to it an invariant given by the weak approximate unitary equivalence classes of $*$-homomorphisms from $\mathfrak{A}$ to a chosen separable McDuff II_1-factor M. One can show that this object takes the form of a closed, bounded, convex subset of a separable Banach space. This invariant is closely related (and sometimes affinely homeomorphic) to the trace space of $\mathfrak{A}$, but its data is different from that of the trace space in general. We will provide a characterization of extreme points of these convex sets in the cases where either $\mathfrak{A}$ is nuclear or $M = R$–the separable hyperfinite II_1-factor. If time permits, we will discuss some related open problems. (Received August 24, 2015)

1113-47-257 **Jessica E. Stovall*** (jstovall@una.edu). *A Linear Map Associated with a Non-linear Operator on a Banach Lattice.*

A Dedekind complete Banach lattice E with a quasi-interior point e is lattice isomorphic to a space of continuous, extended real-valued functions defined on a compact Hausdorff space X. Orthogonally additive, continuous, monotonic, and subhomogeneous nonlinear functionals on E are analyzed in this talk. Though these maps are not linear, a complete measure on X related to a nonlinear operator T is constructed and thus an associated linear map L is found.
(Received August 24, 2015)

1113-47-277 **Rolando de Santiago*** (rolando-desantiago@uiowa.edu), 14 MacLean Hall, Department of Mathematics, Iowa City, IA 52242, and **Ionut Chifan** and **Thomas Sinclair**. *W^* rigidity for products of hyperbolic ICC groups.*

Two groups are said to be W*-equivalent if they give rise to isomorphic von Neumann algebras. We show that if $\Gamma = \Gamma_1 \times \cdots \times \Gamma_n$ is a product of $n \geq 2$ hyperbolic ICC groups that is W*-equivalent to Λ, then Λ decomposes as an n-fold product as well. This strengthens Ozawa and Popa's unique prime decomposition theorem by removing all assumptions on the target group Λ. This is part one of two talks on this result; the second part will be given by Thomas Sinclair. This is joint work with Ionut Chifan and Thomas Sinclair. (Received August 24, 2015)

1113-47-288 **Gyorgy Pal Geher***, Aradi v. t. 1., Szeged, H6720, Hungary, and **Peter Semrl**. *Isometries of Grassmann spaces.*

Botelho, Jamison, and Molnár have recently described the general form of surjective isometries of Grassmann spaces on complex Hilbert spaces under certain dimensionality assumptions. In this paper we provide a new approach to this problem which enables us first, to give a shorter proof and second, to remove dimensionality constraints completely. In one of the low dimensional cases, which was not covered by Botelho, Jamison, and Molnár, an exceptional possibility occurs. As a byproduct, we are able to handle the real case as well. Furthermore, in finite dimensions we remove the surjectivity assumption. A variety of tools is used in order to achieve our goal. (Received August 25, 2015)

1113-47-301 **Daniel J Hoff*** (d1hoff@ucsd.edu). *Unique Prime Factorization for Von Neumann Algebras of Equivalence Relations.*

A tracial von Neumann algebra M is called prime if it cannot be decomposed as the tensor product of two nontrivial (not type I) subalgebras. Naturally, if M is not prime, one asks if M can be uniquely factored as a tensor product of prime subalgebras. The first result in this direction is due to Ozawa and Popa in 2003, who gave a large class of groups $\mathcal{C}$ such that for any $\Gamma_1, \ldots, \Gamma_n \in \mathcal{C}$, the associated von Neumann algebra

$L(\Gamma_1) \overline{\otimes} \cdots \overline{\otimes} L(\Gamma_n)$ is uniquely factored. This talk will focus on von Neumann algebras arising from a class of measured equivalence relations, and how the techniques of Ozawa and Popa can be adapted to this setting. (Received August 25, 2015)

1113-47-305 **Brittney R. Miller*** (mille753@purdue.edu). *Kernels of Adjoints of Composition Operators on the Hardy Space.* Preliminary report.

Let φ be an analytic function from $\mathbb{D}$ to itself. Then, the composition operator C_φ, with symbol φ, is defined by $C_\varphi f = f \circ \varphi$ for f in a Hilbert space of analytic functions on $\mathbb{D}$. In 2008, Hammond, Moorhouse, and Robbins gave an explicit formula for the adjoint C_φ^* in the Hardy space. If φ is not univalent, it is well known that the kernel of C_φ^* is infinite dimensional. In this talk, I will show how their formula leads to a classification of functions in $\ker C_\varphi^*$ for certain classes of symbols φ. (Received August 25, 2015)

49 ► Calculus of variations and optimal control; optimization

1113-49-25 **Robert Kozma*** (rkozma@memphis.edu), 373 Dunn Hall, The University of Memphis, Memphis, TN 38152, and **Yury Sokolov** and **Paul J. Werbos**. *Stability analysis of approximate dynamic programming (ADP) control using a universal approximator.*

We describe new stability results for an ADP problem using a control algorithm that iteratively improves an internal model of the external world autonomously, based on its continuous interaction with the environment. We extend previous results for Action-Dependent Heuristic Dynamic Programming (ADHDP) control based on general multi-layer neural networks with universal approximation properties based on learning across all layers. We prove that the introduced control approach is uniformly ultimately bounded (UUB) under specific conditions on the learning rates, without explicit constraints on the value of the temporal discount factor. We demonstrate the advantages of our results in controlling linear and nonlinear systems. In particular, we show improved learning and control performance as compared to the state-of-art.

This is a joint work with Luda D. Werbos, IntControl LLC, Arlington, VA, USA.
(Received June 04, 2015)

51 ► Geometry

1113-51-50 **Jean V Bellissard*** (jeanbel@math.gatech.edu), Georgia Tech, School of Mathematics, 686 Cherry Street, Atlanta, GA 30332-0160. *Non-commutative Geometry on Fractals.*

The main tool describing the geometry of compact metric spaces is the concept of "spectral triple" proposed by Connes in the late eighties. Given a compact metric space, the construction of a spectral triple, made by Ian Palmer, will be presented. It will be shown that metric invariants like the Hausdorff dimension or the corresponding Hausdorff measure, can be recovered from this algebraic point of view. If time allows, the question of constructing the analog of a Laplace-Beltrami operator will be addressed. In particular the construction of the Pearson Laplacian will be described. In addition, using the case of the Sierpinski gasket as a model, the problem of defining a local gradient exponent will be described. (Received August 04, 2015)

1113-51-136 **Jordan Watts*** (jordan.watts@colorado.edu), Department of Mathematics, Campus Box 395, Boulder, CO 80309. *The differential structure of an orbifold.*

There are many ways of viewing an (effective) orbifold besides the classical way: as a Lie groupoid, a stack, a diffeological space, a (Sikorski) differential space, a topological space... Not all of these are equivalent. In fact, in the categorical sense, all of the above categories are generally completely different. However, when restricting our attention to "quotients" of manifolds by proper Lie group actions, there is a chain of functors between the above categories, each of which forgets information along the way. If we ignore "maps between orbifolds" and focus only on a fixed orbifold, one may ask: how far along this chain of functors can one go before losing so much information that our orbifold cannot be recovered? (Going all the way to topological spaces, for example, would be too far.)

In this talk I will answer this question with "differential spaces". I will give a minimal set of invariants required to "remember" the orbifold, and show that these all live in the category of differential spaces. Going back to our chain of categories above, what I will be showing can be restated as follows: there is a functor

from orbifolds (as effective proper étale Lie groupoids, say) to differential spaces that is essentially injective. (Received August 17, 2015)

52 ► Convex and discrete geometry

1113-52-21 **Jeremiah D Bartz*** (jbartz@fmarion.edu), Francis Marion University, Department of Mathematics, PO Box 100547, Florence, SC 29502. *Complete 3-nets.*

Nets are certain configurations of lines and points in the complex projective plane. They appear in the study of resonance varieties of complex hyperplane arrangement complements. In this talk, we give a classification of complete 3-nets, a family of nets which satisfy an additional property, and their connections with $K(\pi, 1)$ arrangements. (Received May 31, 2015)

53 ► Differential geometry

1113-53-93 **Laura Scull*** (scull_l@fortlewis.edu), 1000 Rim Drive, Durango, CO 81301. *A new definition of orbifold atlas.*

Orbifolds are spaces which are locally modeled by quotients of finite groups acting smoothly on open subsets of $\mathbb{R}^n$. Conceived as generalizations of manifolds, they were originally described in the same way that manifolds are, using the language of charts and atlases. However, modern mathematicians generally model them using topological groupoids with nice geometric properties. In the effective case, these points of view are equivalent and lead to the same category. However, in the non-effective case, this correspondence no longer holds, and the non-effective groupoids do not match with the current definition of non-effective orbifold atlas. I will discuss a project to create a new definition of orbifold atlas that does correspond to the groupoid definition in the non-effective case, and generalizes the effective case. This is joint work with D. Pronk and M. Tommasini. (Received August 13, 2015)

1113-53-140 **Rui Loja Fernandes*** (ruiloja@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green Street, Urbana, IL 61801. *Riemannian submersions between Riemmanian Lie groupoids.*

I will survey recent joint work with Matias del Hoyo (IMPA) on Riemannian submersions between Riemmanian Lie groupoids. One highlight is a linearization result for split fibrations that can be used to obtain an Ehresmann Theorem for Lie groupoids. From it we deduce rigidity of deformations of compact Lie groupoids. (Received August 18, 2015)

1113-53-190 **carla parvati farsi*** (carla.farsi@colorado.edu), department of mathematics, 395 UCB, boulder, CO 80309-0395, **christopher w seaton** (seatonc@rhodes.edu), Math and Computer Sc., Rhodes College, Memphis, TN 38112, and **emily proctor** (eproctor@middlebury.edu), Mathematics, Middlebury College, Middlebury, VT 05753. *Orbifold versus Manifold Spectral Theory.* Preliminary report.

Orbifolds with boundary are an interesting class of Deligne–Mumford stacks represented by smooth groupoids that can be studied using tools from differential geometry and spectral theory. After outlining their Hodge theory, we focus on certain relations between manifold and orbifold spectra that involve limiting procedures from a local viewpoint. (Received August 21, 2015)

58 ► Global analysis, analysis on manifolds

1113-58-51 **Xiang Tang*** (xtang@math.wustl.edu), 1 Brookings Drive, Department of Mathematics, Washington University, St. Louis, MO 63130, and **Hsian-hua Tseng**, 100 Math Tower, 231 West 18th Avenue, Department of Mathematics, Ohio State University, Columbus, OH 43210. *Duality of Gerbes on Orbifolds.* Preliminary report.

In this talk, we will present some recent progress about the study of duality of gerbes on orbifolds. In particular, we will explain in the case of banded gerbes how the quantum cohomology groups transform under the duality. (Received August 04, 2015)

1113-58-119 **Carla Farsi** and **Markus J Pflaum*** (markus.pflaum@colorado.edu), Department of Mathematics UCB 395, University of Colorado, Boulder, CO 80309, and **Hessel B. Posthuma**, **Christopher Seaton** and **Xiang Tang**. *The inertia space of a proper Lie groupoid and cyclic homology of its convolution algebra.*

Given a proper Lie groupoid G we study the singularity theory of its inertia space, which can be defined as the orbit space of the groupoid action on the loop space. The inertia space carries the structure of a differentiable stratified space which will be explained in the talk. We also show how the space of forms on this singular space relates to the cyclic homology theory of the convolution algebra. (Received August 16, 2015)

1113-58-131 **Thierry Coulhon*** (thierry.coulhon@univ-psl.fr), 62bis, rue Gay-Lussac, 75005 PARIS, France, and **Luke G. Rogers** (rogers@math.uconn.edu), Storrs, CT 06269-3009. *Sobolev spaces on fractals may not be algebras.* Preliminary report.

In 1967, Strichartz proved that the Sobolev space

$$L^p_\alpha(\mathbb{R}^n) = \left\{ f \in L^p;\ \Delta^{\alpha/2} f \in L^p \right\},$$

where Δ is the non-negative Laplacian, is an algebra for the pointwise product for all $1 < p < +\infty$ and $\alpha > 0$ such that $\alpha p > n$. A more general statement is that $\dot{L}^p_\alpha(\mathbb{R}^n) \cap L^\infty(\mathbb{R}^n)$, where $\dot{L}^p_\alpha(\mathbb{R}^n)$ is a homogeneous Sobolev space, is an algebra for the pointwise product for all $1 < p < +\infty$ and $\alpha > 0$. An interesting question is to which extent one can replace in such statements the Euclidean space $\mathbb{R}^n$ by more general spaces. More recently, in works by Coulhon/Russ/Tardivel-Nachef, Badr/Bernicot/Russ, and Bernicot/Coulhon/Frey, it has been shown that Riemannian manifolds still satisfy the Sobolev algebra property, for $\alpha \in (0, 1)$, provided certain heat kernel estimates are satisfied. In this talk, we will go in the opposite direction and show that on certain fractals endowed with their natural Laplace operator, the Sobolev algebra property is not satisfied for a wide range of α and p. (Received August 17, 2015)

60 ► Probability theory and stochastic processes

1113-60-24 **Robert Kozma**, **Miklós Ruszinkó** and **Yury Sokolov*** (ysokolov@memphis.edu), 373 Dunn Hall, The University of Memphis, Memphis, TN 38152. *Activation process on a long-range percolation graph with power law long edge distribution.*

A random graph model $G_{\mathbb{Z}^2_N,p}$ is considered, which is a combination of fixed torus grid edges in $(\mathbb{Z}/N\mathbb{Z})^2$ and random ones. The additional random edges are called long, and the probability of a long edge between vertices $u, v \in (\mathbb{Z}/N\mathbb{Z})^2$ having graph distance d on the torus grid is $p_d = c/Nd$, where c is a constant. We show that, *whp*, the diameter $D(G_{\mathbb{Z}^2_N,p}) = \Theta(\log n)$, and the degree distribution of a vertex $v \in G_{\mathbb{Z}^2_N,p}$ can be approximated by Poisson distribution. We derive critical probabilities for the activation process on $G_{\mathbb{Z}^2_N,p}$.

This is a joint work with Svante Janson, Uppsala University, Sweden. (Received June 04, 2015)

1113-60-179 **Justin Coon**, **Carl P Dettmann*** (carl.dettmann@bris.ac.uk) and **Orestis Georgiou**. *Random geometric graphs in domains with fractal boundaries.* Preliminary report.

Introduced by Gilbert in 1961, random geometric graphs remain a useful model for wireless networks. They are constructed from a Poisson point process by linking points with mutual distance below a fixed bound. Here we also impose a line-of-sight condition if the domain is not convex. At high density, the probability that the graph is connected is controlled by isolated points, which are more likely near boundaries of the domain. This probability can be approximated using a sum over boundary components if the boundaries are smooth, and the connection probability approaches unity. In contrast, fractal boundaries, relevant to networks in complex environments, lead to stretched exponential decay of the probability with density. For exactly self-similar boundaries, the exponent is related to the similarity dimension. The question of what dimension is relevant more generally will also be discussed. (Received August 21, 2015)

62 ► Statistics

1113-62-193 **J. Marcus Jobe** (jobejm@miamioh.edu), Information Systems and Analytics Dept., Farmer School of Business, Miami University, Oxford, OH 45056, and **Michael Pokojovy*** (michael.pokojovy@uni-konstanz.de), Dept. of Mathematics and Statistics, 78457 Konstanz, Germany. *A Cluster-Based Outlier Detection Scheme for Multivariate Data.*

Detection power of the squared Mahalanobis distance statistic is significantly reduced when several outliers exist within a multivariate data set of interest. To overcome this masking effect, we propose a computer-intensive

cluster-based approach that incorporates a reweighted version of Rousseeuw's minimum covariance determinant method with a multi-step cluster-based algorithm that initially filters out potential masking points. Compared to the most robust procedures, simulation studies show that our new method is better for outlier detection. Additional real data comparisons are given. (Received August 21, 2015)

1113-62-244 **Iwona Pawlikowska*** (iwona.pawlikowska@stjude.org), Department of Biostatistics, St Jude Children's Research Hospital, 262 Danny Thomas Place, Memphis, TN 38105, and **Stan Pounds** (stanley.pounds@stjude.org), Department of Biostatistics, St Jude Children's Research Hospital, 262 Danny Thomas Place, Memphis, TN 38105. *A method for robust and rigorous control of the false discovery rate.* Preliminary report.

The analysis of mega-dimensional data often involves performing a very large number of hypothesis tests. Multiple-testing analyses can produce many false discoveries (Type I errors) if no adjustments are performed. Benjamini and Hochberg (1995; BH95) and Storey (2002; St02) introduced methods to adjust p-values for multiple-testing. They also developed formal mathematical proofs that rigorously establish the false discovery rate (FDR) control properties of those methods under certain conditions. However, BH95 and St02 have exhibited empirical instability in some simulation studies and applications. Thus, other methods have been proposed that fit curves to the observed distribution of p-values in order to stabilize results. However, the FDR control properties have not been rigorously established by formal mathematical proof for any of these curve-fitting methods. Here, we propose cmFDR as a method that uses curve-fitting to empirically stabilize results and formally prove that it has similar FDR control properties similar to BH95 and St02. In simulation studies, cmFDR exhibits similar FDR control and less variability than BH95 and St02. These results suggest that cmFDR may be the preferred FDR method for some applications. (Received August 24, 2015)

65 ► Numerical analysis

1113-65-15 **Razvan Alexandru Mezei*** (razvan.mezei@lr.edu). *Sage Interacts for Calculus and Numerical Analysis.*

Sage Math is a free open source software that has a very easy-to-learn Python-like syntax. It can be installed on a machine or it can be accessed using a web browser.

Sage Math is quickly becoming a popular choice for many areas of Mathematics such as Linear Algebra, Calculus, Number Theory, Cryptography, Numerical Computation, Group theory, Combinatorics, and Graph Theory.

I this talk I will demonstrate how Sage Interacts can easily be created and used in Calculus and Numerical Analysis courses. (Received April 22, 2015)

1113-65-29 **Dr. Fola Adeyeye*** (adeyeye.fola@fupre.edu.ng), Dept. of Maths/computer science, college of science, PMB 1221, Fed. Uni. of Petroluem Resources, Effurrun, +234, Nigeria, and **Prof Emmanuel Ibijola** (emmaibj@yahoo.com), Dept. of Mathematics, Ekiti state uni, Ado- Ekiti, +234, Nigeria. *THE SOLUTION OF SOME LOGISTIC PROBLEM IN ORDINARY DIFFERENTIAL EQUATION BY A NEW HYBRID ADM.*

In this paper we present a relatively new technique call the New Hybrid of Adomian decomposition method (ADM) for solution of an Abelian Logistic Differential equation. The numerical results of the equation have been obtained in terms of convergent series with easily computable component. These methods are applied to solve some problem represented as Abelian differential equation and the current results compared with an established Runge-kutta of order IV in order to verify the accuracy and also with Actual solution . This findings confirm that some know methods and the New Hybrid are powerful and efficient tools for solving some logistic differential equation in Abelian form. (Received July 13, 2015)

1113-65-128 **Jin Wang***, University of Tennessee at Chattanooga, Chattanooga, TN 37403. *Computing fluid-structure interaction.*

The interactions between fluid flows and immersed solid structures are nonlinear multi-physics phenomena that have applications to a wide range of scientific and engineering disciplines. Mathematically, such problems are described by systems of evolutionary PDEs linking the dynamics of the fluid and structure. In this talk, I will review representative numerical techniques currently available for computing fluid-structure interaction problems, with a focus on methods of the immersed boundary type. I will discuss opportunities and challenges faced by researchers in this field, and emphasize the importance of interdisciplinary effort for advancing the study in fluid-structure interaction. (Received August 17, 2015)

1113-65-204 **Amanda Diegel**, **Cheng Wang** and **Steven Wise***, Mathematics Department, University of Tennessee, Knoxville, TN 37996. *Unconditional Energy Stability and Optimal-Rate Analysis of a Second Order Mixed Finite Element Method for the Cahn-Hilliard Equation.*

In this talk I will describe and analyze an unconditionally stable, second-order-in-time numerical scheme for the Cahn-Hilliard equation in two and three space dimensions. I will prove that our two-step scheme is unconditionally energy stable and unconditionally uniquely solvable. Furthermore, I show that the discrete phase variable is bounded in $L^\infty(0,T;L^\infty)$ and the discrete chemical potential is bounded in $L^\infty\left(0,T;L^2\right)$, for any time and space step sizes, in two and three dimensions, and for any finite final time T. Using these stabilities, I will show that the approximations converge with optimal rates in the appropriate energy norms in both two and three dimensions. This is joint work with Amanda Diegel, LSU, and Cheng Wang, UMass, Dartmouth. (Received August 21, 2015)

1113-65-215 **Janos Turi*** (turi@utdallas.edu), 800 W Campbell Rd, Richardson, TX 75080. *Convergent Numerical Schemes for Singular Integro-Differential Equations.*

We consider semi- and fully-discrete numerical schemes for a class of singular integro-differential equations of neutral type and show their convergence using the Trotter-Kato semigroup approximation theorem. (Received August 22, 2015)

1113-65-231 **Max Melnikov*** (mmelnikov@cumberland.edu), One Cumberland Square, Lebanon, TN 37087. *Potential numerical implementations of Green's functions analytically constructed for the Black-Scholes equation.* Preliminary report.

In our earlier works summarized in [1], it has been shown that computer-friendly representations can analytically be obtained for Green's functions to a number of terminal-boundary-value problems stated for the Black-Scholes equation. For some problems, these representations might be expressed in a closed elementary functions-containing form making them perfectly suitable for immediate computing. For some other problem settings, their Green's function representations might have uniformly convergent trigonometric series-containing components, in which cases their computer use does not nevertheless become much more tedious. In the present study, we discuss a prospective for the development of efficient numerical schemes for solution of practical problem settings in financial mathematics that implement Green's functions a priori constructed by means of our recommendation.

[1] Yuri A. Melnikov and Max Y. Melnikov, Green's Functions. Construction and Applications, De Gruyter, Berlin-Boston, 2012. (Received August 23, 2015)

70 ► Mechanics of particles and systems

1113-70-264 **Nandor J Simanyi*** (simanyi@uab.edu), UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170, and **Caleb C Moxley** (ccmoxley@uab.edu), UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170. *Homotopical Complexity of Certain 3D Cylindric Billiards.* Preliminary report.

This is a preliminary report on some new results concerning the homotopical complexity of the orbits of certain $3D$ cylindric billiard flows. There are two models under investigation: The billiard flow in the flat 3-torus T^3 minus two orthogonal, intersecting cylindric scatteres on the one hand, and the billiard flow in the flat 3-torus T^3 minus two orthogonal, disjoint cylindric scatteres on the other hand. The homotopical complexity of long orbit segments is measured in the Cayley graphs of the fundamental groups of these billiard tables, which groups by themselves are pretty intriguing hyperbolic groups. We give lower and upper bounds for the radial sizes of the arising homotopical rotation sets. The primary tool for the construction of long orbit segments following a prescribed homotopical itinerary is the length minimizing variational method. We make this method work by introducing the proper notion of the so called admissible orbit segments for both models.

This is an ongoing joint research project with my PhD student, Caleb C. Moxley. (Received August 24, 2015)

74 ► Mechanics of deformable solids

1113-74-38 **Lauren Ferguson** and **S. M. Mallikarjunaiah***, Department of Mathematics, Mail Stop 3368, Texas A&M University, College Station, TX 77843, and **Jay R. Walton**. *On a Nonlocal Finite Element Formulation of Mode-III Brittle Fracture With Surface Tension Excess Property.*

In this work, we study a nonlocal finite element formulation of mode-III brittle fracture in a homogeneous, linear elastic body. The modified continuum-mechanics model incorporates a curvature dependent surface tension on the crack surface that gives rise to a linearized jump momentum balance (JMB) crack-face boundary condition containing higher order tangential derivatives. For a numerically stable finite element implementation, we propose a reformulation of the JMB using a boundary Green's function and Hilbert's transform resulting in a Fredholm second kind integral equation for the crack-edge Neumann data. The obtained numerical results indicate bounded crack-tip stresses and a cusp-shaped crack-surface opening profile with a sharp crack-tip. (Received July 29, 2015)

76 ► Fluid mechanics

1113-76-208 **Gung-Min Gie***, Department of Mathematics, University of Louisville, Louisville, KY 40292. *Recent progresses in boundary layer analysis.* Preliminary report.

In this talk, we review some recent progresses in boundary layer analysis of singular perturbation problems related to the fluids equations. (Received August 22, 2015)

1113-76-216 **Jerry Bona*** (bona@math.uic.edu), University of Illinois at Chicago, Dept Math., Statistics and Computer Sci., 851 S. Morgan Street MC 249, Chicago, IL 60607, **Hongqiu Chen**, University of Memphis, Department of Mathematical Sciences, 373 Dunn Hall, Memphis, TN 38152, and **Ohannes Karakashian** (ohannes@math.utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 38152. *Solitary-wave Solutions of Systems of Nonlinear Wave Equations.* Preliminary report.

Discussed here are systems of nonlinear, dispersive wave equations. Recent theory has shown that in general, they have more than one class of solitary-wave solutions. The theory also indicates that not all of them are stable.

Using a numerical scheme based upon discontinuous Galerkin ideas, we investigate what happens to unstable waves under small perturbations. This leads to a conjecture about necessary and sufficient conditions for stability and for global well-posedness of the associated initial-value problem. (Received August 22, 2015)

81 ► Quantum theory

1113-81-63 **Marcel Bischoff*** (marcel.bischoff@vanderbilt.edu), Vanderbilt University, Department of Mathematics, 1326 Stevenson Center, Nashville, TN 37240. *Quantum Doubles and Conformal Field Theory.* Preliminary report.

Chiral conformal field theory can be axiomatized using von Neumann algebras, so-called conformal nets. In this setting subfactors arise naturally. On the other hand, finite index finite depth subfactors prescribe quantum symmetries in the sense that they generalize the fixed points by a finite group and it is an open question if all subfactors arise from conformal nets in some way.

We give a definition of what we mean by that a subfactor arises from a conformal net which is motivated by the study of boundaries and topological defects. We then show that a subfactor arises from a conformal net if and only if its quantum double is the representation theory of a conformal net. We give a characterization of conformal nets whose representation category is a quantum double and provide examples. (Received August 07, 2015)

82 ► Statistical mechanics, structure of matter

1113-82-196 **Lei Zhang*** (lzhang98@math.gatech.edu), 686 Cherry St., Atlanta, GA 30332, and **Rafael de la Llave** and **Xifeng Su**. *Equilibrium quasi-periodic configurations in quasi-periodic media.*

We consider an atomic model of deposition of materials over a quasi-periodic medium. The atoms of the deposited material interact with the medium (a quasi-periodic interaction) and with their nearest neighbors (a harmonic interaction). This is a quasi-periodic version of the well known Frenkel-Kontorova model. We consider the problem of whether there are quasi-periodic equilibria with a frequency that resonates with the frequencies of the medium. We show that there are always perturbative expansions. We also prove a KAM theorem in a-posteriori form. We show that if there is an approximate solution of the equilibrium equation satisfying non-degeneracy conditions, we can adjust one parameter and obtain a true solution which is close to the approximate solution. The proof is based on an iterative method of the KAM type. The iterative method is not based on transformation theory as the most usual KAM theory, but it is based on a novel technique of supplementing the equilibrium equation with another equation that factors the linearization of the equilibrium equation. (Received August 21, 2015)

91 ► Game theory, economics, social and behavioral sciences

1113-91-111 **Laurent E Calvet*** (calvet@hec.fr), 1 rue de la Liberation, 78350 Jouy en Josas, France, and **Adlai J Fisher** (adlai.fisher@sauder.ubc.ca), Vancouver, BC V6T 1Z4, Canada. *Extreme risk and fractal regularity in finance.*

As the Great Financial Crisis reminds us, extreme movements in the level and volatility of asset prices are key features of financial markets. These phenomena are difficult to quantify using traditional approaches that specify extreme risk as a singular rare event detached from ordinary dynamics. 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 major forms of scale-invariance. Building on these regularities, researchers have developed a new class of multifractal processes that permit the extrapolation from high-frequency to low-frequency events and generate accurate forecasts of asset volatility. 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 August 15, 2015)

92 ► Biology and other natural sciences

1113-92-39 **B. Veena Shankara N. Rao***, Department of Mathematics, Mail Stop 3368, Texas A&M University, College Station, TX 77843. *A spatiotemporal population dynamics model to track density and average mass of brown shrimp.*

Structured population models are used for modeling changes in the density of individuals over time and other factors such as age, mass, developmental stage and space. Mass is a particularly useful measure of condition of a population. Our approach to modeling mass dependent population dynamics introduces mass as an additional dependent variable. We develop a parabolic-hyperbolic system of coupled nonlinear partial differential equations to track density and average mass of the population at location 'x' and time 't'. Our model provides an insight into the identification of key processes controlling populations over various space and time.

*This is a joint work with Jay R. Walton (Department of Mathematics, Texas A&M University) and Masami Fujiwara (Department of Wildlife and Fisheries Sciences, Texas A&M University). (Received July 29, 2015)

1113-92-86 **Mette S Olufse*** (msolufse@ncsu.edu), Department of Mathematics, 2108 SAS Hall, 2311 Stinson Drive, Raleigh, NC 27695. *Patient specific modeling of cardiovascular system dynamics.*

Cardiovascular models have reached a fairly complex level, yet they have not been used widely within the medical community. One obstacles is the lack of methodologies for rendering models patient specific. To do so it is necessary to adapt models to the specific system studied. This is a complex task given the large inter-individual variation within patients. Moreover, typically only a few quantities can be measured. This talk focus on using sensitivity and correlation analysis to predict a set of identifiable parameters that can be estimated

given the model and available data. These techniques will be illustrated using a model predicting baroreflex regulation during head-up tilt. This model can be described by systems of nonlinear ODEs, with parameters representing physiological quantities. Nominal parameter values are predicted using available patient knowledge and the identifiable parameters are estimated allowing the model to predict measured output. Emphasis is placed on ensuring that states for which data is not available are within physiological bounds. Finally, we show that parameter estimates along with model predictions can be compared within and between groups of subjects, leading the way for development of improved diagnosis and treatment protocols. (Received August 17, 2015)

93 ► *Systems theory; control*

1113-93-34 **LOUIS TEBOU*** (teboul@fiu.edu), Department of Mathematics and Statistics, Florida International University, Miami, FL 33199. *On some stabilization problems for the Timoshenko beam.*

The stabilization of the Timoshenko beam system with localized damping is examined. The damping involves the sum of the bending and shear angle velocities. First, we show that strong stability holds if and only if the support of the damping meets one endpoint of the interval under consideration. Next, we use the frequency domain method combined with the multipliers technique to prove the exponential stability of the associated semigroup when the damping support meets one endpoint of the interval under consideration. When the speed of propagation of the wave generated by the bending and that of the wave generated by the shear angle are distinct, the proof is elementary. However, when the two speeds are equal, an important identity breaks down, and the proof is carried out by the introduction of an appropriate auxiliary equation whose solution plays a critical role in subsequent estimates. Additionally, the stabilization of the Timoshenko beam in the presence of one locally distributed damping acting through the bending equation is investigated. (Received July 28, 2015)

1113-93-160 **Sergei Avdonin*** (s.avdonin@alaska.edu), Department of Mathematics and Statistics, University of Alaska Fairbanks, Fairbanks, AK 99709. *Control and Inverse Problems for Partial Differential Equations on Graphs.*

We consider control and inverse problems on graphs for several types of PDEs including wave, heat and viscoelasticity equations. We demonstrate that, for graphs without cycles, unknown coefficients of the equations and right-hand sides together with the topology of the graph and lengths of the edges can be recovered from the dynamical Dirichlet-to-Neumann map associated with the boundary vertices. For general graphs with cycles additional observations at the internal vertices are needed for stable identification. The corresponding exact controllability results are also proved. (Received August 19, 2015)

1113-93-239 **Mary Ann Horn*** (mhorn@nsf.gov), 4201 Wilson Blvd, Suite 1025, Arlington, VA 22230. *Mathematical Challenges Arising from the Questions of Controllability and Stabilization for Complex Elastic Structures.* Preliminary report.

In the study of control and stabilization of dynamic elastic systems, a significant challenge is the ability to rigorously address whether linked dynamic structures can be controlled using boundary feedback alone. When a structure is composed of a number of interconnected elastic elements or is modelled by a system of coupled partial differential equations, the behavior becomes much harder to both predict and to control.

Structures composed of multiple layers or components of different dimensions pose serious challenges because the energy transferred through the interfaces between components can lead to uncontrollable behavior. This talk focuses on issues that arise when attempting to understand the control and stability of such complex systems. (Received August 24, 2015)

1113-93-268 **Jose de Jesus Martinez*** (jesusmtz@iastate.edu), Department of Mathematics, Iowa State University, Carver Hall, Ames, IA 50010, and **Scott Hansen** (shansen@iastate.edu). *Modeling and controllability of a heat equation with singular density.* Preliminary report.

We consider a linear hybrid system consisting of two rods connected by a thin wall of width 2ϵ and density $1/2\epsilon$. By passing to a limit, we obtain a system describing heat flow of two rods connected by a "point mass" whose dynamics are governed by a differential equation. We show that the system is null controllable with either a Dirichlet or Neumann boundary control at one end. The results are based on spectral analysis together with the moment method. (Received August 24, 2015)

2010 MATHEMATICS SUBJECT CLASSIFICATION

Compiled in the Editorial Offices of MATHEMATICAL REVIEWS and ZENTRALBLATT MATH

00 General
01 History and biography
03 Mathematical logic and foundations
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General algebraic systems
11 Number theory
12 Field theory and polynomials
13 Commutative rings and algebras
14 Algebraic geometry
15 Linear and multilinear algebra; matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory; homological algebra
19 *K*-theory
20 Group theory and generalizations
22 Topological groups, Lie groups
26 Real functions
28 Measure and integration
30 Functions of a complex variable
31 Potential theory
32 Several complex variables and analytic spaces
33 Special functions
34 Ordinary differential equations
35 Partial differential equations
37 Dynamical systems and ergodic theory
39 Difference and functional equations
40 Sequences, series, summability
41 Approximations and expansions
42 Fourier analysis
43 Abstract harmonic analysis
44 Integral transforms, operational calculus
45 Integral equations
46 Functional analysis
47 Operator theory
49 Calculus of variations and optimal control; optimization
51 Geometry
52 Convex and discrete geometry
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57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
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68 Computer science
70 Mechanics of particles and systems
74 Mechanics of deformable solids
76 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
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91 Game theory, economics, social and behavioral sciences
92 Biology and other natural sciences
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0192-5857(2015)36:3;1-P