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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
1121	September 24–25, 2016	Brunswick, ME	July 19	Vol 37, No. 3
1122	October 8–9, 2016	Denver, CO	August 16	Vol 37, No. 3
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
1209	September 23–24, 2017	Orlando, FL	July 25	TBA

ATHENS, GA, March 5–6, 2016

Abstracts of the 1117th Meeting.

00 ► General

1117-00-15 **Amrita Acharyya**, **Jon M Corson** and **Bikash C Das*** (bikash.das@ung.edu), University of North Georgia, Department of Mathematics, 3820 Mundy Mill Rd., Oakwood, GA 30566. *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. 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 universal cover of a profinite graph and we show that it 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 November 07, 2015)

1117-00-55 **Mariana Montiel*** (mmontiel@gsu.edu), 30 Pryor St. Suite 750, Atlanta, GA 30303, and **Robin Baidya** and **Rodrigo Castro Lopez Vaal** (mmontiel@gsu.edu), Atlanta, GA 30312, and **Emiliano Nieto-Montiel**. *Mathematical Music Theory/Post-Tonal Analysis: A Pilot in Course Pairing.* Preliminary report.

The present work reports on the implementation of a pilot course pairing experiment, result of a competitive award process, in which the Mathematics Department and the School of Music participated with their courses "Mathematical Music Theory" and "Post-tonal Analysis" respectively. The motivation is that music presents a rich and varied subject for the application and development of certain mathematical subjects, some of which are not always part of the standard curriculum. Post-tonal music has been a fertile area for the creation of compositional and analytical techniques that draw on mathematics. We will convey how this subject can expose mathematics students to tools and techniques that are not always covered in the core courses of the major. The music students, in turn, can see the formal aspects behind the study of post-tonal analysis, or the analysis of rhythm, which are usually not covered in the courses of their concentration. As an example three final projects are presented by three graduate students, two in mathematics and one in music, in which post-tonal works were created and analyzed using mathematical techniques and language. (Received December 28, 2015)

1117-00-116 **Jeremy Kastine*** (jkastine@isothermal.edu). *An Introduction to G-, S-, and L-Canons.* Preliminary report.

Rhythmic tiling can be used to create canons in which any two distinct parts never overlap. As a result, the texture of such a canon is monophonic. In this talk we will demonstrate the construction of G-canons and S-canons (based on Golomb rulers and Sidon sets) in which any two distinct parts overlap exactly once but always do so in unison. As with tiling canons, these canons are monophonic. Tiling canons, G-canons, and S-canons are part of a broader class which we will call L-canons, in which any two distinct parts overlap no more than once and are in unison when they do overlap. We will demonstrate that, given any melodic motive, we can construct an L-canon based on its translations and scalings. (Received January 07, 2016)

1117-00-132 **Jack Douthett*** (douthett@comcast.net). *n-Cubes, Boolean Rings, and Music Analysis.* Preliminary report.

A subgroup of the 12-cube symmetry group will be extended to a Boolean ring. This 12-cube ring is isomorphic to a 12-cube ring where the vertices represent pcsets, and the transformations are pcisets where the sum of pcisets is their symmetric difference and multiplication is their intersection. This idea will be employed to illustrate connections among the musical cubes of Douthett, Tymoczko, and others. (Received January 09, 2016)

1117-00-175 **Sergei Tabachnikov*** (tabachni@math.psu.edu), Department of Mathematics, Penn State, University Park, PA 16802. *Experimental Mathematics: the journal and the institute.*

I shall describe two venues for the emerging field of experimental mathematics, the journal "Experimental Mathematics", and the Institute for Computational and Experimental Mathematics (ICERM) at Brown University. I am/was involved as the editor-in-chief and as a deputy director. (Received January 12, 2016)

1117-00-209 **Richard James Plotkin***, richardp@buffalo.edu. *The harmonious opposition of maximal displacement and voice-leading parsimony.*

A traditional parsimonious transformation must satisfy a single constraint: minimal change of pitch-class content. To limit this transformation within the chromatic universe, two further fruitful-but-arbitrary rules must be followed: set class preservation, and half- or whole-step voice-leading. An alternate formulation of parsimonious transformations, in which these two rules are replaced by constraints involving scales and maximally even distributions, can take us beyond a discussion of the chord cycles usually examined in neo-Riemannian theory. By way of iterated quantization and Fourier phase analysis, this reformulation allows *maximal displacement* to be clearly defined as the opposite of voice-leading parsimony. Further, the interaction of these two opposing types of transformations reveals interesting harmonic patterns in the works of Debussy and Chopin. (Received January 14, 2016)

1117-00-214 **Olivia D Beckwith*** (olivia.dorothea.beckwith@emory.edu), Dept. of Math and CS, Emory University, 400 Dowman Dr, W401, ATLANTA, GA 30322, and **Michael Mertens**. *The Number of Parts of Integer Partitions in Residue Classes.*

In a previous work of the speaker and Michael Mertens, asymptotic formulas for the number of parts of integer partitions that are 0 (mod N) were found using the Circle Method. In a recent work, we obtain asymptotic formulas for the number of parts in any fixed residue class. (Received January 19, 2016)

1117-00-365 **McKay Sullivan*** (smsulli4@ncsu.edu). *Twisted Logarithmic Modules of the Symplectic Fermions.*

We will discuss the recently defined notion of twisted logarithmic modules of vertex algebras. In particular, we will consider twisted logarithmic modules of free field vertex algebras. Explicit examples of such modules are obtainable as highest weight representations on a certain Fock space. We will use the symplectic fermions (odd super bosons) to demonstrate this construction. (Received January 18, 2016)

1117-00-388 **Wei-Kai Lai*** (laiw@mailbox.sc.edu), 807 Hampton Street, Walterboro, SC 29488, and **Christian Kalacanic** (ckalaca@g.clemson.edu). *The Power Tower and the Digital Root.*

The power tower of a positive integer is defined as the iterated exponentiation of the integer. If the number is iterated for n times, it is called a power tower of order n. Obviously, the value of a power tower hugely increases when the order increases, and that makes it hard to analyze the properties of power towers. In this talk, we will focus on its digital root, and introduce the pattern we found during our study, using congruence. (Received January 18, 2016)

1117-00-406 **PACO GOMEZ*** (fmartin@etsisi.upm.es), 2092 CLOVERDALE DR SE, ATLANTA, GA 30316. *Mathematical Analysis of A Cappella Flamenco Music.*

In this work we present some mathematical techniques for the analysis of flamenco music. Here we consider the problem of similarity in a specific musical repertoire: a cappella flamenco singing, more specifically in debla martinete styles. We start off by briefly describing what flamenco music is like. Next we detail some characteristics of flamenco singing and a cappella singing styles. In the following section we examine the problem of melodic similarity in flamenco music. Two types of features are considered, low-level features and mid-level features. The latter refers to musical features whereas the former refers to certain properties of the audio signal. Such a characterization has to be mathematically treated so that a similarity measure is properly defined. Next section contains the main contributions of our work: the distance based on those features is described and the combined distance is finally defined. Assessment strategies for the obtained similarity distance are thoroughly discussed, including phylogenetic trees, which are also used to visualize clustering and analyze style discrimination. (Received January 18, 2016)

1117-00-460 **Brent A. Milam*** (bamilam@hotmail.com), 1830 Dyson Drive, Decatur, GA 30030. *Deterministic Geometries, Self-Similarity, and the Aesthetics of Music Composition.* Preliminary report.

This presentation explores the use of various mathematically deterministic games, self-similar sequences, and stochastic mechanisms as the basis of novel generative material for musical compositions. The mathematical games include various modified versions of the Sierpinski gasket to produce repeating geometric patterns or deterministic chaos depending on the selection of an initial seed. Self-similar sequences generated by the motion of a line within a square lattice give rise to the fractal pattern known as a "dragon curve" and the hypothetical "rabbit" sequence suggested by Fibonacci. Stochastic algorithms are used to shape a variety of time-dependent probability distributions that in turn create the perceived form of temporal events.

The material generated by such methods is then applied as the basis for the various elements of musical experience including rhythm, event duration, sound density, frequency, timbre, amplitude, envelope, and temporal and spatial relationships.

Finally, the outcomes of these techniques are compared to historical methodologies and a subjective evaluation of the aesthetic value of such generative procedures by composers from differing specialties, backgrounds, and compositional styles are presented. (Received January 19, 2016)

1117-00-505 **Adrian P Childs*** (apchilds@uga.edu), Hugh Hodgson School of Music, 250 River Rd, Athens, GA 30602-7287. *Musical and Mathematical Explorations of a Voice-Leading Graph of Referential Collections and Its Interesting Subgraphs.*

Musical scales (here termed "referential collections") can be defined by a variety of musical or mathematical properties. This paper focuses on the family of 29 referential collections that emerges from two restrictions: that scale steps exist as only whole- or half-steps in chromatic space; and that consecutive half-steps are not permitted. This family—comprising 12 diatonic, 12 acoustic, 3 octatonic, and 2 whole-tone collections—can be represented by a simple, connected graph. Vertices of the graph are labeled with the 29 collections. Edges connect vertices whose collections exhibit one of two common voice-leading relations: the alteration of a single pitch class by one half-step (termed P1 by Douthett and Steinbach 1998); or the splitting of a single pitch class into its neighbors one half-step away (termed split/fuse by Callender 1998).

For any pitch-class set X, an associated induced subgraph can be formed from the vertices labeled by the referential collections of which X is a subset. The properties, symmetries, and musical implications of these subgraphs—which are always connected (unless trivially empty)—will be explored through multiple examples. (Received January 19, 2016)

1117-00-519 **Xin Yang*** (yangxinncut@gmail.com), 805 Bradyville Pike, G08, Murfreesboro, TN 37130, and **Qiang Wu** and **Don Hong**. *Spatial Regularization for Neural Network and Application in Alzheimer's Disease Classification.*

In the past 20 years, there are huge amount of researchers have studied the Alzheimer's Disease image data. Many high-dimensional classification methods use structural MRI brain image for classification between AD and healthy controls. Since the computer computation power has been improved, neural networks have been widely applied in disease diagnosis. However, the neural network does not consider the brain spatial information. This may lose some important information due to the ignore of the neighbor effect. Because the voxel of the 3D brain is not isolated, in reality some brain area has extremely close relationship. To overcome the shortage of spatial correlation problem, in this project, we proposed a new technique Spatial Regularization Neural Network, which

incorporates spatial informa- tion provided by each voxel's 3 dimensional neighbor voxels. Real application results show satisfactory performance from Spatial Regularization Neural Network. (Received January 19, 2016)

1117-00-539 **Clifton Callender*** (clifton.callender@fsu.edu). *Aperiodic Canons, Hemiolas, and Tilings.*

Any rhythm can be described as the quantization of a continuous, monotonic function. Digitized lines of rational slope correspond to maximally-even rhythms (Toussaint), while digitized periodic functions of rational mean slope give rise to oscillating rhythms, such as the ostinato of György Ligeti's *L'escalier du diable*. Functions with irrational mean slopes yield quantized rhythms that are aperiodic. This presentation explores the theoretical and compositional potentials of aperiodic canons, hemiolas, and tilings. Specifically, 1) asymmetric, aperiodic hemiolas of the form $p : q$ result from quantizing a function at values of the domain that are multiples of p and q, respectively; 2) digitized lines of irrational slope a gives rise to n-tuple canons, the voices and relations of which are determined by the terms of the continued fraction expansion of a; and 3) while rhythmic tilings are typically periodic with tiles of finite length, tilings based on quantized rhythms can be aperiodic with infinitely long tiles and a composite rhythm that is a diminution of one or more tiles. (Received January 19, 2016)

01 ► History and biography

1117-01-113 **Danielle Mihram**, U.S.C. LVL-113, 650 W. 35th Street, Los Angeles, CA 90089-2571, and **G. Arthur Mihram*** (dmihram@usc.edu), P.O. Box No. 1188, Princeton, NJ 08542-1188. *The Role(s) of Mathematics in Science: Four Questions for the Active Learner.* Preliminary report.

Science is that human activity devoted to the search for the very explanation for (i.e., for the truth about) any particular naturally occurring phenomenon [OED 4.a, 5.b]. Modern Science's 'Method' [TEOREMA 28(2) 35 2009], a six-stage model-building process: 0.Extant Knowledge; I.Observation + Reflexion Thereon; II.Artwork; III.Perscrutation; IV.Confirmation w/Nature; V.Knowledge Augmentation. Quinn [NOTICES 2012:31] notes: Mathematics is not Science, their validity criteria differ: internal v. external. A. Math not necessary for Science?: cf. Darwin, ORIGIN, 1865; B. Math not sufficient for Science?: [LT More, 1915, LIMITATIONS OF SCIENCE,p151: (Pure) mathematics deals only with abstractions (lines, numbers), not real-world phenomena]; C. Whither Applied Mathematics?: Though math provides statements which are irrefutably true, our three-step theorem-proving [1.Postulates; 2.Logical deductions; 3.Conclusion] falls short for Science. Yet, even if using, as one Postulate, a well-established scientific model, and adding Step 4.Nature's affirmation, the result if not new science, but only further Confirmation for the initiating Postulate. D. Curricula requiring mathematics?: Math education prepares adolescents to reach logical, hopefully nearly irrefutable, adult conclusions. (Received January 06, 2016)

03 ► Mathematical logic and foundations

1117-03-331 **Lars Ruthotto*** (lruthotto@emory.edu), 400 Dowman Drive, W408, Atlanta, GA 30322. *jInv - A Flexible Framework for Parallel PDE Constrained Optimization in Julia.*

jInv is a Julia framework for the solution of large-scale PDE constrained optimization problems. It is based on a discretize-then-optimize approach, uses a (projected) Gauss-Newton method, and provides interfaces state-of-the-art linear solvers (both direct and iterative). The framework exploits Julia's potential for parallel and distributed computation and supports a variety of computational architectures from a single laptop to large clusters of cloud computing engines. Being written in a dynamic language, it is easily extendable and yet fast as will be outlined for large-scale geophysical inverse problems. This is joint work with Eldad Haber, University of British Columbia, Vancouver, Canada. (Received January 17, 2016)

05 ► Combinatorics

1117-05-11 **Zachary Hamaker**, **Joel Brewster Lewis**, **Bendan Pawlowsk** and **Bruce E Sagan*** (sagan@math.msu.edu), Department of Mathematics, Wells Hall, East Lansing, MI 48824. *Pattern avoidance and quasisymmetric functions.*

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. We discuss when this is actually a symmetric function and, in that case, when it is Schur nonnegative. (Received October 29, 2015)

1117-05-18 **Anna, Ying Pun*** (annapunying@gmail.com). *On decomposition of the product of a monomial and a Demazure atom into atoms.* Preliminary report.

Haglund, Haiman and Loehr obtained a combinatorial formula for non-symmetric Macdonald polynomials $E_\gamma(x_1, \ldots, x_n; q, t)$, which shares many properties with symmetric Macdonald polynomials, using skyline fillings of shape γ, satisfying certain constraints. In particular, one can obtain Demazure atoms (first studied by Lascoux and Schützenberger) by $\mathcal{A}_\gamma = E_{\overline{\gamma}}(x_n, \ldots, x_1; \infty, \infty)$ and Demazure characters (key polynomials) by $\kappa_\gamma = E_\gamma(x_1, \ldots, x_n; 0, 0)$, both of which form a basis for the polynomial ring. Haglund, Luoto, Mason, Remmel and van Willigenburg obtained new sets of tableaux-combinatorial objects called semistandard augmented fillings (SSAFs) by further studying the combinatorial formulas for Demazure atoms and characters given by the skyline fillings. They generalized the results on SSYTs like the Pieri Rule, the RSK algorithm and the Littlewood-Richardson(LR) rule. We prove that the product of a monomial and a Demazure atom is a positive sum of Demazure atoms by using the insertion on SSAFs developed by Mason and a refinement of the LR rule. This result proves one particular case in a conjecture which provides an approach to a combinatorial proof of Schubert positivity property. (Received November 14, 2015)

1117-05-22 **Hui Jiang** (jhuink@163.com), Tianjin, 300071, Peoples Rep of China, **Xueliang Li*** (lxl@nankai.edu.cn), Tianjin, Peoples Rep of China, and **Yingying Zhang** (zyydlwyx@163.com), Tianjin, Peoples Rep of China. *Total proper connection of graphs.*

A path in a total-colored graph is a total proper path if (i) any two adjacent edges on the path differ in color, (ii) any two internal adjacent vertices on the path differ in color, and (iii) any internal vertex of the path differs in color from its incident edges on the path. A total-colored graph is called total proper connected if any two vertices of the graph are connected by a total proper path of the graph. For a connected graph G, the total proper connection number of G, denoted by $tpc(G)$, is defined as the smallest number of colors required to make G total proper connected. These concepts are inspired by the concepts of total rainbow connection of graphs. In this paper, we first determine the value of the total proper connection number $tpc(G)$ for some special graphs G. Secondly, we obtain that $tpc(G) \leq 4$ for any 2-connected graph G and give examples to show that the upper bound is sharp. Furthermore, we prove that $tpc(G) \leq \frac{3n}{\delta+1} + 1$ for a connected graph G with order n and minimum degree δ. (Received December 03, 2015)

1117-05-23 **Elliot Krop*** (elliotkrop@clayton.edu), Clayton State University, 2000 Clayton State Boulevard, Morrow, GA 30260, and **Aziz Contractor**. *A class of graphs approaching Vizing's conjecture.*

For any graph $G = (V, E)$, a subset $S \subseteq V$ *dominates* G if all vertices are contained in the closed neighborhood of S, that is $N[S] = V$. The minimum cardinality over all such S is called the domination number, written $\gamma(G)$. In 1963, V.G. Vizing conjectured that $\gamma(G \Box H) \geq \gamma(G)\gamma(H)$ where $\Box$ stands for the Cartesian product of graphs. We define classes of graphs $\mathcal{A}_n$, for $n \geq 0$, so that every graph belongs to some such class, and $\mathcal{A}_0$ corresponds to class A of Bartsalkin and German. We prove that for any graph G in class $\mathcal{A}_1$, $\gamma(G \Box H) \geq \left(\gamma(G) - \sqrt{\gamma(G)}\right)\gamma(H)$.

Keywords: Domination number, Cartesian product of graphs, Vizing's Conjecture (Received December 03, 2015)

1117-05-36 **Adam S. Jobson** and **Andre E. Kezdy*** (kezdy@louisville.edu), Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Jeno Lehel** and **Susan C. White**. *Detour Trees.*

A detour of a graph is a path of maximum length. A vertex that is common to all detours of a graph is called a Gallai vertex. We introduce the notion of a detour tree, a spanning tree of a graph in which the vertex set of any detour (of the graph) induces a subtree. We use detour trees to prove that any connected dually chordal graph has a Gallai vertex. Consequently connected graphs from subfamilies of dually chordal graphs have a Gallai vertex, including the well-studied doubly chordal, strongly chordal and interval graphs. Separately we prove that connected cographs (which are not necessarily dually chordal) have a Gallai vertex. Analogous results for cycles of maximum length follow for 2-connected graphs from these families. We also characterize graphs that have a detour tree. Several open problems will be mentioned. (Received December 19, 2015)

1117-05-39 **Suil O*** (osuilo@sfu.ca), **Gary Greaves** (grwgrvs@gmail.com) and **Bojan Mohar** (mohar@sfu.ca). *Interlacing families and their application to digraphs.* Preliminary report.

Recently, Marcus, Spielman, and Srivastava proved the existence of infinite families of bipartite Ramanujan graphs by using the method of interlacing families of polynomials. In this talk, we apply their method to prove that for any connected graph G, there exists an orientation of G such that the spectral radius of the corresponding Hermitian adjacency matrix is at most that of the universal cover of G. (Received January 13, 2016)

1117-05-46 **Victor Falgas-Ravry*** (victor.falgas-ravry@vanderbilt.edu), Department of Mathematics, Vanderbilt University, 1326 Stevenson Center, Nashville, TN 37240, and **Teeradej Kittipassorn**, **Dániel Korándi**, **Shoham Letzter** and **Bhargav P. Narayanan**. *Separating path systems.*

Let G be a graph on n vertices. A family $\mathcal{F}$ of paths in G constitutes a *separating path system* of G if for every pair of distinct edges e, f in $E(G)$ there exists a path p in $\mathcal{F}$ which contains exactly one of e and f. How small a separating path system can we find?

This question was asked by G.O.H. Katona, with motivation coming from the problem of link-failure detection in networks. We conjecture that all graphs on n vertices have a a separating set system of size at most Cn, for some constant $C \geq 1$. We prove this is true for almost all n-vertex graphs and $C = 48$. We also obtain optimal bounds in the special case of trees.

This is joint work with T. Kittipassorn, D. Korándi, S. Letzter and B.P. Narayanan. Similar results were independently obtained by J. Balogh, B. Csaba, R.R. Martin and A. Pluhár. (Received December 23, 2015)

1117-05-49 **Eva Czabarka** and **Laszlo A. Szekely*** (szekely@math.sc.edu), USC Department of Mathematics, Columbia, SC 29208, and **Stephan Wagner**. *On the number of nonisomorphic subtrees of a tree.*

We show that a tree of order n has at most $O(5^{n/4})$ nonisomorphic subtrees, and that this bound is best possible. We also prove an analogous result for the number of nonisomorphic rooted subtrees of a rooted tree. (Received December 25, 2015)

1117-05-57 **Nathan Fox*** (fox@math.rutgers.edu). *Well-Behaved Solutions to Hofstadter-Like Recurrences.*

For over fifty years, the seemingly chaotic behavior of the Hofstadter Q-sequence has baffled mathematicians. While the sequence superficially seems to exhibit some patterns, it is still unknown whether the sequence even exists for all n. Other related sequences, such as those of Conway, Conolly, and Tanny, have similar definitions, but instead can be easily predicted. In addition, these sorts of recurrences are highly sensitive to their initial conditions. A given recurrence may generate some sequences with highly regular patterns, other sequences that "die" after only a few terms, and yet others that exist for a long time but behave chaotically. For example, Golomb described a quasilinear sequence generated by the Hofstadter Q-recurrence, and Ruskey found another well-behaved solution that contains the Fibonacci numbers as an evenly-spaced subsequence. In this talk, we will explore how we can automatically find (and prove we found) initial conditions to Hofstadter-like recurrences that generate well-behaved solutions akin to those of Golomb and Ruskey. (Received December 29, 2015)

1117-05-58 **Alex Fink**, **Jenna Rajchgot** and **Seth Sullivant*** (smsulli2@ncsu.edu). *Matrix Schubert varieties and Gaussian conditional independence models.*

Matrix Schubert varieties are certain varieties in the affine space of square matrices which are determined by specifying rank conditions on submatrices. We study these varieties for generic matrices, symmetric matrices, and upper triangular matrices in view of two applications to algebraic statistics: we observe that special conditional independence models for Gaussian random variables are intersections of matrix Schubert varieties in the symmetric case. Consequently, we obtain a combinatorial primary decomposition algorithm for some conditional independence ideals. We also characterize the vanishing ideals of Gaussian graphical models for generalized Markov chains.

In the course of this investigation, we are led to consider three related stratifications, which come from the Schubert stratification of a flag variety. We provide some combinatorial results, including describing the stratifications using the language of rank arrays and enumerating the strata in each case. (Received December 29, 2015)

1117-05-63 **Rebecca Conaway**, **Felix Gotti**, **Jesse Horton**, **Christopher ONeill*** (coneill@math.tamu.edu), **Roberto Pelayo**, **Mesa Williams** and **Brian Wissman**. *Minimal presentations of shifted numerical monoids.*

Consider the family of numerical monoids $S_n = \langle n, n + r_1, \ldots, n + r_k \rangle$ obtained by varying n. In this talk, we exhibit periodic behavior of the minimal presentations of S_n when n is sufficiently large. As a consequence, we obtain eventual periodicity results for several arithmetic quantities arising in factorization theory. (Received December 30, 2015)

1117-05-71 **Hao Huang*** (hao.huang@emory.edu), Dept. of Math and CS, 400 Dowman Dr., Atlanta, GA 30322. *On graphs decomposable into induced matchings of linear sizes.*

A Ruzsa-Szemeredi graph is a graph on n vertices whose edge set can be partitioned into induced matchings of size cn. The study of these graphs goes back more than 35 years and has connections with number theory, combinatorics, complexity theory and information theory. In this talk we will discuss the history and some recent developments in this area. In particular, we show that when $c > 1/4$, there can be only constantly many matchings. On the other hand, for $c = 1/4$, the maximum number of induced matchings is logarithmic in n.

This is joint work with Jacob Fox and Benny Sudakov. (Received January 01, 2016)

1117-05-73 **Rao Li*** (raol@usca.edu), Dept. of mathematical sciences, Aiken, SC 29801. *An upper bound for the energy of a graph.*

The energy of a graph is defined as the sum of the absolute values of the eigenvalues of its adjacency matrix. A new upper bound for the energy of a graph will be presented in this talk. The upper bound involves the independence number of the graph. (Received January 02, 2016)

1117-05-74 **Y Zhao*** (yzhao@mail.ucf.edu), Yue Zhao, Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Hamiltonian Cycles in Critical Graphs with Large Maximum Degree.*

It is shown that an overfull Δ-critical graph with n vertices that satisfies $\Delta \geq \frac{n}{2}$ is Hamiltonian. If the Overfull Subgraph Conjecture was proved to be true, then the above result could be said that any Δ-critical graph with n vertices that satisfies $\Delta \geq \frac{n}{2}$ is Hamiltonian. Since the Overfull Subgraph Conjecture is still open, the natural question is how to directly prove a Δ-critical graph with n vertices that satisfies $\Delta \geq \frac{n}{2}$ is Hamiltonian. In 2012, it was shown that a Δ-critical graph with n vertices that satisfies $\Delta \geq \frac{6n}{7}$ is Hamiltonian. In this talk, we show that if G is a Δ-critical graph with n vertices satisfying $\Delta \geq \frac{4n}{5}$, then G is Hamiltonian. (Received January 02, 2016)

1117-05-77 **Norman A. Carey***, ncarey@gc.cuny.edu, and **David L. Clampitt**, clampitt.4@osu.edu. *Varieties and Frequencies of Partitioned Factors in Sturmian Words.*

The results in mathematical music theory due to Clough and Myerson referred to as Cardinality equals Variety (CV) and Structure yields Multiplicity (SM) correspond to statements about Christoffel words. Sturmian words are the infinite counterparts to Christoffel words, characterized as aperiodic but of minimal complexity, i.e., for all $n \in \mathbb{N}$ there are $n + 1$ factors of length n. Berthé showed that the factors of a given length have at most 3 frequencies (probabilities). In this paper we extend to results on factors under a fixed partitioning (decompositions of factors of length n into concatenations of words whose lengths are given by an ordered partition of n into k parts). Any factor of a Sturmian word thus partitioned into k elements belongs to one of $k + 1$ types. We show how to compute the frequencies of the types. These results recapture CV and SM in the Sturmian word. (Received January 03, 2016)

1117-05-94 **Zixia Song*** (zixia.song@ucf.edu) and **Lyall Reid**, Department of Mathematics, University of Central Florida, Orlando, FL 32816. *The Path Cover Number of k-regular graphs with $k \leq 6$.*

The path cover number of a graph G on n vertices is the minimum number of vertex-disjoint paths required to cover the vertices of G. Magnant and Martin in 2009 conjectured that the path cover number of a k-regular graph on n vertices is at most $\frac{n}{k+1}$. They verified the conjecture for $k \leq 5$ by a different argument for each k. Using discharging method, we give a proof of the conjecture for $k \leq 6$. (Received January 05, 2016)

1117-05-107 **Julian D Allagan*** (julian.allagan@ung.edu). *$\mathcal{F}$-WORM Coloring Of Some 2-trees: Partition Vectors.*

Suppose $\mathcal{F} = \{F_1, \ldots, F_t\}$ is a collection of distinct subgraphs of a graph $G = (V, E)$. An *$\mathcal{F}$-WORM* coloring of G is the coloring of its vertices such that no copy of a subgraph $F_i \in \mathcal{F}$ is monochrome or rainbow. This generalizes the notion of F-WORM coloring that was introduced recently by W. Goddard, K. Wash, and H. Xu.

A (restricted) partition vector $(\zeta_\alpha, \ldots, \zeta_\beta)$ is a sequence whose terms ζ_r are the number of $\mathcal{F}$-WORM colorings using exactly r colors, with $\alpha \leq r \leq \beta$. The partition vectors of some 2-trees are discussed. We found that maximal outerplanar graphs, which are members of 2-trees, share a unique partition vector given a K_3-WORM coloring, contrary to the case of classic proper vertex colorings. (Received January 06, 2016)

1117-05-110 **Ronald J Gould*** (rg@mathcs.emory.edu), Dept. Math & CS, 400 Dowman Drive, Atlanta, GA 30322, and **Jill R. Faudree**, **Ralph J. Faudree**, **Paul Horn** and **Michael S. Jacobson**. *Degree Sum and Vertex Dominating Paths.*

A *vertex dominating path* in a graph is a path P such that every vertex outside P has a neighbor on P. In 1988 H. Broersma stated a result implying that every n-vertex k-connected graph G such that $\sigma_{(k+2)}(G) \geq n-2k-1$ contains a dominating path. We show that every n-vertex k-connected graph with $\sigma_2(G) \geq \frac{2n}{k+2} + f(k)$ contains a dominating path of length at most $O(|T|)$, where T is a minimum dominating set of vertices. The main result is that every n-vertex k-connected graph such that $\sigma_2(G) \geq \frac{2n}{k+2} + f(k)$ contains a path of length at most $O(|T|)$ through any set of T vertices where $|T| = o(n)$. (Received January 06, 2016)

1117-05-114 **Edward E Allen**, **Joshua Hallam*** (hallamjw@wfu.edu) and **Sarah K Mason**. *Decomposing dual immaculate quasisymmetric functions into Young quasisymmetric Schur functions.*

Using an analogue of Schensted insertion, we give a combinatorial rule for the coefficients of the decomposition of the dual immaculate quasisymmetric functions into the Young quasisymmetric Schur functions. A Remmel-Whitney style algorithm for computing these coefficients will also be described (Received January 06, 2016)

1117-05-117 **Vitaly I. Voloshin*** (vvoloshin@troy.edu). *Coloring Mixed Hypergraphs: a survey of some recent results and open problems.* Preliminary report.

Mixed hypergraph is a triple $\mathcal{H} = (V, \mathcal{C}, \mathcal{D})$ with vertex set V and two families of subsets called C-edges and D-edges. In a proper coloring of vertices, every C-edge has two vertices of the same color, and every D-edge has two vertices of different colors. A mixed hypergraph $\mathcal{H}$ is called colorable if it admits at least one proper coloring; otherwise it is uncolorable.

A k-partition of a vertex set is called feasible if it is induced by a proper coloring using precisely k colors. For an n-vertex mixed hypergraph, the chromatic spectrum is the sequence $(r_1, r_2, ..., r_n)$, where each r_k is the number of feasible k-partitions.

Mixed hypergraph is called C-perfect if, for any induced subhypergraph, the upper chromatic number coincides with the maximum number of vertices which contain no C-edge. Mixed hypergraph is called minimal C-imperfect, if it is not C-perfect but any induced subhypergraph is C-perfect.

We survey some recent results and open problems concerning chromatic spectrum and C-perfection of mixed hypergraphs.
(Received January 07, 2016)

1117-05-120 **Ran Gu**, **Xueliang Li**, **Zhongmei Qin** and **Yongtang Shi*** (shi@nankai.edu.cn), Center for Combinatorics, Nankai University, No. 94, Weijin Road, Tianjin, 300071, Peoples Rep of China, and **Kang Yang**. *An extension of Mantel's theorem to random 4-uniform hypergraphs.*

A sparse version of Mantel's Theorem is that, for sufficiently large p, w.h.p. every maximum triangle-free subgraph of $G(n,p)$ is bipartite. DeMarco and Kahn proved this for $p > K\sqrt{\log n/n}$ for some constant K, and apart from the value of the constant, this bound is best possible. Denote by T_3 the 3-uniform hypergraph with vertex set $\{a,b,c,d,e\}$ and edge set $\{abc, ade, bde\}$. Frankl and Füredi showed that the maximum 3-uniform hypergraph on n vertices containing no copy of T_3 is tripartite for $n > 3000$. For some integer k, let $G^k(n,p)$ be the random k-uniform hypergraph. Balogh et al. proved that for $p > K \log n/n$ for some constant K, every maximum T_3-free subhypergraph of $G^3(n,p)$ w.h.p. is tripartite and it does not hold when $p = 0.1\sqrt{\log n}/n$. Denote by T_4 the 4-uniform hypergraph with vertex set $\{1,2,3,4,5,6,7\}$ and edge set $\{1234, 1235, 4567\}$. Pikhurko proved that there is an n_0 such that for all $n \geq n_0$, the maximum 4-uniform hypergraph on n vertices containing no copy of T_4 is 4-partite. In this paper, we show that for some constant K and $p > K \log n/n$, w.h.p. every maximum T_4-free subhypergraph of $G^4(n,p)$ is 4-partite. (Received January 07, 2016)

1117-05-125 **Chris Rodger*** (rodgec1@auburn.edu) and **Shanhai Li**. *Equitable block-colorings of C_4-decompositions of $K_v - F$.*

$(V(G), B)$ is said to be an H-decomposition of a graph G if B is a partition of $E(G)$ into sets, each of which induces a copy of H. An H-decomposition $(V(G), B)$ of G is said to have a (s,p)-equitable block-coloring if there exists a surjective function ϕ from B to $\{1, \ldots, s\}$ such that for each $u \in V(G)$: the blocks containing u

are colored with exactly p colors; and $|B(u,i) - B(u,j)| \leq 1$ for each $\{i,j\} \subset C(u)$. ($C(u)$ is the set of colors appearing in blocks containing u and $B(u,i)$ is the number of blocks containing u that are colored i.)

Here we find (s,p)-equitable block-colorings of 4-cycle decompositions of $K_v - F$, where F is a 1-factor of K_v. Of interest is settling the values of $\chi'_p(v)$ and $\bar{\chi}'_p(v)$, namely the least and greatest values of s for which there exists such a block-coloring of some 4-cycle decomposition of $K_v - F$. In this paper, several general results are established, both existence and non-existence theorems. These are then used to find, for all possible values of v, the values of $\chi'_p(v)$ when $p \in \{2,3,4\}$ and $\bar{\chi}'_2(v)$, and to provide good upper bounds on $\bar{\chi}'_3(v)$. (Received January 08, 2016)

1117-05-157 **Jie Han** (jhan@ime.usp.br) and **Yi Zhao*** (yzhao6@gsu.edu). *Forbidding Hamilton cycles in uniform hypergraphs.*

For $1 \leq d \leq \ell < k$, we give a new lower bound for the minimum d-degree threshold that guarantees a Hamilton ℓ-cycle in k-uniform hypergraphs. When $k \geq 4$ and $d < \ell = k-1$, this bound is larger than the conjectured minimum d-degree threshold for perfect matchings and thus disproves a well-known conjecture of Rödl and Ruciński. Our (simple) construction generalizes a construction of Katona and Kierstead and the so-called space barrier for Hamilton cycles. (Received January 12, 2016)

1117-05-164 **Shaohui Wang*** (swang4@go.olemiss.edu), 115 Northgate Dr PMB2033, University, MS 38677, and **Bing Wei**. *The ratio of independent domination number and domination number in bipartite graphs.* Preliminary report.

Let $\gamma(G)$ and $i(G)$ be the domination number and the independent domination number of G, respectively. Hedetniemi and Mitchell proved that $i(G)/\gamma(G) = 1$ if G is a line graph of a tree in 1977. Rad and Volkmann posted a conjecture that $i(G)/\gamma(G) \leq \Delta(G)/2$ for any graph G, where $\Delta(G)$ is its maximum degree. Furuta et al. gave the counterexamples containing an induced clique and disproved the conjecture. In this note, we verify the conjecture for bipartite graphs. Several graph classes attaining the extremal bound and graphs containing odd cycles with the ratio larger than $\Delta(G)/2$ are provided as well. (Received January 12, 2016)

1117-05-168 **Axel Brandt**, **Michael Ferrara*** (michael.ferrara@ucdenver.edu), **Mohit Kumbhat**, **Sarah Loeb**, **Derrick Stolee** 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 January 12, 2016)

1117-05-169 **Henry A. Kierstead**, **Alexandr Kostochka** and **Andrew McConvey*** (mcconve2@illinois.edu), Dept. of Mathematics, 250 Altgeld Hall, 1409 W. Green St., Urbana, IL 61801. *Strengthening theorems of Dirac and Erdős on disjoint cycles.*

Let k be a positive integer, $H_k(G)$ be the set of vertices of degree at least $2k$ in a graph G, and $L_k(G)$ be the set of vertices of degree at most $2k-2$ in G. A seminal result of Corrádi and Hajnal states that a graph G with at least $3k$ vertices and minimum degree at least $2k$ contains k disjoint cycles. In 1963, Dirac and Erdős considered the case that $\delta(G) < 2k$. In particular, they proved if $k \geq 3$ and $|H_k(G)| - |L_k(G)| \geq k^2 + 2k - 4$, then G contains k disjoint cycles. In this talk, we prove the following stronger result. If $k \geq 2$ and $|H_k(G)| - |L_k(G)| \geq 3k$, then G contains k disjoint cycles. In the special case that $V(G) = H_k(G)$, this reduces to the theorem of Corrádi and Hajnal for $k \geq 2$. (Received January 19, 2016)

1117-05-174 **Heather C Smith*** (heather.smith@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30332, and **István Miklós**. *The Single Cut-or-Join Model for Genome Rearrangement.*

Represent a genome with an edge-labelled, directed graph having maximum total degree two. We explore a number of questions regarding genome rearrangement, a common mode of molecular evolution. In the single cut-or-join model, a genome can mutate in one of two ways at any given time: a cut divides a degree two vertex into two degree one vertices while a join merges two degree one vertices into one degree two vertex.

Fix a set of genomes, each having the same set of edge labels. The number of ways for one genome to mutate into another can be computed in polynomial time. The number of medians can also be computed in polynomial time. While single cut-or-join is, computationally, the simplest mathematical model for genome rearrangement,

determining the number of most parsimonious median scenarios is #P-complete. We will discuss these and other complexity results that arose from an abstraction of this problem. (Received January 12, 2016)

1117-05-177 **Mark Ellingham*** (mark.ellingham@vanderbilt.edu), **Wenzhong Liu**, **Dong Ye** and **Xiaoya Zha**. *Orientable quadrilateral embeddings of cartesian products.*

White, Pisanski and others have proved a number of results on the existence of quadrilateral embeddings of cartesian products of graphs; in some cases these provide minimum genus embeddings. In a 1992 paper Pisanski posed three questions. First, if G and H are connected 1-factorable r-regular graphs with $r \geq 2$, does the cartesian product $G\Box H$ have an orientable quadrilateral embedding? Second, if G is r-regular, does the cartesian product of G with sufficiently many even cycles have an orientable quadrilateral embedding? Third, if G is an arbitrary connected graph, does the cartesian product of G with a sufficient large cube $Q_n = \Box^n K_2$ have an orientable quadrilateral embedding? We answer all three questions. The answer to the first question is negative, as we show using some families of 3-regular examples. The answers to the second and third questions are positive, as we show using a general theorem that answers both. (Received January 12, 2016)

1117-05-195 **Jie Han** and **Chuanyun Zang***, 30 Pryor Street SW Room 750, Atlanta, GA 30303, and **Yi Zhao**. *Matchings in k-partite k-uniform Hypergraphs.* Preliminary report.

Let H be a k-partite k-graph where each vertex class is of size n. We prove that if $\delta'_{k-1}(H) \geq \lceil n/k \rceil$, where $\delta'_{k-1}(H)$ is the minimum of $\deg(S)$ over all legal $(k-1)$-tuple S, then H contains a matching covering at least $n-1$ vertices from each class. This answers a question of Rödl and Ruciński and improves a result of Kühn and Osthus, which provides a matching covering at least $n-(k-2)$ vertices from each class. Furthermore, if $k \nmid n$ we show that $\delta'_{k-1}(H) \geq \lfloor n/k \rfloor$ guarantees the existence of a matching covering all but at most $(n \bmod k)$ vertices from each class. In particular, $\lceil n/k \rceil$ is best possible when $n \neq 1 \bmod k$ and $\lfloor n/k \rfloor$ is sharp when $k \nmid n$. (Received January 13, 2016)

1117-05-204 **Gabor Hetyei*** (ghetyei@uncc.edu), Department of Mathematics, University of North Carolina at Charlotte, Charlotte, NC 28223-0001. *Tournaments that arise as dominance graphs of "Efron's coins".* Preliminary report.

We provide necessary and sufficient conditions for a tournament to be the dominance graph of a set of unfair coins. We completely characterize the tournaments that are dominance graphs of sets of coins in which each coin displays its larger side with greater probability. The class of these tournaments coincides with the class of tournaments whose vertices can be numbered in a way that makes them semiacyclic, as defined by Postnikov and Stanley. We provide an example of a tournament on nine vertices that can not be made semiacyclic, yet it may be represented as a dominance graph of coins, if we also allow coins that display their smaller side with greater probability. We conclude with an example of a tournament with 81 vertices that is not the dominance graph of any system of coins. (Received January 13, 2016)

1117-05-225 **Michael H Albert**, **Cheyne Homberger**, **Jay Pantone**, **Nathaniel Shar** and **Vincent Vatter***, vatter@ufl.edu. *Generating permutations with restricted containers.*

In The Art of Computer Science, Knuth asks the reader to prove that the permutations that can be generated by a stack are those that avoid the pattern 312. This exercise is generally credited with initiating the study of permutation patterns.

We study sorting mechanisms called C-machines which generalize the notion of both stacks and queues. Using C-machines we are able to obtain thousands of terms of the enumeration sequence of several classes of permutations which have unknown enumerations. In several of these cases we have evidence indicating that the enumeration sequences are not D-finite. (Received January 14, 2016)

1117-05-227 **Michael D. Plummer*** (michael.d.plummer@vanderbilt.edu), Nashville, TN 37240, and **Robert Aldred** (raldred@maths.otago.ac.nz), Dunedin, New Zealand. *Matching extension in prism graphs.*

If G is any graph, the *prism graph* of G, denoted $P(G)$, is the cartesian product of G with a single edge, or equivalently, the graph obtained by taking two copies of G, say G_1 and G_2, with the same vertex labelings and joining each vertex of G_1 to the vertex of G_2 having the same label by an edge. A connected graph G has property $E(m,n)$ (or more briefly "G is $E(m,n)$") if for every pair of disjoint matchings M and N in G with $|M| = m$ and $|N| = n$ respectively, there is a perfect matching F in G such that $M \subseteq F$ and $N \cap F = \emptyset$. A graph which has the $E(m,0)$ property is also said to be *m-extendable*. In this paper, we begin the study of the $E(m,n)$ properties of the prism graph $P(G)$ when G is an arbitrary graph as well as the more special situations when, in addition, G is bipartite or bicritical. (Received January 14, 2016)

1117-05-228 **Robert W. Peck*** (rpeck@lsu.edu), 102 School of Music, Louisiana State University, Baton Rouge, LA 70803. *A classification of all-interval chords of small order.*

An all-interval chord is a set of musical pitches such that one and only one interval of each size occurs between pairs of its members. All interval chords are related to planar difference sets in combinatorics (i.e., those with $\lambda = 1$); however, they may also be inclusive of one or more involutions. We provide a categorization of all-interval chords of small order ($k \leq 10$), including those with cyclic, non-cyclic abelian, and non-abelian interval groups. (Received January 14, 2016)

1117-05-230 **Emily Sergel Leven***, esergel@ucsd.edu. *A proof of the Square Paths Conjecture.*

The modified Macdonald polynomials, introduced by Garsia and Haiman (1996), have many astounding combinatorial properties. One such class of properties involves applying the related ∇ operator of Bergeron and Garsia (1999) to basic symmetric functions. The first discovery of this type was the (recently proven) Shuffle Conjecture of Haglund, Haiman, Loehr, Remmel, and Ulyanov (2005), which relates the expression ∇e_n to parking functions. In (2007), Loehr and Warrington conjectured a similar expression for ∇p_n in terms of labeled square paths. In this talk, I discuss my extension of Haglund and Loehr's (2005) notion of schedules to labeled square paths and apply it to prove the Square Paths Conjecture. (Received January 14, 2016)

1117-05-235 **Xiaofeng Gu***, Department of Mathematics, University of West Georgia, 1601 Maple Street, Carrollton, GA 30118. *Packing spanning 2-connected k-edge-connected essentially $(2k-1)$-edge-connected subgraphs.*

Let $k \geq 2, p \geq 1, q \geq 0$ be integers. We prove 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 pairwise 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 pairwise edge-disjoint spanning 2-connected subgraphs, and a theorem that every $(6p + 2q)$-connected graph contains p spanning 2-connected subgraphs and q spanning trees, which are all pairwise edge-disjoint. (Received January 15, 2016)

1117-05-236 **Akira Saito*** (asaito@chs.nihon-u.ac.jp), Sakurajosui 3-25-40, Setagaya-Ku, Tokyo 156-8550, Japan, and **R.E.L. Aldred** and **Jun Fujisawa**. *Forbidden subgraphs and 2-factors in graphs.*

For a non-trivial connected graph H, a graph G is said to be *H-free* if G does not contain an induced matching which is isomorphic to H, and for a set $\mathcal{H}$ of non-trivial connected graphs, G is said to be *$\mathcal{H}$-free* if G is H-free for every $H \in \mathcal{H}$. The authors of this talk have previously proved that if $2 \leq |\mathcal{H}| \leq 3$ and there exists an integer $N = N(\mathcal{H})$ such that every graph G in the class of connected $\mathcal{H}$-free graphs of order $\geq N$ and minimum degree ≥ 2 contains a 2-factor, then one member of $\mathcal{H}$ is a star. In this talk, we determine the remaining elements in $\mathcal{H}$ and hence give a complete characterization of the pairs and triples of forbidden subgraphs that guarantee the existence of a 2-factor in this class. (Received January 15, 2016)

1117-05-239 **Jim Haglund**, **Jeff Remmel**, **Brendon Rhoades** and **Andy Wilson*** (andwils@math.upenn.edu). *Statistics on ordered set partitions.* Preliminary report.

We show that several statistics on ordered set partitions are equidistributed, generalizing MacMahon's classical theorem relating inversion number to major index. As a byproduct, we obtain a new bijective proof of MacMahon's theorem. By applying the RSK correspondence to our results, we produce the Schur expansion of a generalization of the Frobenius series of the type A coinvariant ring. (Received January 15, 2016)

1117-05-240 **Nicholas A. Loehr*** (nloehr@vt.edu), Virginia Tech Dept. of Mathematics, 225 Stanger Street, 460 McBryde Hall, Blacksburg, VA 24061-0123. *Variants of the RSK algorithm adapted to combinatorial Macdonald polynomials.* Preliminary report.

We introduce variations of the Robinson-Schensted-Knuth (RSK) algorithm parameterized by positive integers p. Each variation gives a bijection between permutations and pairs of standard tableaux of the same shape. In addition to sharing many of the properties of the classical RSK algorithm, the new algorithms are designed to be compatible with certain permutation statistics introduced by Haglund in the study of Macdonald polynomials. In particular, these algorithms provide an elementary bijective proof converting Haglund's combinatorial formula for Macdonald polynomials to an explicit combinatorial Schur expansion of Macdonald polynomials indexed by partitions μ satisfying $\mu_1 \leq 3$ and $\mu_2 \leq 2$. We challenge the research community to extend this RSK-based approach to more general classes of partitions. (Received January 15, 2016)

1117-05-241 **Anna Weigandt*** (weigndt2@illinois.edu), 1409 W. Green St, Urbana, IL 61801, and **Alexander Yong** (ayong@illinois.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 $\mathbb{Z}[x_1, x_2, \ldots]$. We suggest the "prism tableau model" for these polynomials. This alternative to earlier results directly invokes semistandard tableaux; it does so as part of a colored tableau amalgam. In the Grassmannian case, a prism tableau with colors ignored is a semistandard Young tableau. Our arguments are developed from the Gröbner geometry of matrix Schubert varieties. (Received January 15, 2016)

1117-05-258 **Baogang Xu** (baogxu@njnu.edu.cn), 1 Wenyuan Road, Nanjing, Jiangsu 210023, Peoples Rep of China, **Gexin Yu** (gyu@wm.edu), Department of Mathematics, The College of William and Mary, Williamsburg, VA 23185, and **Xiaoya Zha*** (xzha@mtsu.edu), Department of Mathematical Sciences, Middle Tennessee State University, Murfreesboro, TN 37132. *A note on chromatic number and induced odd cycles.*

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 $\chi(G) \leq 4$ and $\chi(G) \leq 3$ if G has radius at most 3. We also show that, for each vertex u of G, the set of vertices of the same distance to u induces a bipartite subgraph. This answers some questions by Plummer and Zha. (Received January 15, 2016)

1117-05-261 **Bo Lin** (linbo@berkeley.edu), **Bernd Sturmfels**, **XIaoxian Tang** and **Ruriko Yoshida*** (ruriko.yoshida@uky.edu). *Convexity in Tree Spaces.* Preliminary report.

We study the geometry of metrics and convexity structures on the space of phylogenetic trees, here realized as the tropical linear space of all ultrametrics. The CAT(0)-metric of Billera-Holmes-Vogtman arises from the theory of orthant spaces. While its geodesics can be computed by the Owen-Provan algorithm, geodesic triangles are complicated and can have arbitrarily high dimension. Tropical convexity and the tropical metric are better behaved,as they exhibit properties that are desirable for geometric statistics. (Received January 15, 2016)

1117-05-267 **Andrew J Wills*** (andrewwills@rmc.edu), Randolph-Macon College, Mathematics Department, 304 Henry Street, Ashland, VA 23005. *A combinatorial interpretation for Hall-Littlewood polynomials.*

Hall-Littlewood polynomials are symmetric polynomials that are closely related to Schur polynomials and Macdonald polynomials. This talk provides a combinatorial interpretation for antisymmetrized Hall-Littlewood polynomials using objects called abacus-tournaments. We give a bijective proof of a Pieri rule that expands the product of a Hall-Littlewood polynomial P_μ with an elementary symmetric polynomial e_k. (Received January 15, 2016)

1117-05-279 **Michael D. Plummer** (michael.d.plummer@vanderbilt.edu), Department of Mathematics, Vanderbilt University, Nashville, TN 37125, **Dong Ye*** (dong.ye@mtsu.edu), Department of Mathematical Sciences, Middle Tennessee State University, Murfreesboro, TN 37132, and **Xiaoya Zha** (xiaoya.zha@mtsu.edu), Department of Mathematical Sciences, Middle Tennessee State University, Murfreesboro, TN 37132. *On W_v-Paths in Polyhedral Maps on Surfaces.*

The W_v-path conjecture states that any two vertices of a simple polytope can be joined by a path that does not revisit any facet. This is equivalent to the well-known Hirsch Conjecture. Klee conjectured even more, namely that the W_v-conjecture is true for all general cell complexes. Klee proved that the W_v-conjecture is true for 3-polytope (3-connected plane graphs). The general W_v-path conjecture was verified for projective plane and torus by Barnette, and the Klein bottle by Pulapaka and Vince. Recently, however, Santos disproved the Hirsch conjecture.

For every surface Σ, define a function $f(\Sigma)$ such that if for every graph polyhedrally embedded in Σ and for every pair of vertices x and y in $V(G)$, $\kappa_G(x, y) \geq f(\Sigma)$, then there exists a W_v-path joining x and y. Let $\chi(\Sigma)$ be the Euler characteristic of Σ. We show that $f(\Sigma) = 3$ if Σ is the sphere, and for all other surfaces $3 - \tau(\Sigma) \leq f(\Sigma) \leq 9 - 4\chi(\Sigma)$, where $\tau(\Sigma) = \chi(\Sigma)$ if $\chi(\Sigma) < -1$ and 0 otherwise. Further, if x and y are not cofacial, we show that G has at least $\kappa_G(x, y) + 4\chi(\Sigma) - 8$ internally disjoint W_v-paths joining x and y. The bound is sharp for the sphere. (Received January 16, 2016)

1117-05-285 **Éva Czabarka*** (czabarka@math.sc.edu), **László A Székely** and **Stephan Wagner**. *Paths vs. trees in the local profile of trees.* Preliminary report.

We provide an affirmative answer to a recent question by Bubeck and Linial on the local profile of trees. For a tree T, let $p_1^{(k)}(T)$ be the proportion of paths among all k-vertex subtrees (induced connected subgraphs) of T, and let $p_2^{(k)}(T)$ be the proportion of stars. We show that if $T_1, T_2, \ldots$ is a sequence of trees whose size tends to infinity, then the following four are equivalent: $p_1^{(k)}(T_n) \to 0$; $p_2^{(k)}(T_n) \to 1$; the number of k-vertex subtrees grows superlinearly; and the $(k-1)$-st degree moment grows superlinearly. (Received January 16, 2016)

1117-05-300 **James B McKeown*** (mckeown@math.miami.edu), 1365 Memorial Drive, Ungar 528b, Coral Gables, FL 33146. *The Combinatorics of the Waldspurger Decomposition.* Preliminary report.

In 2005 J.L. Waldspurger proved a remarkable theorem. Given a finite reflection group G, the closed cone over the positive roots is equal to the disjoint union of images of the open weight cone under the action of $1-g$.

$$C_R = \bigsqcup_{g \in G} (1-g)\mathring{C}_W$$

When G is taken to be the symmetric group $\mathfrak{S}_n$ the decomposition is related to the familiar combinatorics of permutations but also has some surprising features. To see this, we give a nice combinatorial description of the cone $(1-g)\mathring{C}_w$ in terms of the permutation g. (Received January 16, 2016)

1117-05-301 **Miklos Bona*** (bona@ufl.edu), Department of Mathematics, Little Hall, Gainesville, FL 32611-8105, and **Boris G Pittel**. *Cayley graphs of permutations and the cycle structure of the product of maximal cycles.*

The Cayley graph of a permutation p is of central importance when computing the block interchange distance of p from the identity. That graph, in turn, is closely connected to the cycle structure of the random permutation σ of $[N]$, which is the product of k independent random cycles of maximal length N. Motivated by these facts, we use the character-based Fourier transform to study the number of cycles of σ and also the distribution of the elements of the subset $[\ell]$ among the cycles of σ. Some of our work provides new proofs for results of Stanley, Bernardi, and others, while some of our formulas are new. (Received January 16, 2016)

1117-05-304 **Guantao Chen*** (gchen@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303, and **Zhiquan Hu** and **Feifei Song**. *A degree condition for knitted graphs.*

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 $1 \le i \le t$. A graph G is called *ℓ-knitted* if (G, S) is knitted for all subsets S of $V(G)$ with $|S| = \ell$. Clearly, a $2k$-knitted graph is k-linked. In this talk, we give a new sufficient condition for ℓ-knitted graphs. Our result generalizes a sufficient degree condition for k-linked graphs obtained by Kawarabayashi, Kostochka and Yu. (Received January 16, 2016)

1117-05-313 **Shoichi Tsuchiya*** (s.tsuchiya@isc.senshu-u.ac.jp), 2-1-1 Higashimita, Tama-ku, Kawasaki-shi, Kanagawa 214-8580, Japan. *Maximal homeomorphically irreducible trees in P_6-free graphs.*

A tree with no vertices of degree two of a graph is called a *homeomorphically irreducible tree* (*HIST*) of the graph. In particular, if a HIT is a spanning tree, then it is called a *homeomorphically irreducible spanning tree* (*HIST*). If a graph G has no induced path of order i, then G is called a P_i-free graph. In 2013, it was proved that every connected P_4-free graph with order at least 6 and minimum degree at least 3 has a HIST. Later, it was proved that every connected P_5-free graph with order at least 8 and minimum degree at least 3 has a HIST. Thus one may consider that, for any integer $i \ge 4$, there exist positive integers n and m such that every connected P_i-free graph of order at least n with minimum degree at least m has a HIST. However, recently we found that there exists an infinite family of connected P_6-free graph without HIST even if we assume large order and minimum degree. In this talk, we show a theorem which guarantees a large HIT in a connected P_6-free graph, i.e., there exists a positive integer n_0 such that every connected P_6-free graph of order $n \ge n_0$ with minimum degree at least m has a HIT T of order at least $\frac{m}{m+1}n - 1$. (Received January 17, 2016)

1117-05-320 **Guantao Chen** and **Songling Shan***, songling.shan@vanderbilt.edu. *Vizing's 2-factor Conjecture Involving Large Maximum Degree (for consideration).*

Let G be a connected simple graph of order n and let $\Delta(G)$ and $\chi'(G)$ denote the maximum degree and chromatic index of G, respectively. Vizing proved that $\chi'(G) = \Delta(G)$ or $\Delta(G) + 1$. Following this result, G is called Δ-critical if $\chi'(G) = \Delta(G) + 1$ and $\chi'(G - e) = \Delta(G)$ for every $e \in E(G)$. In 1968, Vizing conjectured that if G is an n-vertex Δ-critical graph, then the independence number $\alpha(G) \leq n/2$. Furthermore, he conjectured that, in fact, G has a 2-factor. Luo and Zhao showed that if G is an n-vertexΔ-critical graph with $\Delta(G) \geq n/2$, then $\alpha(G) \leq n/2$. More recently, they showed that if G is an n-vertex Δ-critical graph with $\Delta(G) \geq 6n/7$, then G has a hamiltonian cycle, and so G has a 2-factor. We show that if G is an n-vertex Δ-critical graph with $\Delta(G) \geq n/2$, then G has a 2-factor. (Received January 17, 2016)

1117-05-323 **Peter Dankelmann*** (pdankelmann@uj.ac.za), Department of Pure and Applied Mathematics, University of Johannesburg, PO Box 524, Johannesburg, 2006, South Africa, and **Rocio M. Casablanca**. *Wiener index and average eccentricity of the strong product of graphs.*

The Wiener index $W(G)$ of a connected graph G is the sum of the distances between all unordered pairs of vertices. The average eccentricity of G is the arithmetic mean of the eccentricities of the vertices of G, where the eccentricity of a vertex v is the maximum of the distances from v to all other vertices of G.

A well-known result states that among all connected graphs of given order the path is the unique graph that maximises the Wiener index. Casablanca, Favaron and Kouider generalised this result: Consider for an arbitrary but fixed connected graph H the Wiener index of the strong product $W(G \boxtimes H)$, where G is chosen from a collection of graphs. If G is chosen from all connected graphs of order n, then $W(G \boxtimes H)$ is maximised if G is a path.

We generalise this result by showing that if G is chosen from all connected graphs of given order and size, then $W(G \boxtimes H)$ is maximised if G is a so-called path-complete graph. We further show that if G is chosen from all $2r$-connected graphs of given order, where $r \in \mathbb{N}$, then $W(G \boxtimes H)$ is maximised if G is the rth power of a cycle.

We give similar results on the average eccentricity of strong products. (Received January 17, 2016)

1117-05-334 **Chi Ho Yuen*** (cyuen7@math.gatech.edu). *Geometric Bijections Between Spanning Trees and Break Divisors.*

The Jacobian group $\mathrm{Jac}(G)$ of a finite graph G is a group whose cardinality is the number of spanning trees of G. The graph G also has a tropical Jacobian which has the structure of a real torus; using the notion of break divisors, one can obtain a polyhedral decomposition of the tropical Jacobian where vertices and cells correspond to the elements of $\mathrm{Jac}(G)$ and the spanning trees of G, respectively. In this talk, I will discuss some aspects of this decomposition, including new combinatorial bijections between spanning trees and $\mathrm{Jac}(G)$, some possible applications in algebraic geometry, and generalizations to regular matroids. (Received January 17, 2016)

1117-05-344 **Alexey Glazyrin*** (alexey.glazyrin@utrgv.edu), One West University Blvd, School of Mathematical & Statistical Sciences, BROWNSVILLE, TX 78520. *Strongly regular graphs and spherical configurations.*

In this talk I will discuss strongly regular graphs, point configurations on spheres they give rise to and various combinatorial and extremal problems connected with such configurations. (Received January 17, 2016)

1117-05-367 **J. Haglund*** (jhaglund@math.upenn.edu), **J. Remmel** and **Andrew Wilson**. *Symmetric function Identities associated to the Delta Conjecture.*

The Delta Conjecture gives a combinatorial prediction for the action of the Macdonald polynomial Delta operator on the nth elementary symmetric function. It contains the well-known Shuffle Conjecture as a special case. In this talk we discuss some of the symmetric function identities which are implied by this conjecture and its refinements. (Received January 18, 2016)

1117-05-370 **George E Andrews*** (gea1@psu.edu), Department of Mathematics, The Pennsylvania State University, University Park, PA 16802. *Implications of the Alladi-Schur Theorem.* Preliminary report.

In 1926, I. Schur proved that if A(n) equals the number of partitions of n into parts congruent to 1 or 5 modulo 6, and B(n) equals the number of partitions of n in which any two parts differ by at least 3 and multiples of 3 differ by more than 3, then A(n)=B(n). In the 1990's K. Alladi noted that if C(n) equals the number of partitions of n into odd parts none repeated more than twice, then also C(n)=B(n). Recently we proved the following refinement of the Alladi-Schur theorem: THEOREM. Let C(m,n) denote the number of partitions

among those enumerated by C(n) that have exactly m parts. Let B(m,n) denote the number of partitions among those enumerated by B(n) where the number of odd parts plus twice the number of even parts equals m. Then B(m,n)=C(m,n). In this talk, we support the contention that, of all the equivalent versions of Schur's original theorem, the Alladi-Schur theorem is the truly intrinsic version of the theorem. This will include a discussion of the implications for the study of partition identities of this nature. (Received January 18, 2016)

1117-05-372 **Daniel Alonzo Gray*** (dagray@georgiasouthern.edu). *Plane Binary Trees and Superpatterns for Layered Permutations.*

Let P be a set of permutation patterns. If τ is a permutation that contains every element of P as a pattern, then we say that τ is a P-superpattern. Since Arratia coined the term in 1999, there have been several investigations into the length of the shortest S_k-superpattern, where S_k is the set of permutations of length k. Here, we will construct superpatterns for layered permutations of length k and explore an interesting connection between this set of superpatterns and plane binary trees on k vertices. (Received January 18, 2016)

1117-05-373 **Hein van der Holst*** (hvanderholst@gsu.edu), Atlanta, GA 30303, and **Serguei Norine** and **Robin Thomas**. *Decomposing 2-cycles.*

For a graph $G = (V, E)$, a 2-cycle $A = [a_{e,f}]$ is an $E \times E$ matrix such that $a_{e,f} = 0$ if e and f have a common vertex, and each row and each column of A is a circulation on G. Examples of 2-cycles are 2-cycles coming from a pairs of disjoint cycles of G. Also on each subgraph of G that is a subdivision of K_5 or $K_{3,3}$, there is a 2-cycle. It had been a conjecture that each 2-cycle can be written as a sum of these types of 2-cycles. This has recently been disproved by Barnett. In this talk, we give a finite list of types of 2-cycles such that each 2-cycle is a sum of 2-cycles from this list. We also show that for Kuratowski-connected graphs, it suffices to have 2-cycles coming from pairs of disjoint cycles of G and 2-cycles on subgraphs of G that are subdivisions of K_5 or $K_{3,3}$. (Received January 18, 2016)

1117-05-377 **Joshua E Ducey*** (duceyje@jmu.edu). *On the critical group of a strongly regular graph.*

The critical group of a graph is an interesting isomorphism invariant that has been receiving much attention recently. Determining this group is equivalent to computing the Smith normal form of the Laplacian matrix of the graph. In this talk we demonstrate a technique that yields information about the critical group of any strongly regular graph. As an application, we learn much about the critical group of a hypothetical Moore graph of diameter 2 and valency 57. (Received January 18, 2016)

1117-05-379 **Joshua E Ducey*** (duceyje@jmu.edu), **Jonathan Gerhard** and **Noah Watson**. *The Smith and critical groups of the $n \times n$ Rook's graph and its complement.*

Let R_n denote the graph with vertex set consisting of the squares of an $n \times n$ grid, with two squares of the grid adjacent when they lie in the same row or column. This is the $n \times n$ Rook's graph, and can also be thought of as the Cartesian product of two complete graphs of order n, or the line graph of the complete bipartite graph $K_{n,n}$. In this talk we compute the Smith group and critical group of the graph R_n and its complement. This is equivalent to determining the Smith normal form of both the adjacency and Laplacian matrix of each of these graphs. In doing so we verify a 1986 conjecture of Rushanan. (Received January 18, 2016)

1117-05-401 **Mathieu Dutour Sikirić**, **Alexey Garber*** (alexey.garber@utrgv.edu), **Achill Schürmann** and **Clara Waldmann**. *Enumeration of five-dimensional Dirichlet-Voronoi parallelohedra.*

In this talk we will report about full classification of combinatorially different five-dimensional Dirichlet-Voronoi parallelohedra for lattices.

The classification of affinely different Delone triangulations (L-type domains) can be done using Voronoi's second reduction theory. It was done completely for small dimensions up to 5. Dimensions 3 and 4 can be done without using the reduction theory, but already in dimension 5 it plays an important for classification. The classification of five-dimensional L-type domains was made by E. Baranovskii and S. Ryshkov in 1973. They found 221 different triangulations, but later P. Engel in 1998 found that they missed one triangulation.

In this talk we will show how one can extend the Voronoi's reduction theory to find all affinely non-equivalent lattice Delone decompositions and combinatorially different Dirichlet-Voronoi parallelohedra in arbitrary dimension and present our computational results in dimension 5.

Our main result is the following. There are 110244 affine types of lattice Delone triangulations and 110244 combinatorial types of Dirichlet-Voronoi parallelohedra in dimension 5. (Received January 18, 2016)

1117-05-405 **Bing Wei*** (bwei@olemiss.edu), Department of Mathematics, University of Mississippi, University, MS 38677. *Multiplicative Zagreb indices of Cactus graphs.*

A graph is a **cactus** if it is connected and all of its blocks are either edges or cycles, i.e., any two of its blocks have at most one common vertex. The first **generalized** and second **Multiplicative Zagreb indices** of graph $G = (V, E)$ are defined as follows: for any real number $c > 0$, $\prod_{1,c}(G) = \prod_{v \in V(G)} d(v)^c$; and $\prod_2(G) = \prod_{uv \in E(G)} d(u)d(v) = \prod_{v \in V(G)} d(v)^{d(v)}$. In this talk, we will present some recent results on the upper and lower bounds of the first generalized and second multiplicative Zagreb indices for cacti. Using the degree sequences, we will also characterize cacti which attain the upper or lower bounds. This is joint work with Shaohui Wang. (Received January 18, 2016)

1117-05-409 **Eric S Egge*** (eegge@carleton.edu), Department of Mathematics and Statistics, Carleton College, Northfield, MN 55057. *A Chromatic Symmetric Function for Signed Graphs.* Preliminary report.

A *signed graph* is an ordinary graph in which each edge is assigned a sign ± 1. A *proper n-coloring* of a signed graph G is a coloring κ of the vertices of G such that if vertices v and w are connected by an edge with sign ϵ, then $\kappa(v) \neq \epsilon\kappa(w)$. In this situation there are two natural analogues of the usual chromatic polynomial: the *chromatic polynomial* $c_G(2n+1)$ counting proper colorings with colors $\{0, \pm 1, \pm 2, \ldots, \pm n\}$ and the *zero-free chromatic polynomial* $c_G^*(2n)$ counting proper colorings with colors $\{\pm 1, \pm 2, \ldots, \pm n\}$. I will discuss an analogue of Stanley's chromatic symmetric function for signed graphs in which the symmetric group is replaced by the group of signed permutations, which is sometimes called the hyperoctahedral group. (Received January 18, 2016)

1117-05-414 **Baogang Xu**, School of Mathematical Science, Nanjing, Jiangsu 210023, Peoples Rep of China, and **Xingxing Yu*** (yu@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *On judicious bisections of graphs.*

A *bisection* of a graph G is a bipartition S_1, S_2 of $V(G)$ such that $-1 \leq |S_1| - |S_2| \leq 1$. Bollobás and Scott conjectured that if G is a graph with m edges and minimum degree at least 2 then G admits a bisection S_1, S_2 such that $\max\{e(S_1), e(S_2)\} \leq m/3$. We confirm this conjecture and show that the triangle is the only extremal graph. Moreover, the bound $m/3$ cannot be improved to $(1/3 - \epsilon)m$, for any $\epsilon > 0$, by excluding K_3 or by increasing the minimum degree from 2 to 3. This is joint work with Baogang Xu (Received January 18, 2016)

1117-05-416 **Frank Sottile*** (sottile@math.tamu.edu), Department of Mathematics, Texas A&M University, College Station, TX 77843-3368, and **H. Praise Adeyemo**, Department of Mathematics, University of Ibadan, Ibadan, Oyo , Nigeria. *Equivariant Cohomology and the Pattern Map.*

Billey and Braden defined a geometric pattern map on flag manifolds which extends the generalized pattern map of Billey and Postnikov on Weyl groups. The interaction of this torus equivariant map with the Bruhat order and its action on line bundles lead to formulas for its pullback on the equivariant cohomology ring and on equivariant K-theory. These formulas are in terms of the Borel presentation, the basis of Schubert classes, and localization at torus fixed points. This is joint work with Praise Adeyemo of the University of Ibadan in Nigeria. (Received January 18, 2016)

1117-05-419 **Alexander Berkovich*** (alexb@ufl.edu), Mathematics Department, University of Florida, 358 Little Hall, Gainesville, FL. *On partitions with a fixed number of odd and even-indexed odd parts.*

This talk is about partitions with fixed number of odd and even-indexed odd parts. I show how to use these partitions to generalize recent results of C. Savage and A. Sills. Moreover, I discuss explicit formulas for generating functions for partitions with bounds on the largest part, the number of parts and with a fixed value of BG-rank or with a fixed value of alternating sum of parts.In addition I provide combinatorial interpretation of the Berkovich-Warnaar identity for Rogers-Szego polynomials. This talk is based on joint work with Ali Uncu. (Received January 18, 2016)

1117-05-420 **Bolor Turmunkh*** (turmunk2@illinois.edu). *Path model for Whittaker vectors of semi-simple Lie algebras.*

Whittaker vectors were defined by Kostant for semi-simple Lie algebras. Matrix elements between Whittaker vectors give rise to Whittaker functions, which hold an important place in the theory of special functions, integrable systems, field theories and the AGT conjecture. While Whittaker functions have been studied extensively, relatively little is known about Whittaker vectors. In this talk, I will give an explicit description of Whittaker

vectors of all semi-simple Lie algebras via a path model. One can recover properties of the Whittaker function from the path model as well. This is joint work with R. Kedem and P. Di Francesco. (Received January 18, 2016)

1117-05-426 **Patrik Norén*** (pgnoren2@ncsu.edu) and **Alexander Engström**. *Algebraic Graph Limits.* Preliminary report.

The theory of algebraic graph limits combine graph theory, real algebraic geometry and statistics.

The theory of graph limits or graphons is a powerful tool in for example extremal graph theory. The graph limits serves two purposes in parallel, they both encode many standard and non-standard random graph models, and they are the natural objects to compactify the space of graphs.

We study a certain subclass of graph limits that in a natural way correspond to polynomials. These algebraic graph limits have many desirable properties and in particular they can be used to study very large networks. (Received January 18, 2016)

1117-05-433 **Matthew R Just*** (mj00788@georgiasouthern.edu), 102 King Dr, Statesboro, GA 30458. *Pattern Containment in Various Words.*

Much work has been done regarding pattern containment in permutations, whether it be subsequence pattern avoidance or packing. For more general words such as preferential arrangements and compositions, more focus has been given to subword patterns and only recently have more general questions been posed. We give two generalizations of layered patterns in the context of preferential arrangements, discussing the roll of specific pattern structures on the structure of optimal words. A new class of patterns is defined for which past results can be utilized to solve the pattern packing problem. (Received January 18, 2016)

1117-05-440 **Gregory S Warrington***, Department of Mathematics & Statistics, University of Vermont, 16 Colchester Ave., Burlington, VT 05401, and **Nicholas A Loehr**. *Quasisymmetric expansions of cycle indices.* Preliminary report.

The cycle index of a subgroup G of S_n is known to be Schur positive by representation-theoretic reasons. As such, it has a positive expansion in terms of fundamental quasisymmetric functions. Such an expansion has a natural interpretation in terms of colorings for which the symmetries in G are taken into account. We derive the quasisymmetric expansions for certain subgroups G and discuss some of the issues that arise in attempting to determine a framework for arbitrary G. (Received January 18, 2016)

1117-05-444 **A Ram** and **M Yip***, martha.yip@uky.edu, and **M Yoo**. *Generalized Kostka polynomials.* Preliminary report.

We study a two-parameter generalization of the Kostka numbers in connection with Macdonald polynomials. In the case of Kostka numbers indexed by partitions of three rows or less, we give a combinatorial formula for computing these in terms of alcove walks. This is joint work with A. Ram and M. Yoo. (Received January 18, 2016)

1117-05-470 **Csaba Biro***, Department of Mathematics, University of Louisville, Louisville, KY 40292, and **Stephen J Young**. *Subdivisions of cover graphs of posets.* Preliminary report.

The dimension of a poset is the least integer d such that the poset can be embedded into $\mathbb{R}^d$. In the recent years a number of results were published along the idea, that if a poset has a simple enough cover graph, then its dimension can not be too large. On the other hand, in 1988, Spinrad proved that the dimension of a poset can be increased arbitrarily by subdividing edges in its cover graph. However, if the cover graph has no K_4 minor, this is no longer true. In this paper we find an upper bound for the dimension of a subdivison of a poset with K_4-free cover graphs in terms of the dimension of the poset. (Received January 19, 2016)

1117-05-480 **V. Nikiforov*** (vnikifrv@memphis.edu), University of Memphis, 373 Dunn Hall, Memphis, TN 38152. *Extrema of graph eigenvalues.*

In 1993 Hong asked what are the best bounds on the k-th largest eigenvalue of a graph G of order n. This challenging question has never been tackled for $2 < k < n$. In this talk some tight bounds are outlined for all $k > 2$, and even tighter bounds are outlined for the k-th largest singular value of G. Some of these bounds are based on Taylor's strongly regular graphs, and others on a method of Kharaghani for constructing Hadamard matrices. A few open problems will be stated. (Received January 19, 2016)

1117-05-493 **Rachel Bass*** (rb06280@georgiasouthern.edu), Mathematical Sciences, Georgia Southern University, Statesboro, GA 30460. *Functions on adjacent vertex degrees of trees and majorization.*

We consider a function on adjacent degrees of a tree, T, to be $f(x, y)$ and the connectivity function associated with f, $R_f(T) = \sum_{uv \in E(T)} f(deg(u), deg(v))$. We first introduce the extremal tree structures, with a given degree sequence, that maximize or minimize such functions. When a partial ordering, called "majorization", is defined on the degree sequences of trees on n vertices, we compare the extremal trees of different degree sequences π and π'. This results in many extremal results as immediate consequences. We will also briefly discuss these applications. (Received January 19, 2016)

1117-05-499 **Selvi Beyarslan*** (sbeyarsl@tulane.edu), Tulane University, Department of Mathematics, 6823 St. Charles Ave., New Orleans, LA 70118, and **Ali Alilooee**, **Arindam Banerjee** and **Huy Tai Ha**. *An Optimal Upper Bound on the Regularity of Powers of Edge Ideals.* Preliminary report.

Let G be a graph and let $I(G)$ be its edge ideal. In this talk, we give the following upper bound for the regularity of powers of edge ideals

$$\operatorname{reg} I^s \leq 2(s-1) + \operatorname{reg}(I)$$

for any graph G and for $s \geq 1$. Then we partially answer the question that for which classes of graphs $\operatorname{reg} I(G)^s = 2s + \nu(G) - 1$. (Received January 19, 2016)

1117-05-501 **John Shareshian*** (shareshi@math.wustl.edu), One North Brookings Drive, St Louis, MO 63130, and **Michelle Wachs**. *Chromatic quasisymmetric functions and regular semisimple Hessenberg varieties, Part 2.*

We defined a refinement of Stanley's chromatic symmetric function and conjectured that, for certain graphs G, our symmetric function is the Frobenius characteristic of a representation of the symmetric group on the cohomology of a variety naturally associated to G. Our conjecture was proved recently by P. Brosnan and T. Chow. We will discuss some combinatorial and representation theoretic consequences of this result and some remaining problems. (Received January 19, 2016)

1117-05-511 **Ali Kemal Uncu*** (akuncu@ufl.edu), University of Florida, Department of Mathematics, Gainesville, FL 32611. *Four Parameter Generalization of Gaussian Polynomials.*

I start this talk by introducing Stanley–Boulet weights for decorated Ferrers Diagrams. I will find generating functions for weighted partitions with bounds on the largest part and the number of parts. These generating functions depend on four parameters a, b, c, and d. In the case a=b=c=d, we get classical Gaussian polynomials. This talk is based on a recent joint work with Alexander Berkovich. (Received January 19, 2016)

1117-05-517 **Joshua Cooper***, 1523 Greene St., Columbia, SC 29208, and **Jeffrey Davis**. *Successful Pressing Sequences for a Bicolored Graph and Binary Matrices.*

We apply matrix theory over GF(2) to understand the nature of so-called "successful pressing sequences" of black-and-white vertex-colored graphs. These sequences arise in computational phylogenetics, where, by a celebrated result of Hannenhalli and Pevzner, the space of sortings-by-reversal of a signed permutation can be described by pressing sequences. In particular, we offer several alternative linear-algebraic and graph-theoretic characterizations of successful pressing sequences, describe the relation between such sequences, and provide bounds on the number of them. We also offer several open problems that arose as a result of the present work. (Received January 19, 2016)

1117-05-520 **Kevin G Milans*** (milans@math.wvu.edu). *Monotone paths in dense edge-ordered graphs.*

In a graph whose edges are are totally ordered, a *monotone path* is a path that traverses edges in increasing order. Let $f(G)$ be the minimum, over all total orderings of $E(G)$, of the maximum length of a monotone path in G. In 1973, Graham and Kleitman proved that $f(K_n) \geq (\sqrt{4n-3} - 1)/2$. The best known upper bound on $f(K_n)$ is due to Calderbank, Chung, and Sturtevant, who proved that $f(K_n) \leq \left(\frac{1}{2} + o(1)\right) n$ in 1984. We show that $f(K_n) \geq \Omega((n/\log n)^{2/3})$. (Received January 19, 2016)

1117-05-524 **John Shareshian** and **Michelle Wachs*** (wachs@math.miami.edu). *Chromatic quasisymmetric functions and regular semisimple Hessenberg varieties, Part I.*

We defined a refinement of Stanley's chromatic symmetric function and conjectured that, for certain graphs G, our symmetric function is the Frobenius characteristic of a representation of the symmetric group on the

cohomology of a variety naturally associated to G. Our conjecture was proved recently by T. Chow and P. Brosnan. We will discuss some combinatorial and representation theoretic consequences of this result and some remaining problems. (Received January 19, 2016)

1117-05-527 **Anton Dochtermann*** (dochtermann@math.utexas.edu), 2313 E 11th Street, Austin, TX 78702. *G-parking function ideals, lattice points, and free resolutions.* Preliminary report.

Associated to a graph G, Postnikov and Shapiro introduced a monomial ideal M_G whose standard monomials are in bijection with G-parking functions. The ideal M_G has close connections to commutative algebra of the abelian sandpile model (or 'chip-firing' on G) via Gröbner degeneration. We study related monomial ideals that arise from lattice points of the associated graphical zonotope, and show how to recover resolutions of M_G for various monomial orders. This leads to combinatorial interpretations of Betti numbers as well as generalizations to other polymatroidal contexts. Part of this is joint work with Raman Sanyal. (Received January 19, 2016)

1117-05-530 **Christian Barrientos** and **Sarah Minion*** (sminion@student.clayton.edu). *Broader Families of Cordial Graphs.*

A binary labeling of the vertices of a graph G is cordial if the number of vertices labeled 0 and the number of vertices labeled 1 differ by at most 1, and the number of edges of weight 0 and the number of edges of weight 1 differ by at most 1. We present general results involving the cordiality of graphs that results of some well-known operations such as the join, the corona, the one-point union, the splitting graph, and the supersubdivision. In addition we show a family of cordial circulant graphs. (Received January 19, 2016)

1117-05-536 **Angela S. Hicks***, ashicks@stanford.edu. *A Symmetric function from a Sandpile model.*

We will introduce two (not obviously related) statistics on recurrent configurations in the sandpile model for the complete graph. Summing over these recurrent configurations, looking at a q-t weight by these statistics, we get a q-t symmetric polynomial. After assigning a set to each recurrent configuration in a natural way, we can add a Gessel quasisymmetric function to each term; the result is surprisingly schur positive. We'll discuss the indirect proof, as well as how it significantly simplifies the proof of a similar conjecture of Dukes and LeBorgne about recurrent configurations in complete bipartite graphs. (Received January 19, 2016)

1117-05-542 **Vijay Jung Kunwar*** (vijay.kunwar@asurams.edu), 504 College Drive, Albany, GA 31705, and **Mark van Hoeij** (hoeij@math.fsu.edu), 1017 Academic Way, Tallahassee, FL 32306. *On Completeness of the Table of Belyi maps with Five Exceptional Points.*

Belyi maps play a crucial role on finding hypergeometric solutions of linear differential equations. Such maps ramify only above 0,1, and infinity. This property gives us a way to compute all Belyi maps (up to Mobius transformation) with n exceptional points. A complete table of such Belyi maps can be used to develop a differential solver to solve a class of linear differential equations with n regular singularities.

In this presentation, we will explain the completeness of the table of Belyi maps with five exceptional points using the 1-1 correspondence between Belyi maps (up to Mobius transformation), dessin d'enfants (up to homeomorphism), and 3-constellations (up to conjugation). (Received January 19, 2016)

1117-05-546 **Jay Schweig** and **Russ Woodroofe*** (rw1003@msstate.edu). *A broad class of shellable lattices.*

Motivated by the problem of shelling the order congruence lattices of finite posets, we have discovered a new broad class of shellable lattices. The definition of the class is, viewed from one perspective, a purely lattice-theoretic analogue of (the subgroup lattice of) a solvable group. Our construction gives a unified proof of shellability for many of the known examples of shellable lattices.

I'll describe the class of lattices, then explain why many subposets of the partition lattice are in this class. This is joint work with Jay Schweig. (Received January 20, 2016)

06 ► Order, lattices, ordered algebraic structures

1117-06-188 **Jason R Elsinger*** (jelsinger@shc.edu), 6700 Wall Street, Mobile, AL 36695. *Orbifolds of lattice vertex algebras under an isometry of order two: irreducible modules, quantum dimensions, and fusion rules.*

Every isometry σ of a positive-definite even lattice Q can be lifted to an automorphism of the lattice vertex algebra V_Q. An important problem in vertex algebra theory and conformal field theory is to classify the representations of the σ-invariant subalgebra V_Q^σ of V_Q, known as an orbifold. In the case when σ is an isometry of Q of order two, we have classified the irreducible modules of the orbifold vertex algebra V_Q^σ and identified them as submodules

of twisted or untwisted V_Q-modules. Here we also investigate their quantum dimensions and fusion rules. The example where Q is a direct sum of two copies of the root lattice A_2 and σ is the permutation automorphism are presented in detail. (Received January 13, 2016)

11 ► Number theory

1117-11-21 **John W Jones*** (jj@asu.edu), SoMSS, PO Box 871804, Tempe, AZ 85287. *The L-functions and Modular Forms Database.* Preliminary report.

We will discuss the LMFDB, a large-scale collaborative project which provides a web interface to data and information relevant to modern number theory. The data includes Cremona's tables of elliptic curves, our tables of local and global fields, automorphic forms of several types, and L-functions. It has already been used to help mathematicians make and test conjectures, and generally makes various complicated abstract objects and conjectures more concrete and accessible. (Received November 20, 2015)

1117-11-35 **Michael J. Mossinghoff*** (mimossinghoff@davidson.edu), Department of Mathematics & Computer Science, Davidson College, Box 6996, Davidson, NC 28035-6996, and **Timothy S. Trudgian** (timothy.trudgian@anu.edu.au), Mathematical Sciences Institute, Australian National University, Canberra, ACT 0200, Australia. *Oscillations in sums involving the Liouville function.* Preliminary report.

The Liouville function $\lambda(n)$ is the completely multiplicative arithmetic function defined by $\lambda(p) = -1$ for each prime p. Pólya investigated its summatory function $L(x) = \sum_{n \le x} \lambda(n)$, and showed for instance that the Riemann hypothesis would follow if $L(x)$ never changed sign for large x. While it has been known since the work of Haselgrove in 1958 that $L(x)$ changes sign infinitely often, oscillations in $L(x)$ and related functions remain of interest in analytic number theory. We describe some recent experimental work that establishes new bounds on the magnitude of the oscillations of $L(x)$ and its relatives. (Received December 19, 2015)

1117-11-41 **A.C. Cojocaru*** (math.cojocaru@gmail.com), 851 S Morgan St, SEO 322, Chicago, IL 60607, **R. Davis**, West Lafayette, IN 47907, **K.E. Stange**, Boulder, CO 80305, and **A. Siverberg**, Irvine, CA 92697. *Arithmetic properties of the Frobenius traces of an abelian variety.*

Given an abelian variety A/Q, with a trivial endomorphism ring (over the algebraic closure of Q), we investigate the arithmetic properties of the coefficients of the p-Weil polynomials of A, as p varies. (Received December 22, 2015)

1117-11-52 **Ken Ono** and **Sarah Trebat-leder*** (strebat@emory.edu). *The* 1729 $K3$ *Surface.*

We revisit the mathematics that Ramanujan developed in connection with the famous "taxi-cab" number 1729. A study of his writings reveals that he had been studying Euler's diophantine equation

$$a^3 + b^3 = c^3 + d^3.$$

It turns out that Ramanujan's work anticipated deep structures and phenomena which have become fundamental objects in arithmetic geometry and number theory. We find that he discovered a $K3$ surface with Picard number 18, one which can be used to obtain infinitely many cubic twists over $\mathbb{Q}$ with rank ≥ 2. (Received December 27, 2015)

1117-11-56 **M Apagodu*** (mapagodu@vcu.edu), 1015 Floyd Avenue, Richmond, VA 23284, and **D Zeilberger**. *Extending the Chen-Hou-Zeilberger method for automatic discovery of Congruence Theorems for Combinatorial Sequences from Single Sums to Multiple Sums.* Preliminary report.

Bill Chen, Qing-Hu Hou and Doron Zeilberger have recently developed an efficient algorithm for discovering, and proving, congruence theorems, modulo primes, of indefinite (single) sums of combinatorial sequences that (like the Central Binomial, Catalan, and Motzkin numbers) may be defined as constant terms of powers of Laurent polynomials of a single variable. They also proved a general theorem linking them to C-finite sequences. In the present work, we extend this work in two directions. Instead of only single summation, we consider multiple summation, and instead of combinatorial sequences defined as constant terms of powers of Laurent polynomials of a single variable, we can handle Laurent polynomials of several variables. We also extend the above theorem where C-finite sequences give way to Holonomic sequences. An important tool is the Apagodu-Zeilberger multi-variable extension of the Almkvist-Zeilberger algorithm. (Received December 29, 2015)

1117-11-70 **Kestutis Cesnavicius*** (kestutis@berkeley.edu), Department of Mathematics, University of California Berkeley, 987 Evans Hall, Berkeley, CA 94703, and **Naoki Imai**. *The remaining cases of the Kramer–Tunnell conjecture.*

For an elliptic curve E over a local field K and a separable quadratic extension of K, motivated by connections to the Birch and Swinnerton-Dyer conjecture, Kramer and Tunnell have conjectured a formula for computing the local root number of the base change of E to the quadratic extension in terms of a certain norm index. The formula is known in all cases except some when K is of characteristic 2, and we complete its proof by reducing the positive characteristic case to characteristic 0. For this reduction, we exploit the principle that local fields of characteristic p can be approximated by finite extensions of $\mathbb{Q}_p$—we find an elliptic curve E' defined over a p-adic field such that all the terms in the Kramer–Tunnell formula for E' are equal to those for E. (Received December 31, 2015)

1117-11-85 **Amita Malik** and **Armin Straub*** (straub@southalabama.edu). *Divisibility properties of sporadic Apéry-like numbers.*

Apéry-like numbers are special integer sequences, going back to Beukers and Zagier, which are modelled after and share many of the properties of the numbers that underlie Apéry's proof of the irrationality of $\zeta(3)$. Among their remarkable properties are connections with modular forms and a number of p-adic properties, some of which remain conjectural. A result of Gessel shows that Apéry's sequence satisfies Lucas congruences. We prove corresponding congruences for all sporadic Apéry-like sequences. While, in several cases, we are able to employ approaches due to McIntosh, Samol–van Straten and Rowland–Yassawi to establish these congruences, there is one sequence in particular, often labeled (η), for which we require a finer analysis. As an application, we investigate modulo which numbers these sequences are periodic. In particular, we show that the Almkvist–Zudilin numbers are periodic modulo 8, a special property which they share with the Apéry numbers. (Received January 04, 2016)

1117-11-101 **Byungchul Cha**, cha@muhlenberg.edu, **Daniel Fiorilli***, daniel.fiorilli@uottawa.ca, and **Florent Jouve**, Florent.Jouve@math.u-psud.fr. *Chebyshev's bias for elliptic curves over function fields.*

Since Chebyshev's observation that there seems to be more primes of the form $4n+3$ than of the form $4n+1$, many other types of 'arithmetical biases' have been found. Mazur and Sarnak observed such a bias in the count of points on reductions of a fixed elliptic curve E; this bias is mainly created by the analytic rank. In this talk we will discuss the analogous question for elliptic curves over function fields. We will first discuss the occurrence of extreme biases, which originate from very different source than in the number field case. Secondly, we will discuss what happens to a 'typical curve', and discuss results of linear independence of the zeros of the associated L-functions. (Received January 05, 2016)

1117-11-137 **Filip Najman*** (fnajman@math.hr), PMF-Matematicki odsjek, Bijenicka cesta 30, 10000 Zagreb, Croatia. *Torsion of elliptic curves over number fields.*

Torsion of elliptic curves over number fields

We will give an overview of known results about the torsion of elliptic curves over number fields, focusing on recent developments in the subject. (Received January 10, 2016)

1117-11-144 **Michael H. Mertens***, 400 Dowman Drive, Atlanta, GA 30322. *Automorphism Groups of Hyperbolic Lattices.*

Based on the concept of dual cones introduced by J. Opgenorth we give an algorithm to compute a generating system of the group of automorphisms of an integral lattice endowed with a hyperbolic bilinear form. (Received January 11, 2016)

1117-11-200 **Ruthi Hortsch*** (rhortsch@math.mit.edu), Department of Mathematics, 2-239A, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139. *Elliptic curves of bounded Faltings height.*

Previous results on counting elliptic curves over $\mathbb{Q}$ have used the naive height, which is tractable but less intrinsically defined than the Faltings height. Although the (exponential) Faltings height and naive height are related, the naive height is not bounded by a constant times the Faltings height, so these results do not apply to the Faltings height.

We count elliptic curves over $\mathbb{Q}$ using the Faltings height. Using a theorem of Silverman, we recast the problem as one of counting lattice points in a particular unbounded region with boundaries given by transcendental curves, and the difficulty then lies in understanding this region. (Received January 13, 2016)

1117-11-206 **Michael Filaseta*** (filaseta@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *Roots of polynomials with integer coefficients.* Preliminary report.

Let $f(x) = a_n x^n + \cdots + a_1 x + a_0 \in \mathbb{Z}[x]$ for which $\deg f = n > 0$ and $|a_0| = 1$. Then it is not difficult to see that $f(x)$ must have a root inside the unit disk $\{z \in \mathbb{C} : |z| \leq 1\}$. The simple argument for this using that the product of the roots of $f(x)$ is $\pm 1/a_n$ has little to do with the condition that the coefficients of $f(x)$ are in $\mathbb{Z}$. It is reasonable to question then whether this condition could imply more structure about the roots of $f(x)$ and what that structure might be. This talk will explore some of this structure and some applications which led to a particular interest in these investigations. (Received January 13, 2016)

1117-11-221 **Álvaro Lozano-Robledo*** (alvaro.lozano-robledo@uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269-6076, and **Enrique González-Jiménez**, Universidad Autonoma de Madrid, Spain. *On the minimal degree of definition of p-primary torsion subgroups of elliptic curves.*

In this talk, we discuss the minimal degree $[K(T) : K]$ of a p-subgroup $T \subseteq E(\overline{K})_{\text{tors}}$ for an elliptic curve E/K defined over a number field K. Our results depend on the shape of the image of the p-adic Galois representation $\rho_{E,p^\infty} : \text{Gal}(\overline{K}/K) \to \text{GL}(2, \mathbb{Z}_p)$. However, we are able to show that there are certain uniform bounds for the minimal degree of definition of T. When the results are applied to $K = \mathbb{Q}$ and $p = 2$, we obtain a divisibility condition on the minimal degree of definition of any subgroup of $E[2^n]$ that is best possible. This is joint work with Enrique González-Jiménez (UAM). (Received January 14, 2016)

1117-11-226 **Andrew V Sutherland*** (drew@math.mit.edu) and **David Zywina**. *Modular curves of prime-power level with infinitely many rational points.*

For each prime power N and subgroup G of $\text{GL}_2(\mathbb{Z}/N\mathbb{Z})$ containing $-I$ with surjective determinant map, let $X_G/\mathbb{Q}$ denote the modular curve that parametrizes elliptic curves whose mod-N Galois representation has image contained in G. We determine a complete list of the 248 modular curves X_G for which $X_G(\mathbb{Q})$ is infinite and construct explicit maps from each X_G to the j-line. In addition to $X(1)$ this list includes 219 modular curves of genus 0 with $N \in \{2, 3, 4, 5, 7, 8, 9, 13, 16, 25, 27, 32\}$, and 28 of genus 1 with $N \in \{11, 16\}$. For each prime ℓ these results provide an explicit classification of $\overline{\mathbb{Q}}$-isomorphism classes of elliptic curves $E/\mathbb{Q}$ according to their ℓ-adic Galois image, up to a finite set of exceptional j-invariants. (Received January 14, 2016)

1117-11-276 **Jennifer Park** (jmypark@umich.edu), **Bjorn Poonen** (poonen@mit.edu), **John Voight*** (jvoight@gmail.com) and **Melanie Matchett Wood** (mmwood@math.wisc.edu). *A heuristic for boundedness of ranks of elliptic curves.*

We present a heuristic that suggests that ranks of elliptic curves E over the rational numbers are bounded. In fact, it suggests that there are only finitely many E of rank greater than 21. Our heuristic is based on modeling the ranks and Shafarevich–Tate groups of elliptic curves simultaneously, and relies on a theorem counting alternating integer matrices of specified rank. We also discuss analogues for elliptic curves over other global fields. (Received January 16, 2016)

1117-11-295 **T. Alden Gassert** and **Katherine E. Stange*** (kstange@math.colorado.edu). *Monogeneity of division fields.* Preliminary report.

Let K be an elliptic division field: a number field generated by the coordinates of the n-torsion points on an elliptic curve. I will discuss work in progress concerning whether the ring of integers of K has a power basis. The main tools are an algorithm of Guàrdia, Montes and Nart, combined with an analysis of the valuations of division polynomials. (Received January 16, 2016)

1117-11-310 **Amod Agashe*** (agashe@math.fsu.edu). *Conjectures concerning the orders of the torsion subgroup, the arithmetic component groups, and the cuspidal subgroup.*

We shall talk about some conjectures that we have made based on numerical evidence concerning the relations between the orders of the torsion subgroup, the arithmetic component groups, and the cuspidal subgroup of an optimal elliptic curve. These conjectures have implications for the second part of the Birch and Swinnerton-Dyer conjecture. (Received January 17, 2016)

1117-11-314 **Eric Katz*** (eekatz@uwaterloo.ca), 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada. *Tropical geometry and torsion point bounds.*

We discuss how tropical geometry techniques can be used to bound the number of torsion points on algebraic curves. We describe our recent progress towards a uniform bound in terms of the first prime of compact type

reduction or the first prime of really awful reduction. This is joint work with Taylor Dupuy, Joseph Rabinoff, and David Zureick-Brown. (Received January 17, 2016)

1117-11-326 **Frank G. Garvan*** (fgarvan@ufl.edu). *Dyson's Conjectures and Predictions in the Work of Ramanujan.*

Let $p(n)$ be the number of partitions of n. Ramanujan proved that $p(5n+4)$ is always divisible by 5 and that $p(7n+5)$ is always divisible by 7. In 1944 Dyson defined the rank of a partition as the largest part minus the number of parts. Dyson conjectured that the residue of the rank mod 5 divides the partitions of $5n+4$ into 5 equal classes, and that the residue of the rank mod 7 divides the partitions of $7n+5$ into 7 equal classes, thus giving combinatorial refinements of Ramanujan's partition congruences. Dyson's rank conjectures were proved by Atkin and Swinnerton-Dyer in 1953. Atkin and Swinnerton-Dyer's main theorem is buried in an identity in Ramanujan's Lost Notebook. We show how this identity of Ramanujan can be extended to all primes greater than 3. It is also related to Dyson's 1987 prediction that there should be a group-theoretical structure, analogous to the structure of Hecke's theory of modular forms, for Ramanujan's mock-theta functions. In 2000 Zwegers made the breakthrough of realizing Ramanujan's mock theta functions as the holomorphic part of harmonic Maass forms. We extend Bringmann and Ono's work on Dyson's challenge, and show how experimental mathematics has played a crucial role. (Received January 17, 2016)

1117-11-378 **Christopher Rasmussen*** (crasmussen@wesleyan.edu), Dept. of Mathematics & Computer Science, 265 Church Street, Middletown, CT 06459, and **Akio Tamagawa**, Research Institute for Mathematical Sciences, Kyoto University, Kyoto, Japan. *Abelian surfaces good away from 2.*

Fix a prime number ℓ and a number field k, and consider abelian varieties whose ℓ-power torsion generates a pro-ℓ extension of $k(\mu_{\ell^\infty})$ which is unramified away from ℓ. It is a necessary, but not generally sufficient, condition that such varieties have good reduction away from ℓ.

In the special case of $\ell = 2$, we demonstrate that for abelian surfaces over $\mathbf{Q}$, good reduction away from ℓ does suffice. The result is extended to elliptic curves and abelian surfaces over certain number fields of low degree. We conclude with an explicit example to demonstrate that good reduction is not sufficient, at $\ell = 2$, for abelian varieties of sufficiently high dimension. (Received January 18, 2016)

1117-11-387 **Nathan Jones*** (ncjones@uic.edu), University of Illinois at Chicago, MSCS Dept., 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60607, and **Ken McMurdy** (kmcmurdy@ramapo.edu). *Elliptic curves with non-abelian entanglements.*

Let K be a number field. An elliptic curve E/K is said to have a non-abelian entanglement if there are relatively prime positive integers, m_1 and m_2, such that $K(E[m_1]) \cap K(E[m_2])$ is a non-abelian Galois extension of K. In this talk, we will discuss our ongoing efforts to classify, using explicit methods, all infinite families of elliptic curves E/K, for a fixed K, with non-abelian entanglements. This problem is closely related to that of determining when the image of ρ_E in $GL_2(\hat{\mathbb{Z}})$ is maximal, and to the study of correction factors for various conjectural constants for elliptic curves over $\mathbb{Q}$. (Received January 18, 2016)

1117-11-395 **Jeremy Rouse** and **David Zureick-Brown*** (dzb@mathcs.emory.edu), 400 Dowman Drive, Atlanta, GA 30322. *Progress on Mazur's program B.*

I'll discuss recent progress on Mazur's "Program B", including my own recent work with Jeremy Rouse which completely classifies the possibilities for the 2-adic image of Galois associated to an elliptic curve over the rationals, and will also discuss a large number of other very recent results by many authors. (Received January 18, 2016)

1117-11-400 **Anastassia Etropolski*** (aetropo@emory.edu), **David Zureick-Brown** and **Jackson Morrow**. *Sporadic Torsion on Elliptic Curves.*

In Mazur's celebrated 1978 Inventiones paper, he classifies the torsion subgroups which can occur in the Mordell-Weil group of an elliptic curve over $\mathbf{Q}$. His result was extended to elliptic curves over quadratic number fields by Kamienny, Kenku, and Momose, with the full classification being completed in 1992. What both of these cases have in common is that each subgroup in the classification occurs for infinitely many elliptic curves, but this no longer holds for cubic number fields. In 2012, Najman showed that there exists an elliptic curve whose torsion subgroup over a particular cubic field is $\mathbf{Z}/21$. This was the first "sporadic" example, because the modular curve $X_1(21)$ classifying such elliptic curves has only finitely many cubic points, therefore there can only be finitely many such curves. In this talk, we will recall what is known so far and introduce new results about sporadic points on the modular curves $X_1(N)$ and $X_1(M,N)$. (Received January 19, 2016)

1117-11-402 **Michael Y. Chou*** (michael.chou@uconn.edu), Department of Mathematics, 196 Auditorium Road, University of Connecticut, Storrs, CT 06269-3009. *Torsion of rational elliptic curves over quartic Galois number fields.*

The classification of the torsion subgroup of elliptic curves over $\mathbb{Q}$ was determined by Mazur. The classification over quadratic number fields was completed due to work of Kamienny, Kenku, and Momose. However, over cubic fields the classification is already incomplete. In this talk we discuss a refined version of this problem: let E be an elliptic curve defined over $\mathbb{Q}$ and K be a number field of degree d; what groups appear as $E(K)_{\text{tors}}$? In particular, we will present a classification over all quartic Galois number fields K and show how the techniques used may be applied to other fields. (Received January 18, 2016)

1117-11-487 **Nicolas Allen Smoot*** (ns02570@georgiasouthern.edu), 114 Blue Heron Court, Richmond Hill, GA 31324. *A Partition Function Connected With the Göllnitz–Gordon Identities.* Preliminary report.

In 1918, Hardy and Ramanujan applied their famous circle method to obtain a remarkable asymptotic formula for the unrestricted partition function. Following later improvements by Rademacher, the method was utilized by Niven, Lehner, Iseki, and others to develop rapidly convergent series representations of various restricted partition functions. Following in this tradition, we use the circle method to develop and study formulæ for counting a restricted class of partitions associated with the Göllnitz–Gordon identities. (Received January 19, 2016)

1117-11-510 **Robert Schneider*** (robert.schneider@emory.edu), Dept. of Mathematics and Computer Science, Emory University, Atlanta, GA 30322. *Arithmetic of partitions.*

We present a natural multiplicative theory of integer partitions (which are usually considered in terms of addition), and find many theorems of classical number theory arise as particular cases of extremely general combinatorial structure laws. (Received January 19, 2016)

12 ► Field theory and polynomials

1117-12-112 **Victoria Powers***, Dept. of Mathematics and Computer Science, Emory University, Atlanta, GA 30322. *Certificates of positivity for polynomials nonnegative on compact semialgebraic sets in the plane.*

Suppose S is a basic closed semialgebraic set in $\mathbb{R}^n$, i.e., a set defined by finitely many nonstrict polynomial inequalities, and a polynomial f with real coefficients is positive, or non-negative, on S. By a **certificate of positivity for f on S** we mean an algebraic expression for f, usually involving sums of squares of real polynomials, from which one can deduce the positivity condition immediately. The theory and practice of such certificates has a long and rich history, going back to work of Hilbert in the late 19th century. Recently, there has been much interest in the subject due to many applications in both pure and applied mathematics. In this talk, we will discuss certificates of positivity for compact basic closed semialgebraic sets in $\mathbb{R}^2$, particularly compact polyhedra. (Received January 06, 2016)

13 ► Commutative rings and algebras

1117-13-64 **Alexandra Seceleanu*** (aseceleanu@unl.edu). *The Waldschmidt constant for squarefree monomial ideals.*

The Waldschmidt constant is an asymptotic invariant associated to a homogeneous ideal. It measures the rate of growth of the initial degree of the symbolic powers of the given ideal. The study of Waldschmidt constants is motivated by geometric considerations, i.e. estimating the lowest degree of a hypersurface vanishing at all the points of a variety to a given order.

In this talk, we give several combinatorial interpretations for the Waldschmidt constant of a squarefree monomial ideals. While Waldschmidt constants are generally very difficult to compute, this will allow us to determine them completely in several important cases and to prove a useful general lower bound conjectured by Cooper-Embree- Hà-Hoefel. This is joint work with C. Bocci, S. Cooper, E. Guardo, B. Harbourne, M. Janssen, U. Nagel, A. Van Tuyl and T. Vu. (Received December 31, 2015)

1117-13-127 **Craig Huneke** and **Ilya Smirnov*** (ismirnov@umich.edu), Department of Mathematics, University of Michigan, 530 Church Street, 2074 East Hall, Ann Arbor, MI 48109. *Prime filtrations of the powers of an ideal.*

Let I be an ideal in a noetherian ring R. It is known for a long time that the set $\cup AssR/I^n$, i.e. the set of all prime ideals that appear as an associated prime of R/I^n for some n, is finite.

Generalizing this classical result I will show that it is possible to choose prime filtrations of all powers R/I^n such that the set of prime ideals that appear in those filtrations is still finite. This result was motivated by the following corollary: in an excellent ring R the intersection of the Cohen-Macaulay loci of all R/I^n is nonempty. (Received January 08, 2016)

1117-13-130 **Luchezar Avramov**, **Alexandra Seceleanu*** (aseceleanu@unl.edu) and **Zheng Yang**. *Polynomial growth for Betti numbers.*

It is well known that the asymptotic patterns of the Betti sequences of the finitely generated modules over a local ring R reflect the structure of R. For instance, these sequences are eventually zero if and only if R is regular and they are eventually constant if and only if R is a hypersurface. We consider the problem of characterizing the rings R such that every R-module has Betti numbers eventually given by some polynomial. We give necessary and sufficient conditions for R to have this property. In some important cases, for example when R is homogeneous, these conditions coincide and therefore characterize R. (Received January 09, 2016)

1117-13-131 **Saeed Nasseh*** (snasseh@georgiasouthern.edu). *DG Homological Algebra And Vanishing Of (Co)homology Over Local Rings.* Preliminary report.

We will talk about the vanishing of Tor over trivial extensions of DG algebras and its applications in commutative ring theory.

This talk is based on joint works with L. L. Avramov, S. B. Iyengar, and S. Sather-Wagstaff. (Received January 09, 2016)

1117-13-133 **Sean Sather-Wagstaff*** (ssather@clemson.edu), Clemson University, and **Rich Wicklein**, MacMurray College. *Adic Semidualizing Modules.* Preliminary report.

Over a commutative noetherian ring R, dualities with respect to R and with respect to a dualizing module (when one exists) are classical notions. Duality with respect to a semidualizing R-module encompasses both of these notions, but it misses other important dualities, e.g., Matlis duality. In this talk, we present a single notion that encompasses all of these dualities simultaneously. We also show how this notion allows us to construct a dualizing complex over a complete local ring without using Cohen's structure theorem. (Received January 09, 2016)

1117-13-162 **Susan Marie Cooper*** (susan.marie.cooper@ndsu.edu), Department of Mathematics, NDSU Dept #2750, PO Box 6050, Fargo, ND 58108-6050. *The Symbolic Polyhedron and Waldschmidt Constant.*

Computing symbolic powers of homogeneous ideals is quite challenging, even for monomial ideals. In this talk we compare symbolic and regular powers of monomial ideals. We will investigate the symbolic polyhedron of a monomial ideal, a convex polyhedron with the property that when scaled by a factor of m it contains the exponent vectors of all monomials in the mth symbolic power of the ideal. We will connect the symbolic polyhedron to the Waldschmidt constant which is an asymptotic invariant defined by the initial degrees of the symbolic powers of the ideal. This is joint work from two projects: the first with R. Embree, H. T. Hà, and A. Hoefel and the second with C. Bocci, E. Guardo, B. Harbourne, M. Janssen, U. Nagel, A. Seceleanu, A. Van Tuyl, and T. Vu. (Received January 12, 2016)

1117-13-191 **Lance Edward Miller***, Department of Mathematical Sciences, 301 SCEN, Fayetteville, AR 72701, and **Alberto Chiecchio**, **Florian Enescu** and **Karl Schwede**. *Test ideals in rings with finitely generated anti-canonical algebras.*

Test ideals are subtle and important invariants for measuring singularities in positive characteristic and are heavily related to multiplier ideals. These are easiest to work with under the assumption that the ambient ring is quasi-Gorenstein or even just Q-Gorenstein. In this talk, we will review some of these results and discuss that many of the results extend provided the anticanonical section ring is finitely generated. This is joint work with Alberto Chiecchio, Florian Enescu, and Karl Schwede. (Received January 13, 2016)

1117-13-192 **Sean Sather-Wagstaff** and **Jonathan Totushek*** (jtotushe@uwsuper.edu). *Complete intersection injective dimension and the Chouinard Formula.* Preliminary report.

Let $(R, \mathfrak{m}, k)$ be a local ring and let X be an R-complex. It is known that $\operatorname{Gfd}_R(X) \leq \text{CI-fd}_R(X) \leq \operatorname{fd}_R(X)$ where fd is the classical flat dimension, CI-fd is the complete intersection flat dimension of Sather-Wagstaff, and Gfd is the Gorenstein flat dimension of Enochs, Jenda, and Xu. However, it remains an open question if $\operatorname{Gid}_R(X) \leq \text{CI-id}_R(X) \leq \operatorname{id}_R(X)$ where id is the classical injective dimension, CI-id is the complete intersection injective dimension of Sather-Wagstaff, and Gid is the Gorenstein injective dimension of Enochs, and Jenda. In this talk we will investigate how the Chouinard formula relates to the complete intersection dimension and show some special cases when the latter set of inequalities hold. (Received January 13, 2016)

1117-13-194 **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 intersection rings for which the index is strictly less than the generalized Löewy length. (Received January 13, 2016)

1117-13-203 **Louiza Fouli**, **Paolo Mantero*** (pmantero@uark.edu) and **Yu Xie**. *On a conjecture by G. V. Chudnovsky.* Preliminary report.

A long-standing conjecture of G. V. Chudnovsky predicts lower bounds for the minimal degree of a hypersurface passing with multiplicity m through a set of n fixed (simple) points in $\mathbb{P}^N_{\mathbb{C}}$. The conjectured bounds have been proved for any sets of points in $\mathbb{P}^2$ and for sets of generic points in $\mathbb{P}^3$. So far, the best lower bound for $N > 3$ was proved by Esnault-Viehweg in 1983 (using methods from Complex Geometry). In 2011 Harbourne and Huneke posed a suggestive conjecture (wide-open for $\mathbb{P}^N$ with $N > 3$) on inclusions between symbolic and ordinary powers of ideals, which would imply Chudnovsky's conjecture.

In this talk we prove Chudnovsky's conjecture for very general points in $\mathbb{P}^N$ and Harbourne-Huneke conjecture for sets of very general points of certain cardinality. (Received January 13, 2016)

1117-13-212 **Luke Oeding*** (oeding@auburn.edu), Department of Mathematics and Statistics, 221 Parker Hall, Auburn, AL 36849. *Are all secant varieties of Segre products arithmetically Cohen-Macaulay?* Preliminary report.

Implicitization problems are central in Applied Algebraic Geometry. Starting with an algebraic-statistical model for structured data (such as tensors with low rank) we often ask for the implicit defining equations for the associated algebraic variety. Usually some of these equations can be found (for example by linear algebra, ad hoc methods, or analyzing symmetry). A difficult problem is then to determine when the known equations suffice. Algebraic properties such as the arithmetically Cohen-Macaulay (aCM) property can be a big help, if it can be determined.

In this talk I will focus on tensors of restricted border rank, or secant varieties of Segre products. I will present what is known about the aCM question and how it can be used for the implicitization problem. I'll present recent computational experiments as well as a structural property of secant varieties that leads me to conjecture an affirmative answer to the aCM question. (Received January 14, 2016)

1117-13-218 **Federico Galetto*** (galettof@math.mcmaster.ca), **Anthony V. Geramita** and **David Wehlau**. *Symmetric complete intersections.* Preliminary report.

Complete intersection ideals in polynomial rings are parametrized by the degrees of their generators. We consider complete intersection ideals that are stable under the action of the symmetric group permuting the variables. These ideals are further parametrized by the representation type of a stable generating subspace. We classify the possible representation types for stable complete intersection ideals and obtain formulas for the graded characters of the corresponding quotient rings. (Received January 14, 2016)

1117-13-219 **Anurag K. Singh*** (singh@math.utah.edu). *Maps from Ext modules to local cohomology modules.* Preliminary report.

We will discuss the injectivity of the natural maps from Ext modules to the corresponding local cohomology modules, in the context of a question of Eisenbud, Mustata, and Stillman. This has connections with the cohomology of thickenings of projective varieties, and leads to a version of the Kodaira vanishing theorem for these thickenings.

The talk is based on work in progress with Bhatt, Blickle, Lyubeznik, and Zhang. (Received January 14, 2016)

1117-13-247 **Katie Ansaldi***, 255 Hurley Hall, Notre Dame, IN 46556, and **Kuei-Nuan Lin**. *A Dual Operation on Strongly Stable Ideals.*

We introduce a special dual ideal, the lcm-dual, for monomial ideals. We connect the lcm-dual and the Alexander dual for edge ideals. This operation has applications to finding special fiber rings for some classes of monomial ideals. We also find minimal free resolutions for the lcm-dual of strongly stable ideals generated in degree 2. (Received January 15, 2016)

1117-13-251 **Melvin Hochster** and **Luis Nunez-Betancourt*** (lcn8m@virginia.edu). *On the support of local cohomology modules in positive characteristic.* Preliminary report.

It is conjectured that the support of a local cohomology module $H^i_I(R)$ is a Zariski closed subset of $Spec(R)$. In this talk we will discuss the solution for this conjecture for hypersurface rings, and rings with F-finite representation type. (Received January 15, 2016)

1117-13-256 **Scott C. Batson*** (scott.batson@navy.mil). *Predicting Lattice Reduction on Ideal Lattices.* Preliminary report.

Lattices with a special algebraic structure, called ideal lattices, are regularly used in lattice-based cryptographic constructions. Whether or not they offer the same security as general lattices remains an open question. Lattice reduction algorithms are the standard approach to the shortest vector problem (SVP), which is the most considered hard lattice problem. In 2008, Gama and Nguyen published an extensive experimental study regarding the practical performance of several lattice reduction algorithms on general lattices. We propose an analogous experimental study for ideal lattices. Our experiment design also allows for testing and comparing reduction algorithms that exploit the algebraic structure of ideal lattices to find short vectors. We will compare our results with previous studies to reasonably conjecture whether or not the SVP is easier to solve in ideal lattices. (Received January 15, 2016)

1117-13-264 **Dustin Cartwright***, Department of Mathematics, 227 Ayres Hall, Knoxville, TN 37996-1320. *The Gröbner stratification of a tropical variety.*

The Gröbner fan of a homogeneous ideal records the possible Gröbner bases as the weight vector is allowed to vary. The tropicalization of the ideal is the support of a distinguished subfan of the Gröbner fan. However, the tropicalization only depends on the image of the ideal in the Laurent polynomial ring formed by inverting all of the coordinate variables. Working directly in the Laurent polynomial ring, one can form a coarsening, called the Gröbner stratification. The Göbner stratification is closely related to the tropical variety, but in some cases, can contain more information. (Received January 15, 2016)

1117-13-278 **Sara Faridi*** (faridi@mathstat.dal.ca). *Recursive computations for Betti numbers of monomial ideals.* Preliminary report.

In this talk we will present ongoing work on the computation of Betti numbers of monomial ideals. Using combinatorial arguments, we show techniques for recursive computation of graded Betti numbers of monomial ideals. (Received January 16, 2016)

1117-13-297 **Craig Huneke**, **Paolo Mantero**, **Jason McCullough*** (jmccullough@rider.edu) and **Alexandra Seceleanu**. *A Tight Bound on the Projective Dimension of Four Quadrics.*

Motivated by Stillman's question, we show that the projective dimension of an ideal generated by four quadric forms in a polynomial ring is at most 6. (Received January 16, 2016)

1117-13-321 **Sandra Spiroff*** (spiroff@olemiss.edu), P.O. Box 1848, Hume Hall 305, University, MS 38677-1848, and **Florian Enescu**. *Some Properties of Intersection Algebras.* Preliminary report.

We continue the work begun by F. Enescu and S. Malec on intersection algebras. Specifically, when R is a polynomial ring in finitely many variables over a field and I and J are principal monomial ideals, we study $\mathcal{B}_R(I,J) = \bigoplus_{r,s\in\mathbb{N}} I^r \cap J^s$. Our aim is to calculate the Hilbert-Samuel and Hilbert-Kunz multplicities, the divisor class group, and the F-signature of $\mathcal{B}$. (Received January 17, 2016)

1117-13-342 **Teresa Cortadellas Benitez**, **Carlos D'Andrea** and **Florian Enescu*** (fenescu@gsu.edu). *Fan algebras.* Preliminary report.

Let $\mathcal{F}$ be a fan in $\mathbb{R}^m$, $f_1,\dots,f_n$ a family of fan-linear maps on $\mathcal{F}$, and $I_1,\dots,I_n$ ideals in a commutative ring R. Fan algebras are R-algebras associated to this collection of data. It is a concept that provides an interplay between the geometry and combinatorics of the fan and the algebraic properties of the ideals and the fan linear maps. In our talk, we will present some of the main properties of these algebras, focusing on their presentation

ideal. We will describe their presentation ideal and free resolution when $m = 2$ and the ideals I_i, $i = 1, \ldots, n$, are principal, an important case with applications to the intersection algebra of principal ideals. (Received January 17, 2016)

1117-13-366 **Lars Winther Christensen*** (lars.w.christensen@ttu.edu) and **Oana Veliche**.
Somewhere between Gorenstein and Golod. Preliminary report.

Commutative noetherian local rings are often discussed in terms of the algebro geometric hierarchy:

$$\text{regular} \implies \text{hypersurface} \implies \text{complete intersection} \implies \text{Gorenstein}\,.$$

Though Gorenstein rings are everywhere—so says Bass—a random local ring that one encounters is probably not Gorenstein. Outside of the hierarchy, the only other class that we have a handle on is that of Golod rings, and in the talk I will explain how random local rings can be described as being destributed on a spectrum that has Gorenstein at one end and Golod at the other. (Received January 18, 2016)

1117-13-407 **Petter Andreas Bergh** and **David A. Jorgensen*** (djorgens@uta.edu). *A generalized Dade's Lemma for local rings.*

In this talk we discuss a generalized Dade's Lemma for quotients of local rings by ideals generated by regular sequences. That is, given a pair of finitely generated modules over such a ring with algebraically closed residue field, we prove a sufficient (and necessary) condition for the vanishing of all higher Ext or Tor of the modules. This condition involves the vanishing of all higher Ext or Tor of the modules over all quotients by a minimal generator of the ideal generated by the regular sequence. (Received January 18, 2016)

1117-13-413 **Eliana M Duarte***, emduart2@illinois.edu, and **Hal Schenck**. *Tensor product surfaces and syzygies.*

A tensor product surface is the image of a rational map $\phi : \mathbb{P}^1 \times \mathbb{P}^1 - \to \mathbb{P}^3$. 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 the first part of this talk I will explain how the syzygies of the defining polynomials of ϕ determine its implicit equation. For the second part I will present recent progress on improving syzygy based algorithms to solve the implicitization problem for tensor product surfaces. (Received January 18, 2016)

1117-13-438 **Petter A. Bergh**, **David A. Jorgensen** and **W. Frank Moore*** (moorewf@wfu.edu), PO Box 7388, 127 Manchester Hall, Winston-Salem, NC 27109. *Totally Acyclic Approximations.* Preliminary report.

Let R be a commutative local ring. We study the subcategory of the homotopy category of R-complexes consisting of the totally acyclic R-complexes. In particular, in the context where $Q \longrightarrow R$ is a local ring homomorphism such that R has finite flat dimension over Q, we define explicitly an adjoint pair of functors between the homotopy category of totally acyclic R-complexes and that of Q-complexes which are analogous to the classical adjoint pair between the module categories of R and Q. As a consequence, one obtains a precise and useful notion of approximations of totally acyclic R-complexes by totally acyclic Q-complexes. (Received January 18, 2016)

1117-13-446 **Jason M Lutz*** (jlutz3@math.unl.edu). *Homological characterizations of quasi-complete intersections.*

Let R be a commutative Noetherian ring and I an ideal of R. The homology of a Koszul complex on a generating set of I is an invariant of I, and if this homology algebra has the structure of an exterior algebra on $H_1(K)$, then I is said to be a quasi-complete intersection (q.c.i.) ideal. Using Tate's "adjunction of variables" to annihilate the degree 1 homology of K, we obtain a two-step Tate complex. A result of Blanco, Majadas, and Rodicio yields that I is a q.c.i. ideal if and only if this infinite complex is acyclic. Our main results characterize quasi-complete intersection ideals as those ideals for which the homology of a two-step Tate complex vanishes in a finite band of sufficient size. (Received January 18, 2016)

1117-13-447 **Janet Striuli*** (jstriuli@fairfield.edu), North Benson rd, Fairfield, CT 06825. *ANother Proof of Braun's Theorem.* Preliminary report.

In this talk we present an alternative proof of a theorem of Braun that states that over a local ring, a module with finite projective dimension, reflexive, with a free endomorphism ring is in fact free. (Received January 18, 2016)

1117-13-450 **Mengyao Sun*** (msun@tulane.edu). *Regularity of edge ideal of vertex decomposable graphs.* Preliminary report.

The edge ideal construction gives one-to-one correspondence between squarefree monomial ideals and simple hypergraphs. This allows us to study the regularity of squarefree monomial ideals in terms of combinatorial

data from associated hypergraphs. In this talk, our focus will be on finding bounds for the regularity of the edge ideal of a vertex decomposable graph. We provide two upper bounds for the regularity in terms of the induced matching number and the number of cycles and show that they are incomparable. (Received January 18, 2016)

1117-13-458 **Hailong Dao***, Lawrence, KS , and **William Sanders**, Trondheim, Norway.
Cohomological support and the geometric join. Preliminary report.

Let M, N be finitely generated modules over a local complete intersection R. Assume that all the modules $\mathrm{Tor}_i^R(M,N)$ are zero for $i>0$. We prove that the cohomological support of $M \otimes_R N$ (in the sense of Avramov-Buchweitz) is equal to the geometric join of the cohomological supports of M, N. This result gives a new connection between two active areas or research, and immediately produces several corollaries as well as new questions. (Received January 19, 2016)

1117-13-459 **Liana M Şega*** (segal@umkc.edu). *Poincaré series of local rings.* Preliminary report.

In recent work with M. Rossi, we showed that the Poincaré series of all finitely generated modules over compressed Gorenstein local rings are rational. Naturally, one can ask what can be said if we remove the hypothesis that the ring is Gorenstein. I will provide some answers in this direction. (Received January 19, 2016)

1117-13-469 **J Cameron Atkins*** (atkinsj6@email.sc.edu) and **Adela Vraciu** (vraciu@math.sc.edu). *Existence of Totally Reflexive Modules.*

We prove that for a standard graded Cohen-Macaulay ring R, if the quotient $R/(\underline{x})$ admits non-free totally reflexive modules, where $\underline{x}$ is a system of parameters consisting of elements of degree one, then so does the ring R. As an application, we consider the question of which Stanley-Reisner rings of graphs admit non-free totally reflexive modules. (Received January 19, 2016)

1117-13-477 **Christopher A Francisco**, **Jeffrey Mermin** and **Jay Schweig***, 401 MSCS, Stillwater, OK 74078. *LCM lattices and pure resolutions.*

The LCM lattice of a monomial ideal I is the lattice of all lcms of minimal generators of I, ordered by divisibility. Amazingly, the multigraded Betti numbers of I are encoded in this lattice as homological ranks of intervals. When I is a monomial ideal with a pure resolution, its LCM lattice satisfies a certain topological condition that we call homological monotonicity. We show a converse to this condition: If a lattice L is homologically monotonic, then there must be an ideal I, with pure resolution, whose LCM lattice is L. (Received January 19, 2016)

1117-13-496 **Robert Krone*** (rk71@queensu.ca). *Equivariant Gröbner bases of symmetric toric ideals.*

It has been shown previously that a large class of monomial maps equivariant under the action of an infinite symmetric group have finitely generated kernels up to the symmetric action. We prove that these symmetric toric ideals also have finite Gröbner bases up to symmetry for certain monomial orders. An algorithm is presented to compute equivariant Gröbner bases of these ideals, given the monomial map. (Received January 19, 2016)

1117-13-504 **Jennifer Biermann*** (jbierman@mtholyoke.edu), **Augustine O'Keefe** and **Adam Van Tuyl**. *Bounds on the regularity of toric ideals of graphs.* Preliminary report.

Let G be a finite simple graph. We find a lower bound for the Castelnuovo-Mumford regularity for the toric ideal I_G associated to G in terms of the sizes and number of induced complete bipartite graphs in G. When G is a chordal bipartite graph, i.e., a bipartite graph with no induced cycles of length six or larger, we find an upper bound on the regularity of I_G in terms of the size of the bipartition of G. As a corollary, the regularity of the toric ideal of the complete bipartite graph $K_{m,n}$ is the minimum of m and n. (Received January 19, 2016)

1117-13-508 **Louiza Fuolli**, **Jonathan Montaño** and **Gabriel E Sosa*** (gsosa@amherst.edu). *Rees Algebras and integral closures of initial lex-segment ideals.* Preliminary report.

Given K a field with char(k)=0 and a strongly stable ideal I of $K[X_1,\ldots,X_n]$ with minimal generators of the same degree, we compute a Gröbner basis for the defining ideal of the Rees algebra, $\mathcal{R}(I)$, from a Gröbner basis of the defining ideal of its special fiber, $\mathcal{F}(I)$.

In the case where L is an initial lex-segment ideal previous results imply that $\mathcal{R}(L)$ is a Koszul, Cohen-Macaulay normal domain, and the defining equations of $\mathcal{R}(L)$ can be given explicitly.

We also provide an estimate for the reduction number of initial lex-segment ideals and prove that their powers are integrally closed. (Received January 19, 2016)

1117-13-522 **Felipe Perez** (jperezvallejo@gsu.edu) and **Yongwei Yao*** (yyao@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30302. *Uniformity in reduction to characteristic p.*

Let A be a Noetherian domain and R a f.g. A-algebra. For every $P \in Spec(A)$ such that the residue field $\kappa(P)$ has prime characteristic, consider the fiber ring $R_{\kappa(P)}$.

We obtain uniform properties of $R_{\kappa(P)}$ for all P within a non-empty open subset. There is a uniform bound for all the normalized Hilbert-Kunz functions of all localizations of $R_{\kappa(P)}$. Under mild conditions, there is a uniform rate of convergence for the sequence of normalized Hilbert-Kunz functions and the sequence of normalized F-splitting numbers.

As corollaries, consider a finitely generated $\mathbb{Z}$-algebra R (say reduced). Let I be an ideal of R such that, mod p, R_p/I_p has finite length for all $p \gg 0$. Then the convergence of $e_{HK}(I_p, R_p)$ is equivalent to the convergence of $\ell(R_p/I_p^{[p]})$ as $p \to \infty$; and they have the same limit if convergence occurs. (Similar results have been obtained independently by K. Tucker and independently by V. Trivedi.) We also get corresponding results for normalized F-splitting numbers and F-signature.

General results are obtained in terms of an R-module M instead of R. And they cover all the results above as special cases. This is joint work with Felipe Perez. (Received January 19, 2016)

14 ► Algebraic geometry

1117-14-9 **Douglas A Torrance***, Piedmont College, PO Box 10, 1021 Central Ave, Demorest, GA 30535. *Generic forms of low Chow rank.*

The least number of products of linear forms that may be added together to obtain a given form is the Chow rank of this form. The Chow rank of a generic form corresponds to the smallest s for which the sth secant variety of the Chow variety fills the ambient space. We show that, except for certain known exceptions, this secant variety has the expected dimension for low values of s. (Received September 28, 2015)

1117-14-38 **Dhruv Ranganathan*** (dhruv.ranganathan@yale.edu), 10 Hillhouse Avenue, New Haven, CT 06511. *The Skeleton of the Virtual Fundamental Class.* Preliminary report.

I will discuss the tropical geometry of compact moduli spaces of ramified (logarithmic) stable maps to toric varieties. Though usually very singular, these spaces carry a virtual fundamental class that allows one to define "enumerative" invariants for curves in toric varieties with prescribed tangency orders with the toric boundary. We introduce a new tropicalization for this space using Berkovich spaces and Artin-Olsson fans. This allows us to explore the relationship between the realizability problem for tropical curves, deformation-obstruction theory for logarithmic stable maps, and the skeleton of the virtual fundamental class. (Received December 21, 2015)

1117-14-50 **Mee Seong Im*** (mim2@illinois.edu), 646 Swift Road, Thayer Hall, Office 249, D/Math, United States Military Academy, West Point, NY 10996. *A categorification of* $\mathfrak{sl}_2$*-Verma modules.* Preliminary report.

The notion of a categorification of a vector space V is to find a category $\mathcal{C}$ whose Grothendieck group $K_0(\mathcal{C})$ is isomorphic to the vector space. The technique of categorification gives us deeper structure about vector spaces often resulting in profound classification and understanding about them. I will outline the construction of a categorification of $\mathfrak{sl}_2$-Verma modules and give some conjectures in using geometric techniques to categorify Verma modules. This is joint with Ben Cox. (Received December 26, 2015)

1117-14-51 **Tif Shen***, jifeng.shen@yale.edu. *Compactified Jacobians and Break Divisors.* Preliminary report.

We apply tropical methods to study the geometry of compactified Jacobians of genus g curves $\mathcal{X}$ over a DVR. Let $\overline{J_g}(\mathcal{X})$ be the degree g compactified Picard scheme of $\mathcal{X}$ introduced by Caporaso. Using break divisors, we show that all degree g Simpson compactified Jacobians of $\mathcal{X}$ are isomorphic to $\overline{J_g}(\mathcal{X})$. To do so, we prove that slope-stable rank-1 torsion-free sheaves on X are described by break divisors. (Received December 27, 2015)

1117-14-87 **Justin Sawon*** (sawon@email.unc.edu), Department of Mathematics, University of North Carolina, Chapel Hill, NC 27599-3250. *On the topology of compact hyperkähler manifolds.*

In this talk we will describe some results about Betti, Hodge, and characteristic numbers of compact hyperkähler manifolds. In (complex) dimension four one can find universal bounds for all of these invariants (Beauville, Guan); in higher dimensions it is still possible to find some bounds. We also describe how these bounds are related to the question: are there finitely many hyperkähler manifolds in each dimension, up to deformation? (Received January 04, 2016)

1117-14-118 **Yuecheng Zhu*** (yuecheng@sas.upenn.edu), 209 South 33rd Street, Philadelphia, PA 19104. *Compactification of moduli of polarized abelian varieties.*

I will discuss the compactification problem for the moduli space of polarized abelian varieties. In general, we know how to compactify the moduli space of pairs consisting of a Calabi-Yau variety and an ample divisor, the so called KSBA stable pairs. But this does NOT give a compactification of the moduli space of the underlying Calabi-Yau varieties, since the degeneration of a family of polarized Calabi-Yau varieties depends on the choice of divisors. However, for a family of polarized abelian varieties, there is a canonical set of divisors that gives a canonical degeneration of the abelian varieties. This is because the degeneration only depends on some tropical data, and any choice of a divisor from this canonical set gives the same tropical data. I will explain how to get this canonical set of divisors. If time permited, I will also explain how the existence of this canonical set is predicted by mirror symmetry. (Received January 07, 2016)

1117-14-119 **Howard J Nuer*** (hjn11@math.rutgers.edu), Piscataway, NJ 08854. *Moduli of sheaves on Enriques surfaces via Bridgeland stability.*

While stable sheaves on surfaces with trivial canonical bundle, i.e. K3 or Abelian surfaces, have been extensively studied, stable sheaves on Enriques surfaces have received less attention. We will begin by discussing our recent results which give precise criteria for the non-emptiness and irreducibility of moduli spaces of stable sheaves. We will also describe some of the geometry of these moduli spaces. Time permitting, we present a near complete on-going project describing the MMP of these moduli spaces. A crucial tool in all of the above is the use of Bridgeland stability and wall-crossing techniques. (Received January 07, 2016)

1117-14-129 **David Jensen*** (dave.h.jensen@gmail.com), 109 N Mill St, Apt 201, Lexington, KY 40507. *Tropical Independence and the Maximal Rank Conjecture for Quadrics.*

The maximal rank conjecture, which has roots in the work of Noether and Severi in the late 19th and early 20th centuries, predicts the Hilbert function of the general embedding of a general curve. In recent joint work with Sam Payne, we show that this conjecture holds for the Hilbert function evaluated at m=2, meaning that such a curve is contained in the expected number of independent quadrics. From this we deduce that the general curve of genus g and degree d in projective space of dimension r is projectively normal if and only if (r+2)(r+1)/2 is at least 2d-g+1. Our proof uses techniques from tropical and nonarchimedean geometry. (Received January 08, 2016)

1117-14-216 **Huajun Huang** and **Luke Oeding*** (oeding@auburn.edu), Department of Mathematics and Statistics, 221 Parker Hall, Auburn, AL 36849. *Symmetrization of Principal Minors and Cycle Sums.*

We solve the Symmetrized Principal Minor Assignment Problem, that is we show how to determine if for a given vector $v \in \mathbb{C}^n$ there is an $n \times n$ matrix that has all $i \times i$ principal minors equal to v_i. We use a special isomorphism (a non-linear change of coordinates to cycle-sums) that simplifies computation and reveals hidden structure. We use the symmetries that preserve symmetrized principal minors and cycle-sums to treat 3 cases: symmetric, skew-symmetric and general square matrices. We describe the matrices that have such symmetrized symmetrized principal minors as well as the ideal of relations among symmetrized principal minors / cycle-sums. We also connect the resulting algebraic varieties of symmetrized principal minors to tangential and secant varieties, and Eulerian polynomials. (Received January 14, 2016)

1117-14-222 **Jonathan D Hauenstein**, **Bernard Mourrain** and **Agnes Szanto*** (aszanto@ncsu.edu), Department Of Mathematics, NCSU, Campus Box 8205, Raleigh, NC 27695. *On the multiplicity structure of isosingular roots.*

We present a new construction to compute the so-called inverse system or dual basis for singular solutions of polynomial systems. We construct a system of equations in the original variables plus a relatively small number of new variables that completely deflates the root in one step. We show that the isolated simple solutions of this new system correspond to roots of the original system with given multiplicity structure up to a given order. This construction is "exact" in that it permits one to treat all conjugate roots simultaneously and can be used in certification procedures for singular roots and their multiplicity structure with respect to an exact rational polynomial system. (Received January 14, 2016)

1117-14-252 **Farbod Shokrieh***, farbod@math.cornell.edu. *A non-Archimedean Poincaré formula for theta divisors.*

Let X be a curve over $\mathbb{C}$. The classical Poincaré formula for theta divisors compares the fundamental classes of Θ (the theta divisor) and W_d (the subset of $\mathrm{Pic}^d(X)$ of line bundles with nonempty linear systems). I will discuss a non-Archimedean/tropical version of this formula. (Received January 15, 2016)

1117-14-262 **Dustin Cartwright***, Department of Mathematics, 227 Ayres Hall, Knoxville, TN 37996-1320. *On dual complexes of degenerations.*

The dual complex of a degeneration records how the components of the special fiber intersect. It appears in tropical geometry as a parametrizing object for the tropicalization and as a skeleton for the Berkovich analytification. I will discuss how the topology of the dual complex reflects the geometry of the algebraic variety above the general fiber. (Received January 15, 2016)

1117-14-263 **Dustin Cartwright***, Department of Mathematics, 227 Ayres Hall, Knoxville, TN 37996-1320. *A quantitative version of Mnëv's theorem.*

A matroid is a combinatorial structure recording all incidences between vectors in a fixed vector configuration and the linear spaces spanned by subsets of vectors. Mnëv's theorem says that realization spaces of matroids can be as complicated as arbitrary systems of polynomial equations, in terms of singularities and in terms of finding rational solutions. I will give some background on this theorem and then talk about a version of Mnëv's theorem over the integers, for which the size of the matroid can be bounded in an explicit way. (Received January 15, 2016)

1117-14-268 **Sonja Petrovic*** (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 IA. 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 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. Along the way, we answer two open problems for toric ideals of hypergraphs. (Received January 15, 2016)

1117-14-270 **Jesus A. De Loera**, **Sonja Petrović*** (sonja.petrovic@iit.edu) and **Despina Stasi**. *Random Sampling in Computational Algebra: Helly Numbers and Violator Spaces.*

Solving systems of polynomial equations is a cornerstone of computational algebra today, but it is well-known that many algorithms have high worst-case complexity. In this talk, I will describe a new randomized algorithm for computing solutions of (large) systems of polynomial equations that has expected runtime linear in the number of input polynomials.

In particular, our work transfers a randomized algorithm, originally used in geometric optimization, to computational problems in commutative algebra. We show that Clarkson's sampling algorithm can be applied to two problems in computational algebra: solving large-scale polynomial systems and finding small generating sets of graded ideals. The cornerstone of our work is showing that the theory of violator spaces of Gärtner et al. applies to polynomial ideal problems. To show this, one utilizes a Helly-type result for algebraic varieties. The resulting algorithms have expected runtime linear in the number of input polynomials, making the ideas interesting for handling systems with very large numbers of polynomials, but whose rank in the vector space of polynomials is small (e.g., when the number of variables and degree is constant). (Received January 15, 2016)

1117-14-303 **Grigoriy Blekherman**, **Daniel Plaumann**, **Rainer Sinn*** (sinn@math.gatech.edu) and **Cynthia Vinzant**. *Low rank psd lifts of nonnegative quadratic forms.* Preliminary report.

We fix a projection on the space of real symmetric matrices given by its kernel L. Given a quadratic form q that is nonnegative on the variety defined by the quadrics in L, we find the lowest rank of a positive quadratic form in the fibre of q under additional assumptions on the variety $\mathcal{V}(L)$. We will count the number of such low rank extensions in case the variety is a rational normal scroll of dimension 2. (Received January 16, 2016)

1117-14-315 **Nathan Pflueger*** (pflueger@math.brown.edu), 151 Thayer Street, Providence, RI 02912. *Chains of cycles and general m-gonal curves.*

We generalize the work of Cools, Draisma, Payne, and Robeva to analyze the Brill-Noether theory of chains of cycles with arbitrary edge lengths. By choosing specific edge lengths and applying tropical lifting results, we prove partial analogs of the Brill-Noether Theorem for general curves of fixed gonality. (Received January 17, 2016)

1117-14-340 **Man Wai Cheung**, **Lorenzo Fantini**, **Jennifer Park*** (jmypark@umich.edu) and **Martin Ulirsch**. *Faithful realizability of tropical curves.*

Every algebraic curve over a nontrivially valued field has a corresponding tropical curve via tropicalization, where tropical curves are defined as balanced weighted 1-dimensional rational polyhedral complexes. It is then natural to ask whether tropical curves can be realized as the tropicalization of a smooth, complete and connected algebraic curve. Further, we ask whether the tropicalization can be faithful. In this talk, I will answer the above question of faithful realizability for a large class of tropical curves. This work is joint with Man Wai Cheung, Lorenzo Fantini and Martin Ulirsch. (Received January 17, 2016)

1117-14-350 **Kalina Mincheva*** (mincheva@math.jhu.edu), Johns Hopkins Universtiy, 3400 N Chalres Street, Krieger Hall 404, Baltimore, MD 21218. *Prime congruences and tropical geometry.*

We define the Zariski spectrum of a commutative semiring. Since ideals do not retain their distinguished role in the theory of semirings, the points of this spectrum correspond to certain congruence relations, which we call prime congruences. Motivated by tropical geometry, the key theme of our work is to study the prime spectrum of tropical polynomial semirings, but many of the results presented apply to any additively idempotent semiring as well. As an application we prove an analogue of the Nullstellensatz for tropical polynomials. We will also show that the notion of primes we introduced yields a Krull dimension which is "well-behaved" for additively idempotent polynomial semirings. (Received January 17, 2016)

1117-14-371 **Martha Precup*** (mprecup@math.northwestern.edu) and **Edward Richmond** (edward.richmond@okstate.edu). *Generalized Kostant Polynomials.* Preliminary report.

Let $\mathfrak{g}$ be a semisimple Lie algebra and W denote the corresponding Weyl group. The Kostant polynomial K_w corresponding to $w \in W$ is a degree $\ell(w)$ polynomial that satisfies certain vanishing properties on the orbit $W \cdot S_r$ of a regular semisimple element of $\mathfrak{g}$. The values of each K_w on the W-orbit points are given by a combinatorial formula which has applications to equivariant Schubert calculus and is closely related to the geometry of the Schubert variety X_w.

In this talk, we define polynomials that satisfy analogous vanishing conditions on the W-orbit of an arbitrary semisimple element S and use these to analyze the coordinate ring $\mathbb{C}[W \cdot S]$. We are motivated to do so by a result of Jim Carrell proving that in many cases $Gr\,\mathbb{C}[W \cdot S]$ is isomorphic to the cohomology ring of the Springer fiber $\mathcal{B}^N$ where N is a regular nilpotent element of the Levi subalgebra $\mathfrak{z}_{\mathfrak{g}}(S)$ of $\mathfrak{g}$. (Received January 18, 2016)

1117-14-383 **Douglas Ulmer*** (douglas.ulmer@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30306. *Rational curves on elliptic surfaces.*

Given a non-isotrivial elliptic curve E over $K = \mathbf{F}_q(t)$, there is always a finite extension L of K which is itself a rational function field such that $E(L)$ has large rank. The situation is completely different over complex function fields: For "most" E over $K = \mathbf{C}(t)$, the rank of $E(L)$ is zero for any rational function field $L = \mathbf{C}(u)$. The yoga that suggests this theorem leads to other remarkable statements about rational curves on surfaces generalizing a conjecture of Lang. (Received January 18, 2016)

1117-14-389 **Daniel A. Brake*** (danielthebrake@gmail.com), 152 B Hurley, Notre Dame, IN 46556, and **Jonathan D. Hauenstein**, **Andrew P. Murray**, **David H. Myszka** and **Charles W. Wampler**. *The complete solution of Alt-Burmester synthesis problems for four-bar linkages.*

Precision-point synthesis problems for design of four-bar linkages have typically been formulated using two approaches. The exclusive use of path-points is known as "path synthesis", whereas the use of poses, i.e. path-points with orientation, is called "rigid-body guidance" or the "Burmester problem". We consider the family of "Alt-Burmester" synthesis problems, in which some combination of path-points and poses are specified, with the extreme cases corresponding to the typical approaches.

The Alt-Burmester problems that have, in general, a finite number of solu- tions include Burmester's original five-pose problem and also Alt's problem for nine path-points. The elimination of one path-point increases the dimension of the solution set by one, while the elimination of a pose increases it by two. Using techniques from

numerical algebraic geometry, we tabulate the dimen- sion and degree of all problems in this Alt-Burmester family, and provide more details concerning all the zero- and one-dimensional cases. (Received January 18, 2016)

1117-14-392 **Melody Chan**, **Soren Galatius** and **Sam Payne*** (sam.payne@yale.edu).
Tropicalization of the moduli space of curves: Topology and applications.

I will discuss joint work with Melody Chan and Soren Galatius using techniques from combinatorial topology to study moduli spaces of tropical curves and applications to moduli spaces of algebraic curves. (Received January 18, 2016)

1117-14-396 **Swarnava Mukhopadhyay*** (swarnava@umd.edu), University of Maryland, College Park, MD 20742, and **Richard Wentworth** (raw@math.umd.edu), University of Maryland, College Park, MD 20742. *Hecke Transforms and a Hitchin type connection for twisted Spin bundles.*

In this talk, we will discuss Hecke type transformations on the space of non-abelian theta functions for the moduli stack of Clifford bundles with fixed norm over a smooth curve (also known as twisted Spin bundles). In particular, I will explain the proof of a Verlinde type formula, conjectured by Oxbury-Wilson, for twisted spin bundles. We will also construct a Hitchin connection for these non-abelian theta functions and give a flat basis when the level is one. If time permits, we will discuss applications of these basis elements to strange duality. This is a joint work with Richard Wentworth. (Received January 18, 2016)

1117-14-415 **Zheng Zhang*** (zzhang@math.tamu.edu). *On motivic realizations for variations of Hodge structure of Calabi-Yau type over Hermitian symmetric domains.*

Based on the work of Gross and Sheng-Zuo, Friedman and Laza have classified variations of real Hodge structure of Calabi-Yau type over Hermitian symmetric domains. Specifically, over every irreducible Hermitian symmetric domain there exists a canonical variation of real Hodge structure of Calabi-Yau type. A natural question to ask is whether the canonical Hermitian Calabi-Yau variations of Hodge structure come from families of Calabi-Yau manifolds (geometric realization). In general, this is very difficult and is still open for small dimensional domains. We will discuss an intermediate question, namely does the canonical variations occur in algebraic geometry as sub-variations of Hodge structure of those coming from families of algebraic varieties (motivic realization). In particular, we will give motivic realizations for the canonical Calabi-Yau variations over irreducible tube domains of type A using abelian varieties of Weil type. (Received January 18, 2016)

1117-14-425 **Robert Krone*** (rk71@queensu.ca). *Some boundary components of non-negative rank matrices.* Preliminary report.

The non-negative rank of a matrix is useful in statsitics, but difficult to compute. The set of matrices with rank and non-negative rank both equal to r forms a semi-algebraic, Zariski-dense subset of the variety of rank r matrices. Describing all the boundary components of this set can provide a membership test, and this was accomplished previously in the case of rank 3 by Mond, Smith and van Straten. Using a different approach, we describe some of the boundary components in the higher rank cases. (Received January 19, 2016)

1117-14-429 **William Graham** (wag@math.uga.edu) and **Victor Kreiman*** (kreiman@uwp.edu).
Cominuscule points of Schubert varieties. Preliminary report.

We define the notion of a cominuscule point of a scheme with torus action, and give formulas for the Hilbert series and multiplicity at cominuscule points. All T-fixed points of Schubert varieties in cominuscule G/P are cominuscule, but there are also T-fixed points of Schubert varieties in non-cominuscule G/P which are cominuscule. For example, for any G/P of type A, if x is a fully commutative Weyl group element, then xP is a cominuscule point of any Schubert variety containing it. In type A, we use pipe dreams both to identify cominuscule points and to evaluate the Hilbert series and multiplicity formulas. (Received January 18, 2016)

1117-14-463 **Anand Deopurkar***, anandrd@math.columbia.edu. *Limits of plane quintics via covers of stacky curves.*

Which stable curves are limits of smooth plane curves? I will describe the answer explicitly in the first non-trivial case, namely the case of plane quintics. To do so, we will interpret such a curve in terms of a branched cover, but with a twist: the base of the cover will be a stack. The answer will then follow from a nice compactification of the moduli space of stacky branched covers. (Received January 19, 2016)

1117-14-478 **Julie Rana*** (jrana@umn.edu), **Jenia Tevelev** and **Giancarlo Urzua**. *The Craighero-Gattazzo surface is simply-connected.*

We show that the Craighero-Gattazzo surface, the minimal resolution of an explicit complex quintic surface with four elliptic singularities, is simply-connected. This was first conjectured by Dolgachev and Werner. The proof utilizes an interesting technique: to prove a topological fact about a complex surface we use algebraic reduction mod p and deformation theory. (Received January 19, 2016)

1117-14-485 **Letao Zhang*** (letao.zhang@stonybrook.edu) and **Zhiyuan Li** (zhiy.lee@gmail.com). *Special Cubic Fourfolds.*

We study the degrees of special cubic divisors on moduli space of cubic fourfolds with at worst ADE singularities. We show that the generating series of the degrees of such divisors is a level three modular form. (Received January 19, 2016)

1117-14-500 **Brandilyn Stigler*** (bstigler@smu.edu), 3200 Dyer Street, Dallas, TX 75275. *Using Groebner Bases to Characterize Data in Biological Network Inference.* Preliminary report.

Predicting mathematical models of biological phenomena from experimental data is sensitive to the amount of data used as input. When there are too few data, the number of possible models that explain the data are too numerous, thereby reducing the probability of selecting biologically relevant models. In the context of systems biology where substantial costs are incurred in laboratory experiments, having an estimate of the amount of data required to infer the network becomes important and aids in minimizing wasted resources.

In this talk, we introduce the problem of inferring networks from experimental data using a class of discrete models, called polynomial dynamical systems (PDSs). We show how Groebner bases can be used to detect which data sets will yield a unique PDS for a biological network of interest. In particular we describe how certain geometric properties of the associated monomial staircases reveal viable data sets. (Received January 19, 2016)

1117-14-507 **Cristian M Martinez*** (martinez@math.ucsb.edu), Department of Mathematics, South Hall, Room 66, University of California, Santa Barbara, CA 93106. *Gieseker moduli as Bridgeland moduli.*

Bridgeland Stability Conditions have become an important tool to study the geometry of moduli spaces of Gieseker semistable sheaves, specially for surfaces, where they have been used to describe nef and effective cones, change of polarization, and much more. Of course, the first step is finding stability conditions for which the only semistable objects are the Gieseker semistable sheaves. In this talk I will review some of the main ideas involving the interplay between wall-crossing for stability conditions and the birational geometry of the Gieseker moduli space on surfaces. I will hint how similar ideas can be used to study the Gieseker moduli on threefolds for special types of Chern characters. This talk is based on past work with Aaron Bertram and current work with Benjamin Schmidt. (Received January 19, 2016)

1117-14-512 **Laura Rider*** (laurajoymath@gmail.com). *Mixed Structures in geometric representation theory.* Preliminary report.

A powerful tool in geometric representation theory is that of mixed sheaves — these often give a natural grading on representation theoretic categories of interest. My talk will be primarily expository. I'll discuss Deligne's theory of weights, mixed structures for affine stratifications versus non-affine, and mixed structures in positive characteristic. I'll also discuss some results in this setting from works joint with Pramod Achar and Amber Russell. (Received January 19, 2016)

1117-14-531 **Matthew Grimes*** (matthew.grimes@colorado.edu). *Relative moduli stacks of vector bundles and good moduli spaces.*

It is well-known that for a fixed degree and rank every smooth curve admits a moduli space of slope semi-stable vector bundles. A natural question to ask is if these moduli spaces can be stitched together to form a universal moduli space of vector bundles over the moduli space of curves. Simpson showed that this is possible over the moduli space of automorphism-free curves, and work of Caporaso (rank 1) and Pandharipande provides a universal moduli space of vector bundles over the moduli space of Deligne–Mumford-stable curves via Geometric Invariant Theory.

We will discuss recent work in this area, including an extension of these results to Schubert's moduli space of pseudo-stable curves, obstacles to continuing along the Hassett–Keel program on $\overline{M}_g$, and an exploration of the problem from the perspective of constructing good moduli spaces for moduli stacks. (Received January 19, 2016)

1117-14-538 **Tulay Ayyildiz Akoglu***, Department of Mathematics, Box 8205, NC State University, Raleigh, NC 27695. *Certifying Solutions of Polynomial Systems.*

The first part of this work is concerned with certifying that a given point is near an exact root of an overdetermined polynomial system with rational coefficients. Our certification is based on hybrid symbolic-numeric methods to compute an exact *rational univariate representation* (RUR) of a component of the input system from approximate roots. The accuracy of the RUR is increased via Newton iterations until the exact RUR is found, which we certify using exact arithmetic. Since the RUR is well-constrained, we can use it to certify the given approximate roots using α-theory. The second part focuses on certifying isolated singular roots of well-constrained polynomial systems with rational coefficients. We use a determinantal form of the *isosingular deflation*. The resulting polynomial system is overdetermined, but the roots are now simple, thereby reducing the problem to the overdetermined case. In the third part, we describe how to use the Hermite matrices to certify the real roots of polynomial systems with given approximate roots. (Received January 19, 2016)

1117-14-544 **Alexander Woo**, **Benjamin Wyser*** (bwyser@illinois.edu) and **Alexander Yong**. *Isomorphisms of Mars-Springer varieties for $GL_p \times GL_q$ and interval pattern avoidance.* Preliminary report.

Consider the closure of an orbit of the symmetric subgroup $GL_p \times GL_q$ on the flag variety GL_{p+q}/B. We consider the question of when such an orbit closure possesses one of a certain class of properties P (examples being P="smooth", "normal", "Gorenstein", among others), in terms of the combinatorics of a symbol called a "clan" which parametrizes the orbit. The main result is that such properties can always be characterized by a combinatorial notion called interval pattern avoidance. The proof of this is essentially geometric, relying on an isomorphism between certain locally closed subvarieties of the orbit closures which we call Mars-Springer varieties. (Received January 20, 2016)

15 ► Linear and multilinear algebra; matrix theory

1117-15-90 **Jiu Ding***, Department of Mathematics, 118 College Dr, Box 5045, Hattiesburg, MS 39406, and **Noah Rhee** (rheen@umkc.edu), Department of Mathematics and Statistics, Kansas City, MO 64110. *Solving a quadratic matrix equation.*

Let A be square matrix. We try to solve the quadratic matrix equation AXA = XAX for some classes of matrices A to find all commuting solutions or all solutions. Such classes include diagonalizable and nilpotent ones. (Received January 04, 2016)

1117-15-369 **Michael W Berry*** (mberry@utk.edu), 401 Min H. Kao Building, 1520 Middle Drive, University of Tennessee, Knoxville, TN 37996. *Unsupervised Learning Using Separable Nonnegative Matrix Factorization.*

Gillis and Vavasis have demonstrated the robustness of *separable* nonnegative matrix factorizations for solving hyperspectral unmixing problems. For such problems, it can be shown that there exists a cone spanned by a small subset of the columns of the input nonnegative data matrix. For text mining applications, such a cone can facilitate summarization and concept tracking, especially for time-sensitive documents and social media. In this study, we show how separable nonnegative matrix factorization (SNMF) can be used for both word disambiguation and topic extraction from twitter streams with no prior labeling. (Received January 18, 2016)

1117-15-543 **Hashim A Saber*** (hashim.saber@ung.edu), 4624 Rotterdam Pl, Flowery Branch, GA 30542. *A Model Reduction Algorithm for Simulating Sedimentation Velocity Analysis.* Preliminary report.

An algorithm for the construction of a reduced model is developed to efficiently simulate a partial differential equation with distributed parameters. The algorithm is applied to the Lamm equation, which describes the sedimentation velocity experiment. It is a large scale inverse model that is costly to evaluate repeatedly. Moreover, its high-dimensional parametric input space, compounds the difficulty of effectively exploring the simulation process. The proposed parametric model reduction is applied to the simulating process of the sedimentation velocity experiment. The model is treated as a system with sedimentation and diffusion parameters to be preserved during model reduction. Model reduction allows us to reduce the simulation time significantly and, at the same time, it maintains a high accuracy. (Received January 19, 2016)

16 ► Associative rings and algebras

1117-16-7 **Alexandru Chirvasitu*** (chirva@uw.edu), University of Washington, Department of Mathematics, Seattle, WA 98195, and **Paul Smith**. *Quantum symmetry for quantum projective spaces.*

AS-regular algebras are non-commutative analogues of smooth projective schemes, with those of global dimension four behaving in many ways like three-dimensional projective space. In this talk I will introduce a specific family of such algebras arising from certain elliptic solutions for the quantum Yang-Baxter equation and study the phenomenon whereby a quantum group acts on each algebra in the family.

The quantum group action gives rise to autoequivalences of the category of (graded) modules that do not come from genuine algebra automorphisms. This then helps in classifying certain well-behaved modules that play the role of lines inside the quantum projective space.

(joint w/ S. Paul Smith) (Received January 16, 2016)

1117-16-160 **Ian M. Musson***, Department of Mathematical Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI. *Shapovalov elements for basic classical simple Lie superalgebras.*

We provide upper bounds on the degrees of the coefficients of Shapovalov elements for a simple Lie algebra. If $\mathfrak{g}$ is a contragredient Lie superalgebra and γ is a positive isotropic root of $\mathfrak{g}$, we prove the existence and uniqueness of the Shapovalov element for γ and we obtain upper bounds on the degrees of its coefficients. For type A Lie superalgebras we give a closed formula for Shapovalov elements. We also explore the behavior of Shapovalov elements when the Borel subalgebra is changed, and the survival of Shapovalov elements in factor modules of Verma modules.

Now suppose that X is a set of orthogonal isotropic roots and $\lambda \in \mathfrak{h}^*$ is such that $\lambda + \rho$ is orthogonal to all roots in X. Shapovalov elements can be used to construct a highest weight module $M^X(\lambda)$ with character $\epsilon^\lambda p_X$. Here p_X is a partition function that counts partitions not involving roots in X. Examples of such modules can be constructed via parabolic induction provided X is contained in the set of simple roots of some Borel subalgebra. However our construction works without this condition and provides a highest weight module for the distinguished Borel subalgebra. (Received January 12, 2016)

1117-16-319 **Ivan Loseu***, 360 Huntington Avenue, Boston, MA 02115. *Cacti and cells.*

I will introduce a cactus group action on the corresponding Weyl group that is nicely compatible with Kazhdan-Lusztig cells. (Received January 17, 2016)

1117-16-529 **Alimjon Eshmatov*** (aeshmat@math.cornell.edu), Ithaca, NY 14850, **Xiaojun Chen** (xjchen@scu.edu.cn), Chengdu, Sichuan 610064, Peoples Rep of China, **Farkhod Eshmatov** (olimjon55@hotmail.com), Chengdu, Sichuan 610064, Peoples Rep of China, and **Song Yang** (syang.math@gmail.com), Chengdu, Sichuan 610064, Peoples Rep of China. *Non-commutative Poisson structures on Calabi-Yau algebras.*

The notion of Calabi-Yau(CY) algebras is introduced by V. Ginzburg and may be viewed as non-commutative generalization of affine CY varieties.We will see that that under some mild conditions, on each algebra CY algebra A, there is a derived non-commutative Poisson structure which induces a graded Lie algebra structure on the cyclic homology of A. This is joint work with X. Chen, F. Eshmatov and S. Yang. (Received January 19, 2016)

17 ► Nonassociative rings and algebras

1117-17-31 **Irfan Bagci***, 3820 Mundy Mill Rd, Oakwood, GA 30566. *On representations of map superalgebras.*

Map superalgebras are Lie superalgebras consisting of maps from an algebraic variety to a target Lie superalgebra. They form a large class of Lie superalgebras that generalize the loop and current Lie superalgebras. Recently there has been some interest in the representation theory of map superalgebras and the particular interest is the classification of finite dimensional irreducible representations. The cases when the target is a finite dimensional basic classical Lie superalgebra irreducible finite dimensional representations both for twisted and untwisted map superalgebras recently has been classified. In this talk I will address the case when the target is a Cartan type Lie superalgebra. In particular, I will present a classification of the irreducible finite-dimensional representations in this case. (Received December 17, 2015)

1117-17-72 **Brian D. Boe***, Department of Mathematics, University of Georgia, Athens, GA 30602, and **Christopher M. Drupieski**, **Tiago R. Macedo** and **Daniel K. Nakano**. *Extensions for Generalized Current Algebras.* Preliminary report.

Given a complex semisimple Lie algebra $\mathfrak{g}$ and a commutative $\mathbb{C}$-algebra A, let $\mathfrak{g}[A] = \mathfrak{g} \otimes A$ be the corresponding generalized current algebra. In this talk we explore questions involving the finite-dimensionality and computation of extension groups for finite-dimensional $\mathfrak{g}[A]$-modules. Formulas for computing Ext^1 and Ext^2 between simple $\mathfrak{g}[A]$-modules are presented. As an application of these methods, we completely describe $\mathrm{Ext}^2_{\mathfrak{g}[A]}(L_1, L_2)$ for $\mathfrak{g} = \mathfrak{sl}_2$ and $A = \mathbb{C}[t]$, when L_1 and L_2 are simple $\mathfrak{g}[A]$-modules which are each given by the tensor product of two evaluation modules. (Received January 02, 2016)

1117-17-124 **Angelo Bianchi** (acbianchi@unifesp.br), **Tiago Macedo*** (tmacedo@unifesp.br) and **Adriano Moura** (aamoura@ime.unicamp.br). *Demazure and local Weyl modules for hyper current algebras.*

A hyper algebra is a Hopf algebra associated to a Lie algebra, similar to its universal enveloping algebra, and obtained from it by first choosing a certain integral form and then changing scalars. They provide a way to pass from a category of modules for a Lie algebra over an algebraically closed field of characteristic zero to its analog in positive characteristic. When the underlying simple Lie algebra is simply laced, we show that local Weyl modules are isomorphic to certain Demazure modules, extending to positive characteristic a result due to Fourier and Littelmann. For other simple Lie algebras, we extend a result of Naoi by proving that local Weyl modules admit a filtration whose factors are isomorphic to Demazure modules. Using these results, we are able to confirm a conjecture of Jakelic and Moura, stating that the character of local Weyl modules for hyper loop algebras are independent of the (algebraically closed) ground field. (Received January 08, 2016)

1117-17-126 **Vyacheslav Futorny**, **Dimitar Grantcharov*** (grandim@uta.edu) and **Luis Enrique Ramirez**. *Singular Gelfand-Tsetlin modules.*

The classical Gelfand-Tsetlin formulas provide a basis in terms of tableaux for every irreducible finite-dimensional module of $\mathfrak{gl}(n)$. These formulas can be used to define a $\mathfrak{gl}(n)$-module structure on some infinite-dimensional modules - the so-called generic Gelfand-Tsetlin modules. One important property of these modules is that for every generic tableau T there exists a unique irreducible generic Gelfand-Tsetlin module containing T as a basis element. In this talk we will introduce a new class of non-generic Gelfand-Tsetlin modules, which we call 1-singular. These modules play important role in the classification of the irreducible Gelfand-Tsetlin modules of $\mathfrak{gl}(3)$. The talk is based on a joint work with V. Futorny and L.E. Ramirez. (Received January 08, 2016)

1117-17-146 **Alex J Feingold*** (alex@math.binghamton.edu), Dept of Mathematical Sciences, Binghamton University, SUNY, 4400 Vestal Parkway East, Binghamton, NY 13902-6000, and **Diego A Penta** (diegopenta@gmail.com). *Decomposition of the rank 3 hyperbolic Kac-Moody algebra $\mathcal{F}$ with respect to a rank 2 hyperbolic subalgebra Fib.* Preliminary report.

In 1983 Feingold-Frenkel studied the structure of a rank 3 hyperbolic Kac-Moody algebra $\mathcal{F}$ containing the affine KM algebra $A_1^{(1)}$. In 2004 Feingold-Nicolai showed that $\mathcal{F}$ contains all rank 2 hyperbolic KM algebras with symmetric Cartan matrices, $A = \begin{bmatrix} 2 & -a \\ -a & 2 \end{bmatrix}$, $a \geq 3$. The case when $a = 3$ is called *Fib* because of its connection with the Fibonacci numbers (Feingold 1980). Some important structural results about $\mathcal{F}$ come from the decomposition with respect to its affine subalgebra $A_1^{(1)}$. Here we study the decomposition of $\mathcal{F}$ with respect to its subalgebra *Fib*. This current work is joint with Diego Penta. (Received January 11, 2016)

1117-17-187 **Maarten J. Bergvelt*** (bergv@illinois.edu). *N-Bosonization and Q-systems.*

In the usual bosonization of representations of affine Lie algebras one chooses a Heisenberg subalgebra. In this talk we will discuss a variant of the construction where one uses, instead of a Heisenberg algebra, the lower triangular subgroup N of the loopgroup. To the usual bosonization integrable systems are attached, given by infinite hierarchies of differential equations. In case of N bosonization one also gets integrable systems, but now they consist of difference equations. The simplest case of the loop group of $SL(2)$ on obtains the Q-system known from statistical mechanics and other parts of representation theory. (Received January 13, 2016)

1117-17-243 **Andrew J. Talian*** (atalian@cord.edu). *Lie superalgebra modules of constant Jordan type.*

Modules of constant Jordan type were first defined and studied over finite group schemes by Carlson, Friedlander, and Pevtsova. In a series of works, these authors and several others demonstrate many useful and interesting properties of these modules as well as their use in constructing new vector bundles over $\mathbb{P}^n$ of low rank.

In this talk, an adaption of these techniques is applied to finite dimensional modules over a Lie superalgebra $\mathfrak{g} = \mathfrak{g}_{\overline{0}} \oplus \mathfrak{g}_{\overline{1}}$. We will introduce the corresponding definition in this context, note some properties of these modules, and show their closure under many standard operations. We will also discuss how the Jordan type detects projectivity and the property of being endotrivial, as well as examining stronger results in the specific case of modules over the type $\mathfrak{f}$ detecting subalgebra and the construction of vector bundles, if time permits. (Received January 15, 2016)

1117-17-255 **Diego A. Penta*** (penta@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, 4400 Vestal Parkway East, Binghamton, NY 13850, and **Alex J. Feingold** (alex@math.binghamton.edu), Department of Mathematical Sciences, Binghamton University, 4400 Vestal Parkway East, Binghamton, NY 13850. *Rank 2 'Fibonacci' modules inside the rank 3 Feingold-Frenkel algebra $\mathcal{F}$.*

Motivated by the 1983 work of Feingold and Frenkel, we investigate the decomposition of the rank 3 hyperbolic Kac-Moody Lie algebra $\mathcal{F}$ with respect to its rank 2 hyperbolic subalgebra Fib (Cartan matrix $\begin{bmatrix} 2 & -3 \\ -3 & 2 \end{bmatrix}$). We study highest and lowest weight Fib-modules in $\mathcal{F}$, as well as a curious type of irreducible module that is neither highest nor lowest with respect to Fib. This is a continuation of the earlier talk by Alex Feingold. (Received January 15, 2016)

1117-17-265 **Darlayne Addabbo*** (addabbo2@illinois.edu). *Q-systems and Generalizations in Representation Theory.*

Certain tau functions for the Toda lattice are solutions to a discrete integrable system called a Q-system. These tau functions can be written as matrix elements for the basic representation of $\widehat{sl_2}$, the universal central extension of the loop algebra of sl_2, on fermionic Fock space. It is then natural to ask what sort of discrete equations are satisfied by analogous tau functions written as matrix elements for the basic representation of $\widehat{sl_3}$. Since Q-systems appear in many places in representation theory, we hope that these new discrete equations satisfied by our $\widehat{sl_3}$ tau functions will also have interesting applications. We will discuss this new system of equations as well as the progress we have made in exploring its applications. (Joint work with M. Bergvelt) (Received January 15, 2016)

1117-17-390 **Oleg N Smirnov***, College of Charleston, Charleston, SC 29424. *Graded Lie Algebras and Kantor Pairs.* Preliminary report.

Isai Kantor studied a class of triple systems, now called Kantor triple systems, and developed the relationship of these systems with 5-graded Lie algebras. He classified finite dimensional simple Kantor triple systems over an algebraically closed field of characteristic 0.

These systems constitute one of the largest classes of nonassociative objects for which such a classification result has been obtained. The class includes Jordan triple systems as well as triple systems constructed from associative algebras, Jordan algebras, and many interesting exceptional objects.

Given a Kantor triple system one can construct a Kantor pair by doubling. So in this sense Kantor pairs are generalizations of Kantor triple systems. Moreover, pairs are more natural objects to consider from the viewpoint of graded Lie algebras.

In this talk a new version of classification theorem for simple Kantor pairs will be presented. This version is based on Zelmanov's classification of simple Lie algebras with finite grading and on our work on associative graded algebras.

This is a joint work with Bruce N. Allison (Univ. of Alberta) and John R. Faulkner (Univ. of Virginia) (Received January 18, 2016)

1117-17-403 **E. G. Jurisich*** (jurisiche@cofc.edu) and **B. L. Cox**. *Free field realizations of the three-point algebra.*

The definition of the three point algebra will be reviewed, and two field representations for this algebra will be introduced. The three-point algebra is perhaps the simplest nontrivial example of a Krichever– Novikov algebra beyond an affine Kac–Moody algebra. We provide a natural free field realization in terms of a beta- gamma system and the oscillator algebra of the three-point affine Lie algebra when $\mathfrak{g} = \mathfrak{sl}(2, C)$. (Received January 18, 2016)

1117-17-417 **Laura Rider** and **Amber Russell*** (acrusse3@butler.edu). *Sheaves on the Nilpotent Cone and Lusztig's Relative Weyl Groups.* Preliminary report.

Lusztig's generalized Springer correspondence describes perverse sheaves on the nilpotent cone in terms of his relative Weyl groups. I'll discuss recent work joint with Rider on a description of the ambient equivariant derived category. (Received January 19, 2016)

1117-17-449 **Antun Milas***, 1400 Washington Avenue, Albany, NY 12110. *Unrolled Quantum Groups and W-Algebras.* Preliminary report.

We discuss certain vertex W-algebras, realized as subalgebras of the Heisenberg vertex algebra, in connection to (higher rank) unrolled quantum groups at root of unity. (Received January 18, 2016)

1117-17-481 **Ben L. Cox*** (coxbl@cofc.edu), Math Department, College of Charleston, 66 George Street, Charleston, 29401, and **Kaiming Zhao** (kzhao@wlu.ca), , Canada. *On the Universal Central Extension of Certain Krichever-Novikov Algebras.*

Let $p(t) \in \mathbb{C}[t]$ be a polynomial with distinct roots and nonzero constant term. We describe, using Faá de Bruno's formula and Bell polynomials, the universal central extension in terms of generators and relations for the Krichever-Novikov algebras of the form $\mathfrak{g} \otimes R$ and $\mathrm{Der}(R)$ whose coordinate ring is $R = \mathbb{C}[t, t^{-1}, u | u^2 = p(t)]$. (Received January 19, 2016)

1117-17-513 **Jordan Alexander** (jordan.alexander@tamucc.edu) and **Markus Hunziker*** (markus_hunziker@baylor.edu). *Modules of covariants and category $\mathcal{O}$.* Preliminary report.

We show how to solve some famous problems (old and new) from classical invariant theory by using the structure of certain categories of highest weight modules. For example, we will use the structure of a category of highest weight modules for the symplectic Lie algebra $\mathfrak{sp}_{2n}(\mathbb{C})$ to compute the homological dimension of the modules of covariants for the action of the orthogonal group $O_k(\mathbb{C})$ on $\mathbb{C}^k \oplus \cdots \oplus \mathbb{C}^k$ (n-copies) which leads to a simple explicit characterization of the Cohen–Macaulay modules of covariants. (Received January 19, 2016)

18 ► Category theory; homological algebra

1117-18-431 **Michael K Brown**, **Claudia Miller*** (clamille@syr.edu), **Peder Thompson** and **Mark E Walker**. *Adams operations for matrix factorizations and a conjecture of Dao and Kurano.*

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, avoiding simplicial theory altogether.

As an application, we prove a conjecture of Dao and Kurano on the vanishing of Hochster's theta pairing 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 January 18, 2016)

19 ► K-theory

1117-19-381 **J. Matthew Douglass*** (mdouglas@nsf.gov). *A factorization of the T-equivariant K-theory of flag varieties.* Preliminary report.

Suppose G is a connected, reductive algebraic group, B is a Borel subgroup of G, and T is a maximal torus in B. Let P be a subgroup of G containing B and let L be the Levi subgroup of P that contains T. The natural projection from G/B to G/P is a fibration with fibre $P/B \cong L/(B \cap L)$. It can be shown that the cohomology of G/B factors as

(1) $H^*(G/B) \cong H^*(G/P) \otimes_{H^*(\mathrm{pt})} H^*(L/(B \cap L))$,

where pt is a one point space. Drellich and Tymoczko have shown that the analog of (1) holds in T-equivariant cohomology, namely

(2) $H^*_T(G/B) \cong H^*_T(G/P) \otimes_{H^*_T(\mathrm{pt})} H^*_T(L/(B \cap L))$.

They have also shown that their factorization is compatible with the forgetful functor to ordinary cohomology, and thus induces the factorization in (1). In this talk I will discuss the analog of (1) and (2) to a factorization

(3) $K_T(G/B) \cong K_T(G/P) \otimes_{K_T(\mathrm{pt})} K_T(L/(B \cap L))$

in T-equivariant K-theory that is compatible with the forgetful functor to K-theory and passage to T-equivariant cohomology. This is joint work with Elizabeth Drellich. (Received January 18, 2016)

20 ► Group theory and generalizations

1117-20-6 **Christopher M Drupieski*** (cdrupies@depaul.edu), Department of Mathematical Sciences, DePaul University, 2320 N Kenmore Ave, Chicago, IL 60614-3210, and **Jonathan R Kujawa** (kujawa@math.ou.edu), Department of Mathematics, University of Oklahoma, Norman, OK 73019-3103. *Support varieties for Lie superalgebras and graded group schemes.* Preliminary report.

Following the pioneering work of Quillen in the 1970s, Carlson, Avrunin and Scott, Friedlander and Parshall, Jantzen, and others made much progress in the 1980s studying the cohomology and representation theory of finite groups and restricted Lie algebras by way of their associated cohomological support varieties. Later, many of these methods and results were generalized first to infinitesimal group schemes by Suslin, Friedlander, and Bendel, and then to arbitrary finite group schemes by Friedlander and Pevtsova.

In this talk I will discuss some results and conjectures concerning how some of the aforementioned methods and results can be generalized to restricted (and non-restricted) Lie superalgebras and to certain finite graded group schemes. This is joint work with Jonathan Kujawa. (Received September 08, 2015)

1117-20-34 **Klaus Lux** and **Nham V Ngo*** (nhamvongo@gmail.com), Department of Mathematics, University of Arizona, Tucson, AZ 85721, and **Yichao Zhang**. *Cohomology of SL_2 and related structures.*

Let SL_2 be the rank one simple algebraic group defined over an algebraically closed field k of characteristic $p > 0$. In this talk we present a new method for computing the dimension of the cohomology spaces $\mathrm{H}^n(SL_2, V(m))$ for Weyl SL_2-modules $V(m)$ using cohomology of Frobenius kernels. Various results are then obtained for extension spaces $\mathrm{Ext}^n_{SL_2}(V(m_2), V(m_1))$ between Weyl modules $V(m_1)$ and $V(m_2)$. Finally, we give explicit upper bounds for the cohomology dimensions of SL_2 and the finite Chevalley group $SL_2(p^s)$ with coefficients in simple modules. (Received December 18, 2015)

1117-20-134 **George J McNinch*** (mcninchg@member.ams.org). *Central subalgebras of the centralizer of a nilpotent element.*

Let G be a connected, semisimple algebraic group over a field k whose characteristic is **very good** for G. In a canonical manner, one associates to a nilpotent element $X \in \mathrm{Lie}(G)$ a parabolic subgroup P – in characteristic zero, P may be described using an $\mathfrak{sl}_2$ triple containing X; in general, P is the "instability parabolic" for X as in geometric invariant theory.

In this setting, we are concerned with the center $Z(C)$ of the centralizer C of X in G. Choose a Levi factor L of P, and write d for the dimension of the center $Z(L)$. Finally, assume that the nilpotent element X is **even**.

In some recent work with Donna Testerman, we show that one may **deform** $\mathrm{Lie}(L)$ to $\mathrm{Lie}(C)$. This deformation produces a d dimensional subalgebra of $\mathrm{Lie}(Z(C))$. Since $Z(C)$ is a smooth group scheme, it follows that $\dim Z(C) \geq d = \dim Z(L)$.

In fact, Lawther and Testerman have proved that $\dim Z(C) = \dim Z(L)$. Despite only yielding a partial result, the interest in the present method is that it avoids the extensive case checking carried out by Lawther-Testerman in the memoir [LT 11]. (Received January 09, 2016)

1117-20-238 **Eric Sommers*** (esommers@math.umass.edu), Department of Mathematics and Statistics, LGRT, UMass Amherst, Amherst, MA 01003. *A family of Weyl group representations.*

We will discuss a family of representations of a Weyl group that arises in different contexts: hyperplane arrangements, affine Springer theory, and rational Cherednik algebras. The focus will be on decomposing the representations into induced pieces and obtaining q-analogues of well-known combinatorial quantities (namely, the Kreweras and Narayana numbers). These q-analogues lead to instances of cyclic sieving. This is joint work with Vic Reiner. (Received January 15, 2016)

1117-20-357 **Jiuzu Hong*** (jiuzu@email.unc.edu), Chapel Hill, NC 27514. *Parametrization of bases and saturation problems.*

Geometric Satake correspondence provides a uniform way to construct all irreducible representations of reductive groups. It also gives rise to bases of representations and the spaces of their tensor invariants. By recent work of Goncharov-Shen, these bases can be parametrized via tropical geometry. Saturation problems concern

multiplicities that appear in the decompositions of representations into irreducible components. I will explain how using Knutson-Tao's saturation theorem, the geometric Satake correspondence and parametrization of bases can be applied to get new results about the saturation problem for the spin group $Spin(2n+1)$. This talk is based on the joint work with Linhui Shen. (Received January 17, 2016)

1117-20-394 **Cornelius Pillen*** (pillen@southalabama.edu), Department of Mathematics and Statistics, University of South Alabama, Mobile, AL 36688. *Lifting modules for a finite group of Lie type to its ambient algebraic group.* Preliminary report.

Let G be a simple algebraic group over an algebraically closed field k of prime characteristic p which is split over the prime field $\mathbb{F}_p$. Set $q = p^r$. The set of fixed points of the rth iterate of the Frobenius map on G, denoted by $G(q)$, form a finite group of Lie type group. We are interested in the following question: Given a $kG(q)$-module M, can it be lifted to a module for the algebraic group G? For example, a well-known result due to Robert Steinberg says that all the simple modules can be lifted. But in general the answer to this question is negative. This talk is a survey of known results together with some explicit SL_2 examples. (Received January 18, 2016)

1117-20-418 **William D Hardesty*** (hardes1@uga.edu). *On Support Varieties and the Humphreys Conjecture in type A.*

Let G be a reductive algebraic group scheme defined over $\mathbb{F}_p$ and let G_1 denote the Frobenius kernel of G. To each finite-dimensional G module M, one can define the support variety $V_{G_1}(M)$, which can be regarded as a G-stable closed subvariety of the nilpotent cone. A G-module is called a tilting module if it has both good and Weyl filtrations. In 1997, it was conjectured by J.E. Humphreys that when $p \geq h$, the support varieties of the indecomposable tilting modules align with the nilpotent orbits given by the Lusztig bijection. We shall verify this conjecture when $G = SL_n$ and $p > n+1$. (Received January 18, 2016)

1117-20-468 **Pramod N Achar*** (pramod@math.lsu.edu), 262 Lockett Hall, Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803-4918, and **Simon Riche** (simon.riche@math.univ-bpclermont.fr). *Reductive groups, the loop Grassmannian, and the Springer resolution.*

Let G be a reductive group over an algebraically closed field $\Bbbk$ of characteristic $p > 0$. Assume that p is larger than the Coxeter number for G. I will discuss relationships between the following four categories: (i) the principal block of G; (ii) representations of a Borel subgroup B that are trivial on its first Frobenius kernel; (iii) coherent sheaves on the Springer resolution for G; (iv) perverse $\Bbbk$-sheaves on the loop Grassmannian for the Langlands dual group. This picture, inspired by characteristic-0 results of Arkhipov–Bezrukavnikov–Ginzburg, leads to a graded analogue of the Finkelberg–Mirković conjecture. This is joint work with Simon Riche. (Received January 19, 2016)

1117-20-475 **Mark Greer** and **Lee Raney*** (lraney@una.edu). *Groups, Loops, and the Baer Trick.* Preliminary report.

Given a uniquely 2-divisible group G, we discuss the Baer trick, a remarkable modification of the group operation which induces a loop $(G, +)$. We will examine the structure of these Baer trick loops $(G, +)$ in general and survey a few known results. We will then discuss necessary and sufficient conditions for the group G to satisfy in order to guarantee a certain desirable structure on the corresponding Baer trick loop. (Received January 19, 2016)

1117-20-484 **Mark B Greer*** (mgreer@una.edu), One Harrison Plaza, UNA Box 5051, Florence, AL 35632. *A general construction for simple right conjugacy closed loops.*

A loop Q is a right conjugacy closed loop (or RCC loop) if R_Q is closed under conjugation. In this talk, we give the first general construction of a large class of nonassociative, finite simple RCC loops. Our construction by no means accounts for all such loops, thus a full classification of finite simple RCC loops is still elusive. It turns out that our construction is not new, but is easily seen to be equivalent to a construction by Hall for non-Desarguesian planes, called Hall planes. Though Hall planes of the same order are isomorphic, the same is not true for the associated RCC loops. Hence, we will discuss the classification of such loops. (Received January 19, 2016)

22 ► Topological groups, Lie groups

1117-22-274 **Ivan Loseu*** (i.loseu@neu.edu), 360 Huntington Avenue, Boston, MA 02446.
Quantizations of nilpotent orbits.

I will discuss my recent results on existence and classification of quantizations of algebras of regular functions on nilpotent orbits in semisimple Lie algebras. (Received January 16, 2016)

1117-22-294 **Sam Evens*** (sevens@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *The Gelfand-Zeitlin integrable system for the orthogonal Lie algebra.*

Kostant and Wallach introduced the Gelfand-Zeitlin integrable system on gl(n,C) and studied the flows of maximal dimension. We will primarily discuss its analogue for so(n,C), and recent results describing the flows of maximal dimension by using the Luna slice theorem. We will also discuss implications for gl(n,C). This talk is based on joint work with Mark Colarusso. (Received January 16, 2016)

1117-22-374 **Leticia I Barchini*** (leticia@math.okstate.edu), 403 Mathematical Science, Oklahoma State University, Stillwater, OK 74074. *On the Characteristic Cycle of Harish-Chandra modules.* Preliminary report.

The Characteristic cycle is an important invariant of Harish-Chandra modules. This invariant encodes deep information about the modules, the related geometry and various actions of finite groups. The aim of the talk is to explore such connections based on concrete computations on examples. (Received January 18, 2016)

1117-22-473 **S. Mehdi**, **P. Pandžić**, **D. A. Vogan** and **R. Zierau*** (roger.zierau@okstate.edu).
Dirac Index and Associated Cycles. Preliminary report.

A conjecture of Mehdi, Pandžić and Vogan relates the Dirac index and the associated cycle for certain Harish-Chandra modules. Suppose (i) G is a complex group, (ii) K is the fixed points of an involution, and (iii) rank(K) = rank(G). The equal rank condition allows one to define an invariant, $DI(X)$, of a Harish-Chandra module X known as the Dirac index. The associated cycle is another invariant of X; it is a formal sum $AC(X) = \sum m_i(X) \cdot [\bar{\mathcal{O}}_i]$, where the $\mathcal{O}_i$ are nilpotent K-orbits in $(\mathfrak{g}/\mathfrak{k})^*$ and each $m_i(X)$ is an integer. The conjecture states that for a certain complex nilpotent G-orbit $\mathcal{O} \subset \mathfrak{g}^*$ (of particular interest), there exist integers c_i so that

$$DI(X) = \sum c_i m_i(X)$$

for all X whose annihilator has associated variety $\bar{\mathcal{O}}$.

The lecture will give an outline of a proof of the conjecture. Some comments will also be made on the computation of the constants. (Received January 19, 2016)

1117-22-486 **William Graham*** (wag@uga.edu). *A generalization of the Springer resolution.*

There is a bijective correspondence between conjugacy classes of nilpotent complex $n \times n$ matrices and irreducible representations of the symmetric group S_n, since both are in bijection with the partitions of n. In 1976, Springer gave an explanation of this bijection which is connected to a resolution of singularities of the variety of nilpotent matrices called the Springer resolution. This explanation extends to the setting of arbitrary semisimple groups, and was further extended by Lusztig, who introduced a generalized Springer correspondence to complete the picture. Springer's theory, and its extension by Lusztig, have had important applications in a number of areas in representation theory. This talk will discuss some of this background, as well as joint work with Martha Precup and Amber Russell on a new approach to the generalized Springer correspondence in type A using a generalization of the Springer resolution. (Received January 19, 2016)

1117-22-498 **Evgeny Mukhin***, Department of Mathematical Sciences, IUPUI, 402 N. Blackford St., LD270, Indianapolis, IN 462023216. *Bethe ansatz for toroidal algebras.*

We describe the spectrum of integrable system associated with the quantum toroidal gl(1) using Bethe ansatz. Our approach allows to deduce the Bethe ansatz equations and the spectrum of the model solely from the representation theory. This is a report on a joint work with B. Feigin, M. Jimbo, and T. Miwa. (Received January 19, 2016)

26 ► Real functions

1117-26-178 **Dmitriy M Stolyarov*** (dms@math.msu.edu). *Anisotropic Ornstein non-inequalities.*
We investigate existence of a priori estimates for differential operators in L^1 norm: for anisotropic homogeneous differential operators $T_1, \dots, T_\ell$, we study the conditions under which the inequality

$$\|T_1 f\|_{L_1(\mathbb{R}^d)} \lesssim \sum_{j=2}^{\ell} \|T_j f\|_{L_1(\mathbb{R}^d)}$$

holds true. This is a generalization of the classical Ornstein theorem. Using a certain Bellman function, we are able to translate the problem from the language of differential operators to the language of separately convex functions. In this second world, the Ornstein problem appears to be quite elementary.

We also discuss a similar problem for martingale transforms. The talk is based on the joint work with Krystian Kazaniecki and Michal Wojciechowski, see the preprint *Anisotropic Ornstein non-inequalities*, http://arxiv.org/abs/1505.05416. (Received January 12, 2016)

28 ► Measure and integration

1117-28-196 **Mark W Meckes*** (mark.meckes@case.edu), Cleveland, OH 44106. *The magnitude of a compact set in Euclidean space.*
Magnitude is an invariant of metric spaces introduced by Leinster, motivated by considerations from category theory. Although its definition is abstract and algebraic, magnitude rather surprisingly turns out to be closely related to classical geometric quantities, like volume and dimension. I will survey recent progress on magnitude, due to myself and to Juan Antonio Barcelo and Tony Carbery. (Received January 13, 2016)

1117-28-199 **Paata Ivanisvili*** (ivanishvili.paata@gmail.com), 326 Ivan Dr, Kent, OH 44240, and **Alexander Volberg**. *Isoperimetric functional inequalities via the maximum principle: the exterior differential systems approach.*
We will present the unified approach to the solutions of a class of isoperimetric problems by relating them to the exterior differential systems studied by R. Bryant and P. Griffiths. We will illustrate several classical by now isopereimetric inequalities which can be proved in a unified way. This unified approach reduces them to the so-called exterior differential systems studied by Robert Bryant and Phillip Griffiths. To the best of our knowledge, this is the first work where this connection is used. (Received January 13, 2016)

1117-28-464 **Joshua Isralowitz** and **Kabe Moen*** (kabe.moen@ua.edu), P.O. Box 870350, Tuscaloosa, AL 35487. *Poincaré inequalities and estimates for fractional operators on matrix weighted spaces with applications to PDE.*
We will discuss fractional integral operators and fractional maximal operators acting on matrix weighted spaces. In the matrix weighted setting we prove analogous results to the work of Muckenhoupt and Wheeden in the scalar case. We will also prove Poincaré inequalities in matrix weighted spaces and use these inequalities to prove existence and regularity results for systems of degenerate elliptic equations. (Received January 20, 2016)

30 ► Functions of a complex variable

1117-30-79 **Dmitriy Dmitrishin**, **Anna Khamitova** and **Alex Stokolos*** (astokolos@georgiasouthern.edu), Department of Mathematics, Georgia Southern University, Statesboro, GA 30460. *On some applications of complex analysis in non-linear dynamics.*
We consider stability of equilibrium in a discrete autonomous dynamical system. The suggested method involves extremal polynomials of complex variable. The examples of applications include Hénnon map, Burgers mapping, Arnold's Cat map, Ikeda map and several others. (Received January 03, 2016)

1117-30-476 **John C Mayer*** (jcmayer@uab.edu). *Polygons in Laminations — Branch Points in Julia Sets.*
Laminations of the unit disk were introduced by William Thurston as a topological/combinatorial vehicle for understanding the (connected) Julia sets of polynomials, and, in particular, the parameter space of quadratic polynomials. Polygons in laminations represent branch points in the corresponding Julia set, with the number of sides of the polygon corresponding to the branch order of the point. Periodic branch points may first return

to themselves with or without local rotation (that is, with nonzero rational rotation number, or, respectively, rotation number 0). A well-known result of Thurston's for quadratic Julia sets is that there can be no wandering branch points and there can be no periodic branch points that return to themeselves for the first time without rotation. Thurston proved these results using laminations. A corresponding polygon in a lamination that first returns without rotation is called an *identity return polygon*. Kiwi showed that the branch order of a point returning without rotation is limited by the degree of the polynomial. We discuss these results, more precise formulations of them, and extensions in the context of polygons in laminations corresponding to (connected) Julia sets of polynomials of degree > 2. (Received January 19, 2016)

31 ► Potential theory

1117-31-99 **Sergiy Borodachov**, **Doug Hardin** and **Alexander Reznikov*** (aleksandr.b.reznikov@vanderbilt.edu), 1326 Stevenson Center, Department of Mathematics, Vanderbilt University, Nashville, TN 37240, and **Edward B Saff**. *Maximal discrete polarization on manifolds.*

We will survey some new results about asymptotic behavior of maximal discrete polarization on manifolds. In the case of a unit cube, proof of our result reminds of a certain Bellman function procedure. (Received January 05, 2016)

32 ► Several complex variables and analytic spaces

1117-32-96 **Greg Knese**, Washington University in St Louis, St Louis, MO, **Lukasz Kosinski**, Jagiellonian University, Krakow, Poland, **Thomas J Ransford**, Laval University, Quebec City, Quebec , Canada, and **Alan A Sola*** (sola@usf.edu), Department of Mathematics and Statistics, University of South Florida, Tampa, FL 33620. *Cyclic polynomials in anisotropic Dirichlet spaces.*

We characterize polynomials in two complex variables that are cyclic for shift operators acting on weighted Dirichlet spaces indexed by two real parameters. (Received January 05, 2016)

1117-32-277 **Robert Rahm*** (robertrahm@gmail.com), 6270 Cates Ave, Apt 1E, St. Louis, MO 63130, **Edgar Tchoundja**, University of Yaounde I, P.O. Box 812, Yaounde, Cameroon, and **Brett Wick**, One Brookings Drive, School of Math, St. Louis, MO 63130. *Sharp Weighted Bounds for the Bergman Projection and Related Operators on $A^2(\mathbb{B}^n)$.*

Using modern techniques of dyadic harmonic analysis, we are able to prove sharp estimates for the Bergman projection and Berezin transform and more general operators in weighted Bergman spaces on the unit ball in $\mathbb{C}^n$. The estimates are in terms of the Bekolle-Bonami constant of the weight. This generalizes results of Pott-Reguera to several variables and to a more general class of operators. (Received January 16, 2016)

1117-32-410 **Amalia Culiuc*** (amalia@math.brown.edu), 151 Thayer st, Providence, RI 02912. *The A_2 conjecture in vector-valued function spaces.*

The famous A_2 conjecture states that if T is a Calderon-Zygmund operator acting on the weighted space L_2 of scalar-valued functions with A_2 weights w, then T is bounded on $L_2(w)$ and the bound depends linearly on the A_2 characteristic. While this conjecture was settled in 2012, its equivalent in the space of vector-valued functions with matrix weights remains open. In this talk we investigate the boundedness of various Calderon-Zygmund operators on weighted vector-valued function spaces and discuss some of the challenges to extending the A_2 conjecture to a more general setting. Joint work with Kelly Bickel, Sergei Treil, and Brett Wick (Received January 18, 2016)

33 ► Special functions

1117-33-145 **Plamen Iliev*** (iliev@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332-0160. *A Lie-theoretic interpretation of bispectral polynomials in several variables.*

I will discuss a Lie-theoretic interpretation of multivariate analogs of the self-dual classical discrete orthogonal polynomials which can be used to derive their bispectral properties. This approach naturally leads to the construction of two commutative algebras of partial difference operators diagonalized by the polynomials: one

consisting of operators acting on the variables of the polynomials, and a second algebra consisting of operators acting on the degree indices. (Received January 11, 2016)

1117-33-535 **Karen T. Kohl*** (karen.kohl@usm.edu), Department of Mathematics, University of Southern Mississippi, Long Beach, MS 39560. *Recurrences for integrals of special functions.* Preliminary report.

The method of brackets is an experimental method for symbolic evaluation of definite integrals, including many involving special functions. We show how to study output in the form of multi-sum series using recurrence-finding algorithms, producing verifiable summation identities in the process. Additionally, the recurrences hold for the integrals themselves, allowing us to extend classes of integrals. (Received January 19, 2016)

34 ► Ordinary differential equations

1117-34-30 **Alex Kasman*** (kasmana@cofc.edu), Department of Mathematics, College of Charleston, 66 George Street, Charleston, SC 29401. *Darboux transformations that do* not *preserve bispectrality.*

Bispectrality occurs when a function satisfies two different eigenvalue equations with the role of spectral and spatial variables exchanged. Its connections to integrable systems (finite dimensional and infinite dimensional, classical and quantum) and to orthogonal polynomials have been of great interest, with recent research focused on the non-commutative case. In the commutative case, one generally expects Darboux transformations to preserve the property of bispectrality, providing a tool for generating new examples from known ones. Surprisingly, this fails to be so when the eigenfunction and eigenvalues are chosen from some non-commutative algebra. This talk will include examples in which even a rational Darboux transformation of a rank one bispectral triple fails to preserve bispectrality. The talk will also review the existing results guaranteeing that bispectrality will be preserved and the open problems that remain. (Received December 17, 2015)

1117-34-95 **Evans M Harrell*** (harrell@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332-0160, and **Anna V Maltsev** (annavmaltsev@gmail.com), Department of Mathematics, University of Bristol, Bristol, BS81SD, United Kingdom. *Localization and spectral problems on quantum graphs.*

It is shown that the Agmon method for establishing exponential decrease of eigensolutions (or subsolutions) can be adapted to quantum graphs. As a generic matter, the rate of decay is controlled by an Agmon metric related to the classical Liouville-Geen estimate for the line, but more rapid decay is typical, arising from the geometry of the graph. Additional theorems capture this effect with alternative Agmon metrics, one adapted to a path and the other using averaging. Time permitting, some recent work on quantum graphs with optimal convex potentials will be described. (Received January 05, 2016)

1117-34-172 **Ahmed Ghatasheh***, UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170, Birmingham, AL 35294, and **Rudi Weikard**, UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170, Birmingham, AL 35294. *Periodic Sturm-Liouville Differential Equations with Distributional Potentials.* Preliminary report.

We consider the equation -u"+(q-zw)u=0 on the real line, where q is an a-periodic distribution, w is an a-periodic locally integrable function, and z the spectral parameter. We introduce Floquet Theory for this equation and we show a lot of interesting properties of the discriminant of this equation. Finally we show selfadjointness and existence of the spectrum with respect to periodic, semi periodic, and separated boundary conditions. (Received January 12, 2016)

1117-34-176 **Rudi Weikard*** (rudi@math.uab.edu), Department of Mathematics, University of Alabama at Birmingham, Birmingham, AL 35294-1170. *The spectral problem for the dispersionless Camassa-Holm equation.*

We analyze the spectral problem for $-y'' + qy = \lambda wy$ where q is a non-zero positive distribution (or measure) and w a real distribution of order zero decaying at infinity. We then investigate the inverse spectral problem and discuss the application of the results to the Camassa-Holm equation.

This is joint work with Malcolm Brown and Christer Bennewitz. (Received January 12, 2016)

35 ► Partial differential equations

1117-35-5 **Thinh Kieu*** (thinh.kieu@ung.edu), 2514 Education Way Apt#2514, Oakwood, GA 30566, and **Luan Hoang** (luan.hoang@ttu.edu), Box 41042, Lubbock, TX 79409. *Global estimates for generalized Forchheimer flows of slightly compressible fluids in porous media.*

. In this article, 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 21, 2015)

1117-35-12 **Maryam Yashtini*** (myashtini3@math.gatech.edu), School of Mathematics, Georgia Tech, 686 Cherry St NW, Atlanta, GA 30332. *Fast Alternating Minimization Methods for Convex and Non-convex Inverse Problems and Applications.* Preliminary report.

In the first part, I will introduce a fast alternating direction approximate Newton method for solving total variation regularized inverse problems. The proposed algorithm is designed to handle applications where the matrix in the fidelity term is a large dense, ill conditioned. Numerical results are provided using test problems from parallel magnetic resonance imaging. In the second part, I will focus on the Euler's Elastica-based inpainting model. The associated Euler-Lagrange equation of this model is fourth order hence minimization of energy functional becomes very complex. I will introduce new methods to solve this problem much more efficiently. Comparisons are made with some state of art algorithms on image inpainting. (Received November 01, 2015)

1117-35-24 **Viktoria Savatorova*** (vsavatorova@gmail.com) and **Alexey Talonov** (alextalonov@gmail.com).
Homogenization of PDEs arising in Dual-Porosity Models for Fluid Flow in Organic-Rich Shales.

We consider a single phase fluid flow through a porous medium, consisting of organic inclusions imbedded into inorganic matrix. There exist a contrast of properties and spatial scales between the matrix and inclusions. The pore size can vary from micro- to nanometers, permeability and diffusivity can differ by several orders of magnitude. The double porosity model is derived as a system of coupled parabolic equations, the interchange of fluid between the matrix and the inclusions is taken into account. We apply multi-scale analysis to mass balance equations considering such processes as desorption of gas from organic nanopores, diffusion, and filtration. We assume that the free gas is in the inorganic pores and transported by the mechanisms of filtration and molecular diffusion, whereas the sorbed phase is in the inclusions and transported by the surface diffusion mechanism. We focus on the upscaling from pore-scale to the core-scale and then from core-scale to reservoir scale. We derive homogenized macroscopic problem for fluid concentration in effective medium for the given initial and boundary conditions. The properties of effective medium depend on size and spatial distribution of the inclusions as well as on properties of both inclusions and matrix. (Received December 07, 2015)

1117-35-33 **Marcelo M Disconzi*** (marcelo.disconzi@vanderbilt.edu), 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240, and **David G Ebin**, Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *The free boundary Euler equations in 3D.*

We study the incompressible free boundary Euler equations with surface tension in three spatial dimensions. After establishing local well-posedness of the equations, we show that, under natural hypotheses, solutions are near those of the Euler equations in a fixed domain if the surface tension is sufficiently large. (Received December 18, 2015)

1117-35-40 **Seung Hyun Kim*** (skim227@u.rochester.edu). *An effective Log-transform method with the the fixed free Boundary for the approximation of the free boundary and solution in one-phase Stefan problem.* Preliminary report.

In this talk, we present an effective log-transform method which fixes the free boundary in one-phase Stefan problem into a straight line and, thus, changes the curvy domain into a rectangular domain. Then, we compare the numerical result obtained by this method with the exact solution. (Received December 21, 2015)

1117-35-54 **Alberto Bressan** and **Geng Chen*** (gchen73@math.gatech.edu). *Lipschitz metric for variational wave equation.*

Abstract: The nonlinear wave equation: $u_{tt} - c(u)[c(u)u_x]_x = 0$ is a natural generalization of the linear wave equation. In this talk, we will discuss a recent breakthrough addressing the Lipschitz continuous dependence of solutions on initial data for this quasi-linear wave equation. Our earlier results showed that this equation determines a unique flow of conservative solution within the natural energy space $H^1(R)$. However, this flow is not Lipschitz continuous with respect to the H^1 distance, due to the formation of singularity. To prove the desired Lipschitz continuous property, we constructed a new Finsler type metric, where the norm of tangent vectors is defined in terms of an optimal transportation problem. For paths of piecewise smooth solutions, we carefully estimated how the distance grows in time. To complete the construction, we proved that the family of piecewise smooth solutions is dense, following by an application of Thom's transversality theorem. This is a collaboration work with Alberto Bressan. (Received December 28, 2015)

1117-35-67 **Michele Coti Zelati*** (micotize@umd.edu) and **Jacob Bedrossian**. *Enhanced dissipation and hypoellipticity in shear flows.*

We analyze the decay and instant regularization properties of the evolution semigroups generated by two-dimensional drift-diffusion equations in which the scalar is advected by a shear flow and dissipated by full or partial diffusion. We consider both the case of space-periodic and the case of a bounded channel with no-flux boundary conditions. In the infinite Péclet number limit, our work quantifies the enhanced dissipation effect due to the shear. We also obtain hypoelliptic regularization, showing that solutions are instantly Gevrey regular even with only partial diffusion. (Received December 31, 2015)

1117-35-69 **Eunhee Park***, 831 East 3rd St, Dept of Mathematics at Indiana University, Boomington, IN 47405, and **CY Jung** and **R. Temam**. *Boundary layer analysis for nonlinear reaction-diffusion equations in polygonal domains.* Preliminary report.

We consider a singularly perturbed nonlinear reaction-diffusion equation that its solution display thin and sharp boundary layers near the boundary of a polygonal domain. We analyze the singular behaviors of the solutions at any given order with respect to the arbitrarily given small parameter. The key features of the article are that we deal with the corner boundary layers which the smooth domain does not possesses and analysis of the nonlinear term by truncated error. (Received December 31, 2015)

1117-35-75 **Xiaoming Wang*** (wxm@math.fsu.edu), Department of Mathematics, Florida State University, Tallahassee, FL 32306. *Models for hyporheic flows.*

We present a few recent results on some models of hyporheic flows that take into account the non-trivial geometry of the riverbed and the influence of the temperature. (Received January 02, 2016)

1117-35-80 **Xiaoqian Xu*** (xxu@math.wisc.edu) and **Alexander Kiselev** (kiselev@rice.edu). *Suppression of chemotactic explosion by mixing.*

Chemotaxis plays a crucial role in a variety of processes in biology and ecology. One of the most studied PDE models of chemotaxis is given by Keller-Segel equation, which describes a population density of bacteria or mold which attract chemically to substance they secrete. However, solution of Keller-Segel equation can exhibit dramatic collapsing behavior. In other words, there exist initial data leading to finite time blow up. In this talk, we will discuss the possible effects resulting from interaction of chemotactic and fluid transport processes, namely we will consider the Keller-Segel equation with additional advection term modeling ambient fluid flow. We will prove that the presence of fluid can prevent the singularity formation. We will discuss two classes of flows that have the explosion arresting property. Both classes are known as very efficient mixers. (Received January 03, 2016)

1117-35-81 **Roman Shterenberg*** (rshterenberg@gmail.com), 1300 University Blvd, Campbell Hall 452, Birmingham, AL 35294, and **Leonid Parnovski** and **Yulia Karpeshina**. *Recent progress in spectral analysis of almost-periodic differential operators.*

We will present recent results in spectral analysis of multi-dimensional almost-periodic differential operators and some of their applications. (Received January 04, 2016)

1117-35-84 **Mimi Dai*** (mdai@uic.edu) and **Alexey Cheskidov**. *Regularity for the 3D Navier-Stokes equations and related problems.*

As one of the most significant problems in the study of partial differential equations arising in fluid dynamics, Leray's conjecture in 1930's regarding the appearance of singularities for the 3-dimensional (3D) Navier-Stokes equations (NSE) has been neither proved nor disproved. The problems of blow-up have been extensively studied

for decades using different techniques. By using a method of wavenumber splitting which originated from Kolmogorov's theory of turbulence, we obtained a new regularity criterion for the 3D NSE. The new criterion improves the classical Prodi-Serrin, Beale-Kato-Majda criteria and their extensions. Related problems, such as the well/ill-posedness, will be discussed as well. (Received January 04, 2016)

1117-35-93 **Cristi Guevara** (cguevara@lsu.edu) and **Phuc Cong Nguyen*** (pcnguyen@math.lsu.edu). *On nonexistence of Leray's self-similar solutions to the 3D Navier–Stokes equations.*

It is shown that Leray's backward self-similar solutions to the Navier–Stokes equations with profiles in $L^{12/5}(\mathbb{R}^3)$ or in the Marcinkiewicz space $L^{q,\infty}(\mathbb{R}^3)$, $q \in (12/5, 6)$, must identically be zero. This follows from a more general result formulated in terms of Morrey spaces and the first order Riesz's potential. (Received January 05, 2016)

1117-35-122 **Dehua Wang*** (dwang@math.pitt.edu). *Global solution to the stochastic compressible Navier-Stokes equations.*

The three-dimensional compressible Navier-Stokes equations with stochastic forces will be considered. First the stochastic PDEs will be reviewed. Then the global existence of martingale solutions will be discussed. (Received January 08, 2016)

1117-35-159 **Zoi Rapti*** (zrapti@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green Street, Urbana, IL 61801, and **Carla Eva Caceres**. *Infectious disease in a model organism: modeling within and between host transmission and the role of the ecological network of predators and resources.*

We introduce a four-population partial differential equations (PDE) model to investigate the invasibility and prevalence of an obligately-killing fungal parasite (Metschnikowia bicuspidata) in a zooplankton host (Daphnia dentifera) as they are embedded in an ecological network of predators and resources. Our results provide key insights into the role of ecological interactions that vary with the age of infection. Specifically, the virulent effects of the pathogen on host fecundity and mortality (both intrinsic mortality and extrinsic due to predation) increase with the age of infection. Using a combination of analytical results and simulations, we show that selective predation, which is known both theoretically and empirically to reduce disease prevalence, does not always limit disease spread. Second, low host resources and intense predation can prevent disease spread, but once conditions allow the invasion of the parasite, the qualitative dynamics of the system do not depend on the intensity of the selective predation. Third, a comparison of the PDE model with a model based on ordinary differential equations (ODE model) reveals a parametrization for the ODE version that yields an endemic steady state and basic reproductive ratio that are identical to those in the PDE model. (Received January 12, 2016)

1117-35-211 **Seonguk Kim*** (ksw8755@gmail.com), 2163 17TH Ave South, Terrace Apartment, Birmingham, AL 35205, and **Yulia Karpeshina** (karpeshi@uab.edu), UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35205. *The perturbation formulas for Gross-Pitaevskii Equation (GPE) with periodic potential.*

In this talk, we investigate the perturbation formulas for Gross-Pitaevskii Equation (GPE) with periodic potential which is relevant to study Bose-Einstein condensate loaded into optical lattices. In the fi rst part of this study, we consider the perturbation formulas for Linear Schrödinger equation with periodic potential. In the second part, we use the results of the perturbation formulas of the linear equation to fi nd a stationary solution and its corresponding value for GPE. Here, we need a several methods, such as perturbation theory, spectral theory and successive method. (Received January 14, 2016)

1117-35-254 **Laxmi P. Paudel*** (laxmi.paudel@asurams.edu), 1447 US Highway 19 South, Unit 1-C, Leesburg, GA 31763, and **Joseph Iaia**. *Traveling Wave Solutions of the Porous Medium Equation.* Preliminary report.

We reduce the Porous Medium Equation (PME) into an ordinary differential equation (ODE), and prove the existence of its of solutions. We prove that the one parameter family of our solutions are stable under a suitable class of perturbations. This work includes extension of the various results, J. Iaia and S. Betelu got in two dimensional Porous Medium Equation, to three dimensions. (Received January 15, 2016)

1117-35-275 **Ilia Binder** (ilia@math.toronto.edu), **David Damanik** (damanik@rice.edu), **Michael Goldstein** (gold@math.toronto.edu) and **Milivoje Lukic*** (mlukic@math.toronto.edu). *KdV equation with almost periodic initial data.*

In the 1960s, the KdV equation was discovered to have infinitely many conserved quantities, explained by a Lax pair formalism. Due to this, the KdV equation is often described as completely integrable. Similar features

were soon found in other nonlinear equations, spurring the field of integrable PDEs in which the KdV equation continues to be one of the flagship models. These ideas were originally implemented for fast decaying initial data and, in the 1970s, for periodic initial data. In this talk, we will describe recent progress for almost periodic initial data, centered around a conjecture of Percy Deift that the solution is almost periodic in time. We will discuss the proof of existence, uniqueness, and almost periodicity in time, in the regime of absolutely continuous and sufficiently "thick" spectrum, and in particular, the proof of Deift's conjecture for small analytic quasiperiodic initial data. (Received January 16, 2016)

1117-35-298 **Yanni Zeng*** (ynzeng@uab.edu). *General hyperbolic-parabolic balance laws and thermal non-equilibrium flows.*

In this talk we discuss a general system of hyperbolic-parabolic balance laws in m space dimensions ($m \geq 1$). The system has rank deficient viscosity matrices and a lower order term whose Jacobian matrix is rank deficient as well. We show that the Cauchy problem with small data around a constant equilibrium state has solution global in time. The assumptions are reasonable and sufficiently general for applications to physical models. In particular, we study the gas flow with an internal non-equilibrium mode besides the translational non-equilibrium. Our general result recovers the existing results in literature on hyperbolic-parabolic conservation laws and hyperbolic balance laws, respectively, as two special cases. (Received January 16, 2016)

1117-35-308 **Xiang Xu*** (x2xu@odu.edu) and **Arghir Zarnescu**. *Eigenvalue preservation for the Beris-Edward system modeling nematic liquid crystals.*

We consider an incompressible Navier-Stokes and Q-tensor system modeling liquid crystal flows of nematic type. The main aim is to prove the eigenvalue preservation property of the Q-tensor part for solutions to the coupled system in 3D. (Received January 16, 2016)

1117-35-325 **Dat T Cao*** (dcao4@utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 37996. *Potential theory for quasilinear elliptic equations.*

We give necessary and sufficient conditions for the existence of a certain class of solutions to the quasilinear equation $-\Delta_p u = \sigma u^q$, $u > 0$, in $\mathbb{R}^n$, where $\Delta_p u = \operatorname{div}(|\nabla u|^{p-2}\nabla u)$ is the p-Laplacian, σ is an arbitrary nonnegative locally integrable function (or measure), and $0 < q < p - 1$. Sharp global pointwise estimates of solutions in terms of Wolff potentials are also obtained. This is a joint work with Igor E. Verbitsky. (Received January 17, 2016)

1117-35-358 **Alexis Vasseur** (shchengyu@gmail.com), Pittsburgh, PA 15217, and **Cheng Yu*** (yucheng@math.utexas.edu), Mathematics Department, University of Texas, Austin, TX 78712. *On the solutions of compressible Navier-Stokes equations with degenerate viscosities.*

In this talk, we will discuss the construction of global weak solutions to compressible Navier-Stokes equations with degenerate viscosity $\mu = \rho, \lambda = 0$. The main contribution is to derive the Mellet-Vasseur type inequality for the weak solutions, even if it is not verified by the first level of approximation. This provides existence of global solutions in time, for the compressible Navier-Stokes equations,in three dimensional space, with large initial data possibly vanishing on the vacuum. This solves an open problem proposed by Lions. We will also cover our very recent related work on the more physical viscosity. This is a joint work with Alexis Vasseur. (Received January 17, 2016)

1117-35-368 **Helge Kristian Jenssen** and **Charis Tsikkou*** (tsikkou@math.wvu.edu). *Radial Solutions to the Cauchy Problem for $\Box_{1+3}U = 0$ as Limits of Exterior Solutions.*

We consider the strategy of realizing the solution of a Cauchy problem with radial data as a limit of radial solutions to initial-boundary value problems posed on the exterior of vanishing balls centered at the origin. The goal is to gauge the effectiveness of this approach in a simple, concrete setting: the 3-dimensional, linear wave equation $\Box_{1+3}U = 0$ with radial Cauchy data $U(0,x) = \Phi(x) = \phi(|x|)$, $U_t(0,x) = \Psi(x) = \psi(|x|)$.

We are primarily interested in this as a model situation for other, possibly nonlinear, equations where neither formulae nor abstract existence results are available for the radial symmetric Cauchy problem. In treating the 3-d wave equation we therefore insist on robust arguments based on energy methods and strong convergence. Our findings show that while one can obtain existence of radial Cauchy solutions via exterior solutions, one should not expect such results to be optimal. We also show that external Neumann solutions yield better regularity than external Dirichlet solutions. (Received January 18, 2016)

1117-35-430 **Alberto Bressan**, **Geng Chen**, **Mingjie Li** and **Qingtian Zhang*** (qingtian.zh@gmail.com), 915 Southgate Drive, Unit 24, State College, PA 16801. *Some properties on Camassa-Holm equations.*

I will discuss the uniqueness, generic properties of Camassa-Holm equation and two-component Camassa-Holm equation. Wellposedness of cubic Camassa-Holm equation will also be introduced. (Received January 18, 2016)

1117-35-491 **Changhui Tan*** (ctan@rice.edu), Rice University, Department of Mathematics-MS, 6100 Main St. Houston, Houston, TX 77005. *On aggregation equations with alignment.*

In this talk, we introduce a new system of aggregation equations with the presence of alignment. The system is motivated by biological interaction dynamics concerning attraction, repulsion and alignment. The so-called "3-zone" interaction framework is successfully used to model complex behaviors of interacting agents (animals, robots, etc). The proposed system serves as a macroscopic representation of such models. We establish a well-posedness theory for the system, and show rigorously that the system is a hydrodynamic limit of the kinetic 3-zone interaction model with zero inertia. This is a joint work with Razvan Fetacau and Weiran Sun. (Received January 19, 2016)

1117-35-516 **Yi Zhu*** (12110180052@fudan.edu.cn), Skills 225B, 686 Cherry Street, Georgia Institute of Technology, Atlanta, GA 30332, and **Ronghua Pan** and **Yi Zhou**. *Vanishing viscosity method for non-identity viscosity matrix.*

The Cauchy problem for system of conservation laws in one space dimension takes the form

$$u_t + f(u)_x = 0, \tag{1}$$

$$u(0,x) = \bar{u}(x). \tag{2}$$

Here $u = (u_1, ..., u_n)$ is the vector of *conserved quantities*, while the components of $f = (f_1, ..., f_n)$ are the *fluxes*. In the famous paper of Bianchini and Bressan. Global entropy weak solutions to system (1) are constructed by a vanishing viscosity method. That is, the entropy weak solution of the hyperbolic system actually coincide with the limits of solutions to the parabolic system.

$$u_t + f(u)_x = \varepsilon u_{xx}$$

But the case for any physical viscosity matrices is still an open problem. Our aim is to establish the convergence of vanishing viscosity approximations of the form

$$u_t + A(u)u_x = \varepsilon(B(u)u_x)_x \tag{3}$$

for more general viscosity matrices B. Here we just consider the case that matrices A and B commute, thus they have the same eigenvectors. Moreover, we assume that the eigenvalues of matrices B are positive constants. (Received January 19, 2016)

1117-35-518 **Nyla Basharat** and **Yi Hu*** (yihu@georgiasouthern.edu), Department of Mathematical Sciences, Georgia Southern University, Statesboro, GA 30458, and **Shijun Zheng**. *Sharp condition on global well-posedness for nonlinear Schrödinger equations with rotation.* Preliminary report.

We consider the nonlinear Schrödinger equation with rotation (in two and three dimensions) and give sharp conditions on the global well-posedness and blowup in the mass-critical case. (Received January 19, 2016)

1117-35-537 **Kun Zhao*** (kzhao@tulane.edu). *Analysis of a Dissipative Hyperbolic System Arising From Chemotaxis Research.*

In this talk I will report some recent results on the analysis of a dissipative hyperbolic system derived from a Keller-Segel type model for repulsive chemotaxis, which resembles certain feature of classic models in mathematical fluid dynamics. Reported results include, but are not limited to, global well-posedness, long-time asymptotic behavior, vanishing diffusion limit, and formation of boundary layer, in one and/or multiple space dimensions. (Received January 19, 2016)

37 ► Dynamical systems and ergodic theory

1117-37-37 **Jiu Ding*** (jiu.ding@usm.edu), Department of Mathematics, 118 College Dr., Box 5045, Hattiesburg, MS 39402, and **Noah Rhee** (rheen@umkc.edu), Department of Mathematics and Statistics, University of Missouri at Kansas City, Kansas City, MO 64110. *A Piecewise Quadratic Interpolation Method for the Computation of Stationary Densities.*

Let S be a nonsingular transformation of an interval and let P be the corresponding Frobenius-Perron operator. We propose a piecewise quadratic method based on the average value interpolation that can be efficiently used

to approximate a fixed density of P. The convergence of the method for the Lasota-Yorke class of piecewise stretching mappings is proved and numerical results are also presented. (Received December 19, 2015)

1117-37-44 **Leonid A Bunimovich*** (leonid.bunimovich@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30062. *BILLIARDS: where do we stand?*

I will give overview of current mathematical theory of billiard. A variety of open problems will be presented. (Received December 23, 2015)

1117-37-47 **Michael Damron*** (mdamron6@gatech.edu), School of Mathematics, Georgia Institute of Technology, 686 Cherry St., Atlanta, GA 30332, and **Jon Fickenscher** (jonfick@princeton.edu), Department of Mathematics, Fine Hall, Washington Rd., Princeton, NJ 08544. *The number of ergodic measures for minimal shifts of low complexity.*

Consider a one-dimensional minimal shift on a finite alphabet, and let $p(n)$ be the number of distinct words in the system of size n. In 1985, M. Boshernitzan proved that if $\liminf_n p(n)/n = \alpha$ is finite, then the system has at most $\lfloor \alpha \rfloor - 1$ ergodic measures. This bound was recently shown to be tight by V. Cyr and B. Kra, but no improvement has been found. I will discuss work with J. Fickenscher in which we show an improved bound in the setting of "eventually constant complexity growth," meaning that $p(n) - p(n-1)$ is eventually constant. The methods involve introducing and analyzing what we call Special Rauzy Graphs, which allow us to track the interdependencies of words of size n as n increases. (Received December 24, 2015)

1117-37-48 **Jian Li** and **Piotr Oprocha*** (oprocha@agh.edu.pl). *On shadowing property and approximation of invariant measures.* Preliminary report.

Let (X, T) be a dynamical system with the shadowing property. In this talk we will present relations between ergodic measures, entropy, odometers and the structure of the space of all invariant measures $M_T(X)$. Presented results are in some relation to classical result of Sigmund on the structure of the space of invariant measures in topologically mixing hyperbolic systems. (Received December 25, 2015)

1117-37-60 **Jan P. Boronski*** (jan.boronski@osu.cz) and **Piotr Oprocha**. *On dynamics of the Sierpinski Carpet.*

In 1993, Aarts and Oversteegen proved that the Sierpiński curve S admits a transitive homeomorphism, answering a question of Gottschalk. They also showed that it does not admit a minimal one. Earlier, in 1991 Kato proved that S does not admit expansive homeomorphisms. In 2007 Bić, Nakayama and Walczak proved that S admits a homeomorphism with positive entropy, and that it admits a minimal group action. We show that S admits homeomorphisms with strong mixing properties. Namely, there is a homeomorphism $H : S \to S$ that has a fully supported measure m, such that (H, m) is Bernoulli, H has a dense set of periodic points, and H does not have specification property. In particular, S admits a topologically mixing homeomorphism. (Received December 30, 2015)

1117-37-138 **Tamara Kucherenko** (tkucherenko@ccny.cuny.edu), New York, NY 10031, and **Christian Wolf*** (cwolf@ccny.cuny.edu), New York, NY 10031. *Zero Temperature Measures on the Boundary of Rotation Sets.*

Zero-temperature measures are limits of equilibrium states when the temperature goes to zero. They play a fundamental role in statistical physics. In this talk we consider rotation sets $Rot(\Phi)$ associated with a continuous dynamical system $f : X \to X$ on a compact metric space X and a m-dimensional continuous potential $\Phi = (\phi_1, \cdots, \phi_m) : X \to R^m$. We study the question for which boundary values w of $Rot(\Phi)$ one can realize an entropy maximizing measure in the rotation class of w as a zero-temperature measure associated with a certain linear combination of Φ. We show that at an exposed point $w \in \partial Rot(\Phi)$ there always exists a weak zero-temperature measure that maximizes entropy in its rotation class. We also construct examples of rotation sets (in any dimension m) that have exposed boundary points without a strong zero-temperature measure in its rotation class. Finally, we consider non-exposed points and show that the following two phenomena exist: a) boundary points without an associated weak zero-temperature measure; b) boundary points with a unique zero-temperature measure that is not ergodic. This is a joint work with Tamara Kucherenko. (Received January 10, 2016)

1117-37-139 **Jonathan Fickenscher*** (jonfick@princeton.edu), Fine Hall - Washington Road, Princeton, NJ 08544, and **Michael Damron**. *The number of ergodic measures for minimal shifts of low complexity II - shifts related to interval exchange transformations.*

This talk is joint work with Michael Damron.

A general interval exchange transformation on d intervals may expressed as a minimal shift with complexity function $p(n)$ satisfying $p(n) = (d-1)n + 1$ for all $n \geq 0$. It was shown by A. Katok in 1973 that such systems admit at most $d/2$ ergodic probability measures. His proof is geometric in nature.

In 1985, Boshernitzan showed combinatorially that a shift with such a complexity function may have at most $d-2$ ergodic measures. Recently, we improved this bound to $d-3$.

By considering a class of shifts that satisfy a "regular bispecial condition" (a condition satisfied by interval exchange transformation shifts), we are able to further improve the bound to one of the form Cn where $C < 1$. (Received January 10, 2016)

1117-37-149 **W. Patrick Hooper*** (whooper@ccny.cuny.edu), 160 Convent Ave, New York, NY 10031, and **Rodrigo Treviño**. *Random covers of translation surfaces.*

An infinite genus surface has a fundamental group isomorphic to a countably generated free group. This can be used to define a random degree d cover of such a surface. This construction will be applied to translation surfaces (surfaces locally modeled on the plane with a geodesic flow-invariant notion of direction). I will explore how passing to a random degree d cover interacts with the ergodic properties of the geodesic flow on an infinite genus translation surface. This discusses work in appearing in arXiv:1503.00389. (Received January 11, 2016)

1117-37-197 **Judy Anita Kennedy*** (kennedy9905@gmail.com), Department of Mathematics, Lamar University, Beaumont, TX 77710, and **Van C. Nall** (vnall@richmond.edu), Department of Mathematics and, Computer Science, University of Richmond, Richmond, VA. *Horseshoes and lambda-dendroids in generalized inverse limits over intervals.*

Set-valued functions from an interval into the closed subsets of an interval arise in various areas of science and mathematical modeling. When studying the dynamical properties of a set-valued function, the problem is that if one iterates in the standard way, the orbit of a point is not well defined. We study instead the dynamical system of the shift map defined on the inverse of the set-valued function. Here again, as in so many other settings, complicated topology and complicated dynamics go hand-in-hand. As a by-product we have discovered a new type of continuum. (Received January 13, 2016)

1117-37-205 **Mikel Viana*** (mviana3@gatech.edu) and **Rafael de la Llave**. *Almost-Reducibility for fibered holomorphic dynamics.*

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 $K : \mathbb{T}^d \to \mathbb{C}^n$. A Nash-Moser iteration has been developed to efficiently construct such tori, given an approximately invariant torus K_0. It is necessary to add parameters to the system if we want to preserve the frequency.

The asymptotic properties of the derivative cocycle

$$A_{K_0}(\theta) := Df(K_0(\theta), \theta),$$

play a crucial role. We allow central directions E^c for the action of A_{K_0}, and use the notion of approximate reducibility to perform a KAM step. Here some Diophantine conditions (called Melnikov conditions) appear, but it turns out that these conditions are not strictly necessary for the construction of K: We will see that one can still construct non-reducible invariant tori K near K_0. (Received January 17, 2016)

1117-37-242 **Van C. Nall*** (vnall@richmond.edu), 23 Westhampton Way, University of Richmond, Richmond, VA 23173, and **Judy Kennedy**. *Dynamical properties of shift maps on inverse limits with a set valued function.*

The dynamics of a single valued function on a compact space are closely linked to the dynamics of the shift map on the inverse limit with the function as the sole bonding map. It has been shown that the bonding function is chaotic if and only if the shift map is chaotic. One reason for caring about this connection is that the shift map is a homeomorphism on the inverse limit, and therefore the topological structure of the inverse limit space must reflect in its richness the dynamics of the shift map. In the set valued case there may not be a natural

definition for chaos since there is not a single well defined orbit for each point. However, the shift map is a continuous single valued function so it together with the inverse limit space form a dynamical system which can be chaotic in any of the usual senses. For the set valued case we demonstrate with theorems and examples rich topological structure in the inverse limit when the shift map is chaotic and connect that chaos to a property of the set valued function that is a natural generalization of an important chaos producing property of continuous functions. (Received January 15, 2016)

1117-37-245 **Huyi Hu** and **Miaohua Jiang*** (jiangm@wfu.edu), Department of Mathematics and Statistics, Wake Forest University, Winston Salem, NC 27109, and **Yunping Jiang**. *Infimum of Entropy of Volume Preserving Hyperbolic Systems under Smooth Perturbation.* Preliminary report.

For a uniformly hyperbolic system f on a compact Riemmanian manifold, assuming it processes an SRB measure μ_f, the metric entropy with respect to μ_f is positive and changes in general when the map is perturbed in a neighborhood of f while it is topological entropy remains a constant. The question rises whether there is some obstacle that might prevent the entropy from approaching zero while the map is perturbed along a path within the open set of uniformly hyperbolic systems. In a recent paper, we have shown that while the entropy remains positive, it can be made as small as possible by making successive perturbations to f along a C^1-path, preserving the uniform hyperbolicity. In this work, we prove, by mainly using the Dacorogna-Moser theorem, that volume preserving will not pose an obstacle to reduce the entropy with respect to the volume. The entropy can be made as small as possible by making successive smooth perturbations along a homotopic path which lies in the space of volume preserving uniformly hyperbolic systems. (Received January 18, 2016)

1117-37-329 **Xiaolong He***, 686 Cherry St, Atlanta, GA 30332, and **Rafael de la Llave**, 686 Cherry st, Atlanta, GA 30332. *Quasi-periodic solutions for 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 positive measure. All of these results are given in an a-posterior form. Namely, given an approximate solution satisfying some non-degeneracy conditions, there is a true solution nearby. (Received January 17, 2016)

1117-37-346 **Nandor J Simanyi*** (simanyi@uab.edu), 1300 University Blvd. Suite 490B, Birmingham, AL 35294. *Toward Wojtkowski's Falling Ball Conjecture.* Preliminary report.

In 1990 Maciej P. Wojtkowski introduced the model of one-dimensional point masses $m_1 \geq m_2 \geq \cdots \geq m_n$ moving on the vertical half line, positioned at $0 \leq q_1 \leq q_2 \leq \cdots \leq q_n$ subjected to constant gravitation (they are falling down), and colliding with each other and the floor $q = 0$ elastically. (The monotone nonincreasing property of the masses is necessary to avoid the existence of linearly stable periodic orbits, thus hindering hyperbolicity and ergodicity.)Since then this model received a considerable notoriety. Wojtkowski showed at that time that the system is completely hyperbolic, provided that $m_1 \neq m_n$. (In the case of equal masses the system is integrable.) He made the famous conjecture that in this case the system is actually ergodic.

In my talk I will present a road map leading to the proof of the above conjecture in the (slightly) restricted case $m_1 \neq m_2$. (Received January 17, 2016)

1117-37-351 **Nikita Selinger***, selinger@uab.edu. *Classification of Thurston maps with parabolic orbifolds.*

In a joint work with M. Yampolsky, we give a classification of Thurston maps with parabolic orbifolds based on our previous results on characterization of canonical Thurston obstructions. The obtained results yield a partial solution to the problem of algorithmically checking combinatorial equivalence of two Thurston maps. (Received January 17, 2016)

1117-37-361 **Paul Apisa*** (papisa@math.uchicago.edu). *Rational billiards, hyperelliptic curves, and dynamics on moduli space.*

Every holomorphic one-form on a Riemann surface corresponds to a collection of planar polygons with sides identified by translations – a translation surface. The action of GL(2,R) on the plane induces an action on planar

polygons and hence on the moduli space of holomorphic one-forms. Work of Eskin, Mirzakhani, Mohammadi, and Filip establishes that GL(2,R) orbit closures are complex subvarieties. We will classify GL(2,R) orbit closures of dimension greater than three in hyperelliptic components of strata and verify a conjecture of Mirzakhani - that higher rank orbit closures arise from loci of branched covers – in these components. As corollaries, we will derive finiteness results for geometrically primitive Teichmuller curves in hyperelliptic components and discuss applications to the illumination and finite blocking problems in rational billiards. (Received January 18, 2016)

1117-37-364 **Thomas Noll*** (thomas.mamuth@gmail.com), Pfarrstr. 6, D 04860 Torgau, Germany. *The* Aeolian *and the* Major *Substitutions and their associated Dynamical Systems.*

The paper contributes to the study of the diatonic modes on the basis of [1] and [2] and extends [3]. The *aeolian substitution* $a \mapsto abaa, b \to baa$ induces a lattice path transformation, which (together with its dual map) offers relevant music-theoretical interpretations. The dual map further gives rise to a dynamical system on a certain line segment in $\mathbb{R}^2$. This dynamics robustly mimics the descending scale, while the $B - B\flat$-ambiguity corresponds to the only point, where the evolution function is not well-defined. The *major substitution* $a \mapsto ab, b \mapsto ca, c \mapsto bac$ on 3 letters leads to a dynamical system on a plane segment in $\mathbb{R}^2$ with similar chromatic ambiguities.

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(Received January 18, 2016)

1117-37-386 **Alexander Elgart*** (aelgart@vt.edu), **Leonid Pastur** and **Mariya Shcherbina**. *Large block properties of the entanglement entropy of free disordered fermions.*

We consider the macroscopic disordered system of free lattice fermions with the one-body Hamiltonian which is the Schrödinger operator with ergodic potential. Assuming that the expectation of the kernel of the Fermi projection P of the Hamiltonian decays exponentially, we prove that the entanglement entropy satisfies the area law. Moreover, we identify the corresponding limit and show that in the dimension higher than one the entanglement entropy is self-averaging. (Received January 18, 2016)

1117-37-404 **Alexander Blokh*** (ablokh@math.uab.edu), Dept of Math, UAB, Birmingham, AL 35294. *"Pinched double-disk" model for the space of cubic polynomials whose all periodic points are repelling.*

We propose a model for the space of all cubic polynomials with connected Julia sets whose all periodic points are repelling. The model can be viewed as an extension of Thurston's laminational model for the Mandelbrot set. It is obtained by associating a special tag to a polynomial from the above space with critical points c and d. The tag consists of the laminational counterpart of the co-critical point of c (i.e., the point distinct from c with the same image as c) and the laminational counterpart of the image of d. This defines a continuous map from the above space of polynomials to a quotient space of a subspace of double-disk and thus gives a model for our space of polynomials. (Received January 18, 2016)

1117-37-427 **Dinesh Kasti*** (dkasti@fau.edu), **William D Kalies**, **Konstantin Mischaikow**, **Arnaud Goullet** and **Shaun Harker**. *Efficient computation of Lyapunov functions and lattice structures for attractors.*

We provide an efficient algorithm to construct piecewise constant Lyapunov functions for dynamics generated by a continuous nonlinear map. It uses a memory efficient data structure for storing nonuniform grids. It utilizes dijkstra algorithm along with manhattan distance to compute distance potential function which is required to compute the Lyapunov function. We further prove that if the diameters of the grid elements go to zero, then the sequence of piecewise constant Lyapunov functions generated by our algorithm converge to a continuous Lyapunov function for the dynamics generated by the nonlinear map. We illustrate these techniques via the applications on two problems from population biology. Finally, we will elaborate the use and importance of lattice structures of attractors for these techniques. (Received January 18, 2016)

1117-37-434 **Caleb C Moxley*** (ccmoxley@uab.edu), 1300 University Boulevard, Birmingham, AL 35294, and **Nandor Simanyi** (simanyi@uab.edu), 1300 University Boulevard, Birmingham, AL 35294. *Homotopical Complexity of Two Billiard Models.*

We investigate the homotopical complexity of some billiard models. The first is a 3-D flat torus minus three mutually perpendicular, non-intersecting cylindrical scatterers, and the second is a 3-D flat torus with two mutually intersecting and mutually perpendicular scatterers. To describe the homotopical complexity, we construct subsets of the full homotopical rotations sets for each model. We then compute inner radial estimates for the these subsets and, thus, for the full homotopical rotation set. We also provide outer radial measurements for the full rotation set. The construction of orbit segments with prescribed homotopical itineraries utilizes the length minimizing variational method. (Received January 18, 2016)

1117-37-461 **Dominik Kwietniak*** (dominik.kwietniak@uj.edu.pl), Uniwersytet Jagielloński, Instytut Matematyki UJ, ul. Łojasiewicza 6, 31-456 Krakow, Malopolska, Poland. *On arcwise connectedness, density and entropy-density of ergodic measures.*

Invariant measures of a dynamical system given by a continuous map T on a compact metric space X always form a nonempty, convex, and compact set $M_T(X)$. Ergodic measures are the extreme points of this set. During the talk I will describe connections among the following conditions: (D) ergodic measures are dense in $M_T(X)$; (C) the set of ergodic measures is path-connected; (E) entropy density of ergodic measures, that is, for every $\nu \in M_T$ there is a sequence ν_n of ergodic measures such that $\nu_n \to \nu$ in the weak* topology and the same holds for entropies $h(\nu_n) \to h(\nu)$. Properties (D), (C), and (E) are related to various results on large deviations and multifractal analysis. I will present topological conditions implying these properties, and discuss various (counter)examples.

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(Received January 19, 2016)

1117-37-483 **Federico Bonetto*** (bonetto@math.gatech.edu), 686 Cherrty St, ATLANTA, GA 30332. *Kac Particles Interacting With a Thermal Bath.*

We consider a system of particles interacting via random collisions. The system interact with a thermal bath that bring it to equilibrium at a given temperature. We consider different models for the thermostat, both finite and infinite, and discuss their relations. (Received January 19, 2016)

1117-37-495 **James Keesling*** (kees@ufl.edu), Department of Mathematics, University of Florida, P.O. Box 18105, Gainesville, FL 32611-8105, and **Celeste Vallejo**. *A New Way to Analyze a Stochastic Network.* Preliminary report.

Analysis of stochastic networks and queueing theory are fundamental tools in many applications. The applications range from business decision making to epidemiology. An application that we have been involved with is the flow of patients through the various departments in a hospital from admission to discharge. This application has led us to a new way to approach such a system.

Our new approach makes fundamental use of Little's Law. Little's Law is a rule that is used to make difficult calculations in stochastic networks and queueing systems. In our approach we make use of this law as a starting point in analysis of a system rather than as an ancillary tool. Our approach has proved useful in the particular application that we are addressing. It appears to have very wide applicability. (Received January 19, 2016)

39 ► Difference and functional equations

1117-39-352 **Maxim Zinchenko***, Department of Mathematics and Statistics, University of New Mexico. *Lieb–Thirring Inequalities for Finite and Infinite Gap Jacobi Matrices.* Preliminary report.

In this talk I will present Lieb–Thirring bounds (i.e., eigenvalue power bounds) for discrete eigenvalues (in the gaps and above/below the essential spectrum) of perturbed almost-periodic Jacobi matrices with finite and more generally infinite gap essential spectrum. More precisely, I will consider Schatten class perturbations of Jacobi matrices from the isospectral torus associate to a finite or infinite gap set. In particular, I will discuss three specific examples: a finite gap set, a set consisting of infinitely many bands, and a fat cantor set. (Received January 17, 2016)

41 ► Approximations and expansions

1117-41-244 **Neil J Calkin*** (calkin@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634-0975. *Experimental Mathematics: How An Undergraduate Could Be Led To Rediscover A Less Than Well Known Result.*

We will discuss introducing ideas from experimental mathematics into a Computing for Mathematicians class. We will focus on how the class can be led to rediscover some very pretty facts about Newton-Raphson (or the Babylonian) method to approximate square roots. (Received January 15, 2016)

42 ► Fourier analysis

1117-42-43 **Alexander (Oleksandr) V Tovstolis*** (oleksandr.tovstolis@ucf.edu), Department of Mathematics, 4393 Andromeda Loop N, Orlando, FL 32816, and **Xin Li** (xin.li@ucf.edu), Department of Mathematics, 4393 Andromeda Loop N, Orlando, FL 32816. *On Bernstein and Nikolskiĭ Type Inequalities, and Poisson Summation Formula in Hardy Spaces.*

We consider Hardy spaces $H^p(T_\Gamma)$ in tube domains over open cones ($T_\Gamma \subset \mathbb{C}^n$). Bernstein and Nikolskiĭ type inequalities for entire functions of exponential type K belonging to $H^p(T_\Gamma)$ are obtained. The sharpness of the constants in these inequalities is still an open question.

Another result for Hardy spaces $H^p(T_\Gamma)$ with $p \in (0,1]$ is the Poisson summation formula:

$$\sum_{m\in\Lambda} f(z+m) = \sum_{m\in\Lambda} \widehat{f}(m)\, e^{2\pi i(z,m)}, \quad \forall z \in T_\Gamma.$$

The formula holds without any additional assumptions. (Received December 22, 2015)

1117-42-45 **David Cruz-Uribe** and **Virginia Naibo*** (vnaibo@math.ksu.edu), Kansas State University, Department of Mathematics, 138 Cardwell Hall, Manhattan, KS 66506. *Kato-Ponce inequalities on weighted and variable Lebesgue spaces.* Preliminary report.

We will present fractional Leibniz rules and related commutator estimates in the settings of weighted and variable Lebesgue spaces. Uniform weighted estimates for sequences of square-function-type operators and a bilinear extrapolation theorem are the main tools developed for such results. We will also comment on applications of the extrapolation theorem to the boundedness on variable Lebesgue spaces of certain bilinear multiplier operators and singular integrals. (Received December 23, 2015)

1117-42-111 **Paul Hagelstein*** (paul_hagelstein@baylor.edu), Waco, TX 76798. *Solyanik Estimates in Harmonic Analysis.*

Let $\mathcal{B}$ be a collection of open sets in $\mathbb{R}^n$. Associated to $\mathcal{B}$ is the geometric maximal operator $M_{\mathcal{B}}$ defined by

$$M_{\mathcal{B}} f(x) = \sup_{x\in R\in\mathcal{B}} \int_R |f|\,.$$

For $0 < \alpha < 1$, the associated *Tauberian constant* $C_{\mathcal{B}}(\alpha)$ is given by

$$C_{\mathcal{B}}(\alpha) = \sup_{E\subset\mathbb{R}^n : 0<|E|<\infty} \frac{1}{|E|} |\{x \in \mathbb{R}^n : M_{\mathcal{B}}\chi_E(x) > \alpha\}|\,.$$

A maximal operator $M_{\mathcal{B}}$ such that $\lim_{\alpha\to 1^-} C_{\mathcal{B}}(\alpha) = 1$ is said to satisfy a *Solyanik estimate*.

In this talk we will prove that the uncentered Hardy-Littlewood maximal operator satisfies a Solyanik estimate. Moreover, we will indicate applications of Solyanik estimates to smoothness properties of Tauberian constants and to weighted norm inequalities. We will also discuss several fascinating open problems regarding Solyanik estimates. This research is joint with Ioannis Parissis. (Received January 06, 2016)

1117-42-143 **Amalia Culiuc**, **Francesco Di Plinio*** (fradipli@brown.edu) and **Yumeng Ou**, Brown University Mathematics Department. *Modulation invariant Carleson embedding theorems and applications.* Preliminary report.

We develop a localized theory of Carleson embeddings for the wave packet transform, in the setting of outer measure spaces introduced by Do and Thiele. Our main embedding theorem involves a novel modulation invariant version of the Calderón-Zygmund decomposition. As an application, we prove estimates for multilinear modulation invariant singular integral operators, like the bilinear Hilbert transform, by multilinear positive sparse operators. This, in particular, entails a novel rich sharp weighted theory for the bilinear Hilbert transform. (Received January 11, 2016)

1117-42-153 **Shahaf Nitzan*** (shahaf.nitzan@math.gatech.edu). *A few remarks on approximation and density.*

Abstract: In their work regarding the approximation of delta functions over a uniformly discrete sequence, Olevskii and Ulanovskii prove that if such approximations are possible by functions with spectra supported on a given compact, then the corresponding discrete sequence can not be too dense. In this talk I will describe an extension of this result to non-compact spectra and discuss a dual question, regarding the approximation of exponentials. (Received January 11, 2016)

1117-42-158 **Benjamin J Jaye*** (bjaye@kent.edu). *Reflectionless measures for singular integral operators.*

In this talk we shall be concerned with necessary and sufficient conditions on a measure so that an associated singular integral operator is bounded. Our analysis hinges on a description of certain objects called reflectionless measures. We shall reduce certain well-known problems at the interface of harmonic analysis and geometric measure theory to a description of the reflectionless measures associated to singular integral operators. Furthermore, we show that this approach yields promising new results. The results described are joint work with Fedor Nazarov, Maria Carmen Reguera, and Xavier Tolsa. (Received January 12, 2016)

1117-42-215 **Nicholas Boros*** (nboros@olivet.edu), Olivet Nazarene University, Department of Mathematics, One University Avenue, Bourbonnais, IL 60914. *Matrix Weights, Littlewood-Paley Inequalities and the Riesz Transform.*

We will discuss estimates for the squares of the Riesz transforms $R_1^2, \dots, R_m^2$ on $L^2(W)$ where $W \in \mathbb{C}^{d\times d}$ is an A_2 weight. We will show that if the "Heat A_2 characteristic" of W is sufficiently close to 1 then there is a dimensional constant $c > 0$ such that

$$\|R_i^2\|_{2,W} \leq 1 + c\sqrt{[W]_{A_2^h} - 1},$$

for all $i = 1, \dots, m$. This is accomplished by proving a Littlewood-Paley estimate with the use of the Bellman function technique. This is a joint result with Nikolaos Pattakos. (Received January 14, 2016)

1117-42-237 **Mishko Mitkovski*** (mmitkov@clemson.edu). *Determinacy problem for measures.*

A finite positive measure μ is said to be a-determinate if there is no other finite positive measure ν such that the Fourier transforms of μ and ν agree on some interval of length a. For a given measure μ we show how to estimate the largest a for which μ is a-determinate by looking only at the support of μ. Our approach is partly based on the de Branges-Naimark extreme point method. We use the same method to improve the famous result of Eremenko and Novikov concerning oscillations of measures with a spectral gap. I will also present some more recent results about the determinacy part of the classical moment problem. This is joint work with A. Poltoratski. (Received January 15, 2016)

1117-42-253 **Francesco Di Plinio** and **Yumeng Ou*** (yumeng_ou@brown.edu). *Banach-valued $T(1)$ theorems.*

We prove several Banach-valued $T(1)$-type theorems both in one parameter, and of multi-parameter, mixed-norm type. A distinguishing feature of our $T(1)$ theorems is that the usual explicit assumptions on the distributional kernel of T are replaced with testing-type conditions. Our proofs rely on a newly developed Banach-valued version of the outer L^p space theory of Do and Thiele. (Received January 15, 2016)

1117-42-288 **Lucas Chaffee** and **Rodolfo H. Torres*** (torres@ku.edu), Department of Mathematics, University of Kansas, Lawrence, KS 66045, and **Xinfeng Wu**. *MULTILINEAR WEIGHTED NORM INEQUALITIES UNDER INTEGRAL TYPE REGULARITY CONDITIONS.* Preliminary report.

Weighted norm inequalities for operators corresponding to non-smooth versions of Calderón-Zygmund and fractional integral multilinear operators are revisited and improved in a unified way. Graded classes of weights matching the amount of regularity assumptions on the operators are also studied. (Received January 16, 2016)

1117-42-311 **Fedor L Nazarov*** (nazarov@math.kent.edu) and **Alexander Olevskii**. *A simple example of a characteristic function of a set of finite measure on the line whose Fourier transform vanishes outside a set of zero density.* Preliminary report.

We shall construct a characteristic function of a set of finite measure on the line whose Fourier transform vanishes outside a set of zero density. (Received January 17, 2016)

1117-42-333 **Qing Hong**, **Guozhen Lu** and **Lu Zhang*** (luzhang.math@gmail.com). *L^p estimates for some rough bi-parameter Fourier integral operators.*

We mainly study the L^p estimates for some rough bi-parameter Fourier integral operators. Such operators are motivated by the classical one-parameter FIOs. We first define the bi-parameter FIOs with both the non-smooth amplitude functions $a(x,\xi,\eta) \in L^\infty BS^m_\rho$, and the phase functions $\varphi(x,\xi) \in L^\infty \phi^2$ which satisfy a rough non-degeneracy condition. Then we establish their L^p boundedness properties when $1 \le p \le \infty$. (Received January 17, 2016)

1117-42-341 **Joshua B Isralowitz*** (jisralowitz@albany.edu). *Boundedness of paraproducts, commutators, and H^1-BMO duality in the two matrix weighted setting.*

In this talk we will discuss an extention of a very recent preprint by Irina Holmes, Michael Lacey, and Brett Wick to the fully matrix setting. More precisely, we will discuss the characterization of the two matrix weighted boundedness of commutators between matrix functions and any of the Riesz transforms in terms of a natural two matrix weighted BMO space (when both of the weights are matrix A_p weights.)

We will also discuss the characterization of the two matrix weighted boundedness of matrix symbolled dyadic paraproducts in terms of a dyadic version of this two matrix weighted BMO space and discuss the identification of our two matrix weighted BMO space as the dual of a natural two matrix weighted H^1 space in the special case of both weights being matrix A_2 weights. Finally, as a consequence of our results we will discuss a matrix Buckley summation condition for matrix A_2 weights and a John-Nirenberg theorem for matrix A_2 weighted BMO that generalizes the classical scalar result due to Muckenhoupt and Wheeden. (Received January 17, 2016)

1117-42-356 **Oleksandra V Beznosova*** (ovbeznosova@ua.edu). *Weighted T(1) theorem and two weight inequalities for perfect dyadic operators.* Preliminary report.

We present a decomposition of perfect dyadic operators in the spirit of T(1) theorem which allowes us to lift T(1) theorem for such operators to the weighted case and obtain two weight estimates for such operators. (Received January 17, 2016)

1117-42-362 **Leonid Slavin*** (leonid.slavin@uc.edu) and **Pavel Zatitskiy**. *Dimension-free estimates for harmonic BMO.* Preliminary report.

We consider BMO($\mathbb{R}^n$) equipped with the Garsia norm,

$$\|\varphi\|_G = \sup_{z\in\mathbb{R}^{n+1}_+} \big(\varphi^2(z) - \varphi(z)^2\big)^{1/2},$$

where $g(z)$ denotes the harmonic extension of a function g on $\mathbb{R}^n$ into the upper half-space. We show how one can obtain estimates for expressions of the form

$$f(\varphi)(z)$$

in terms of $\varphi(z)$, $\varphi^2(z)$ and $\|\varphi\|_G$. Here f is a fixed function on $\mathbb{R}$, a priori assumed locally bounded and uniformly bounded from below. For example, $f(t) = e^t$ gives the harmonic analog of the integral John–Nirenberg inequality.

It turns out that if f is such that the corresponding inequality holds for BMO$\big((0,1)\big)$ equipped with the classical (L^2-based) BMO norm, then we automatically have the same bound for the functional above; in particular, all such bounds are dimension-free. The proof uses Bellman functions for the classical formulation as locally concave majorants for those in the harmonic formulation. Analogous results hold for related function classes, such as A_p. (Received January 18, 2016)

1117-42-384 **Guozhen Lu***, Department of Mathematics, Wayne State University, Detroit, MI 48202, and **Qiaohua Yang**, School of Mathematical Sciences, Wuhan University. *Sharp estimates for Trudinger-Moser and Hardy-Adams type inequalities on hyperbolic spaces.* Preliminary report.

Sharp estimates for geometric inequalities play an important role in analysis, geometry and PDEs. In this talk, we will report some recent works on sharper estimates for Moser-Trudinger and Hardy-Adams type inequalities on hyperbolic spaces than those existing results in the literature. We establish the best constants for such inequalities under much less restrictive norm constraints. (Received January 18, 2016)

1117-42-397 **David V. Cruz-Uribe*** (dcruzuribe@ua.edu), Department of Mathematics, University of Alabama, Box 870350, Tuscaloosa, AL 35487. *Weighted norm estimates in variable Lebesgue spaces.*

The variable Lebesgue spaces $L^{p(\cdot)}$ are a generalization of the classical Lebesgue spaces: intuitively, they consist of functions f such that

$$\int |f(x)|^{p(x)}\,dx < \infty$$

for a fixed exponent function $p(\cdot)$. We are interested in extending the theory of Muckenhoupt weights to the variable Lebesgue spaces. In this setting the correction condition is $w \in A_{p(\cdot)}$:

$$\sup_Q \|w\chi_Q\|_{L^{p(\cdot)}} \|w^{-1}\chi_Q\|_{L^{p'(\cdot)}} < \infty.$$

With minimal regularity assumptions on the exponent $p(\cdot)$, Fiorenza, Neugebauer and I showed that the Hardy-Littlewood maximal operator satisfies

$$\|(Mf)w\|_{L^{p(\cdot)}} \leq C\|fw\|_{L^{p(\cdot)}}.$$

In more recent work with D. Wang, we showed that this yields a Rubio de Francia extrapolation theorem for variable Lebesgue spaces. As a consequence we immediately get norm inequalities for the classical operators of harmonic analysis. We have also explored the structural theory for $A_{p(\cdot)}$ weights. In this talk we will review this work and then discuss open questions related to the sharp exponent problem in the variable Lebesgue spaces. (Received January 18, 2016)

1117-42-432 **Dario Mena*** (dario.mena@math.gatech.edu). *Characterization of Matrix-Valued BMO by commutators with the Hilbert transform.*

We prove that the space of two parameter, matrix-valued BMO functions can be characterized by considering iterated commutators with the Hilbert transform. Specifically, we prove that

$$\|B\|_{BMO} \lesssim \|[[M_B, H_1], H_2]\|_{L^2(\mathbb{R}^2;\mathbb{C}^d)\to L^2(\mathbb{R}^2;\mathbb{C}^d)} \lesssim \|B\|_{BMO}.$$

The upper estimate relies on Petermichl's representation of the Hilbert transform as an average of dyadic shifts, and the boundedness of certain paraproduct operators, while the lower bound follows Ferguson and Lacey's proof for the scalar case. (Received January 18, 2016)

1117-42-436 **Dmitriy Bilyk*** (dbilyk@math.umn.edu) and **Michael Lacey**. *Tessellations of the sphere, one-bit sensing, restricted isometries, and discrepancy.*

We investigate the question of uniform tessellations of the sphere by hyperplanes, in other words, the problem asking under which conditions the map

$$x \to \{\text{sgn } \langle x, z_j\rangle\}_{j=1}^N, \;\; x \in \mathbb{S}^d$$

where z_j are (random or deterministic) unit vectors, has the δ-RIP (restricted isometry property) from the sphere (or its subset) into the Hamming cube. Such questions are central to the so-called one-bit compressed sensing. We exploit ideas from empirical processes and discrepancy theory to address these questions. We show that in the random case the optimal number of hyperplanes is $N \approx d\delta^{-2}$, while generally there is a dimensional correction $N \approx \delta^{-2+\frac{2}{d+1}}$. We explore a number of other questions: the case of sparse vectors, small cell properties, connections to tight frames, etc. (Received January 18, 2016)

1117-42-472 **Kabe Moen** and **Cong Quoc Hoang*** (cqhoang@crimson.ua.edu), Apartment J, 533 18th street, Tuscaloosa, AL 35401. *weighted estimates for bilinear fractional integral operators and their commutators.* Preliminary report.

In this talk we will discuss about several weighted estimates for bilinear fractional integral operators and their commutators with BMO functions. We also show maximal function control theorem for these operators, that is, we prove the weighted L^p norm is bounded by the weighted L^p norm of a natural maximal operator when the weight belongs to A_∞. (Received January 19, 2016)

1117-42-525 **Alex Iosevich*** (iosevich@math.rochester.edu), 145 Dunrovin Lane, Rochester, NY 14618. *Spectral sets and tiling.*

We prove a result (co-authored with Mayeli and Pakianathan) which shows that the celebrated Fuglede Conjecture holds in $\mathbb{Z}_p^2$ if p is a prime. (Received January 19, 2016)

43 ► Abstract harmonic analysis

1117-43-76 **Irina Holmes*** (iholmes6@math.gatech.edu), 686 Cherry St, Atlanta, GA 30332, **Michael T. Lacey** (lacey@math.gatech.edu), 686 Cherry St, Atlanta, GA 30332, and **Brett D. Wick** (wick@math.wustl.edu), One Brookings Drive, St. Louis, MO 63130. *Commutators in the two-weight setting.*

We discuss recent results on two-weight inequalities for commutators with Calderón-Zygmund operators. These results extend a foundational paper by Coifman, Rochberg and Weiss, where the $L^p(\mathbb{R}^n) \to L^p(\mathbb{R}^n)$ norm of a commutator $[b, T]$ with a Calderón-Zygmund operator T is characterized in terms of the BMO norm of b. Here we consider $[b, T]$ acting between two different weighted Lebesgue spaces $L^p(\mathbb{R}^n; \mu) \to L^p(\mathbb{R}^n; \lambda)$, where μ and λ are A_p weights. We characterize this two-weight norm of $[b, T]$ in terms of a certain weighted BMO space. A first such result was obtained by Bloom in 1985, for the Hilbert transform. (Received January 03, 2016)

1117-43-305 **Ishwari J. Kunwar*** (ikunwar3@math.gatech.edu), 686 Cherry Street NW, Atlanta, GA 30332. *Weighted estimates for multilinear dyadic operators and their commutators.*

I will discuss the boundedness properties of the multilinear dyadic paraproducts and Haar multipliers in the weighted setting. Weighted estimates for the commutators of these operators with dyadic BMO functions will also be presented. (Received January 16, 2016)

1117-43-353 **Xiaoyue Cui*** (cuixe@ucmail.uc.edu), 727 Martin Luther King W, Apt. 514W, Cincinnati, OH 45220, and **Guozhen Lu** (gzlu2001@gmail.com). *L^p-differentiability of the functions in Sobolev space on Heisenberg groups.*

L^p differentiability was introduced by Calderon and Zygmund in their study of the local properties of solutions of elliptic differential equations. As the Sobolev spaces arise readily in the study of partial differential equations. it is not surprsing that Sobolev functions possess an L^p derivative. It would be natuarl to expect an analogue L^p-type convergence to be true for functions in the Sobolev space $W^{1,p}(\mathbb{H})$. We establish the necessary and sufficient condition for $f \in W^{1,p}(\mathbb{H})$ as $p > 1$. In fact, we characterize the Sobolev functions in $W^{1,p}$ on Heisenberg groups. (Received January 17, 2016)

46 ► Functional analysis

1117-46-165 **Ben Li*** (bxl292@case.edu), 12000 Fairhill Road. Apt 710, Cleveland, OH 44120, and **Elisabeth M Werner**. *Affine invariant points for functions.*

Gruenbaum introduced affine invariant points and mappings for convex bodies and Meyer Schuett and Werner carried out an extensive study of these notions.

We introduce them for log-concave and s-concave functions. We give new examples of affine invariant points and mappings for functions, e.g., the John function, the Loewner function and the floating function. (Received January 12, 2016)

1117-46-269 **Beatrice-Helen Vritsiou*** (vritsiou@umich.edu), Department of Mathematics, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109-1043, and **Jordan Radke**. *On the thin-shell conjecture for the Schatten classes.*

In this talk we will present two main results concerning the thin-shell conjecture for the Schatten classes. The first result entails the truth of the conjecture for the operator norm, as well as an improved estimate, compared to the best thus far known bound for the Schatten classes due to Barthe and Cordero-Erausquin, for a few more cases. The second result is that a necessary condition for the conjecture to be true for any of the Schatten classes is a rather strong negative correlation property. We plan on discussing a couple of implications of, as well as giving some sort of justification for, this negative correlation property.

This is joint work with Jordan Radke. (Received January 15, 2016)

1117-46-272 **Umut Caglar*** (ucaglar@fiu.edu) and **Elisabeth M. Werner**. *Mixed f-divergence and inequalities for log concave functions.*

Mixed f-divergences, a concept from information theory and statistics, measure the difference between multiple pairs of distributions. We introduce them for log concave functions and establish some of their properties. Among them are affine invariant vector entropy inequalities, like new Alexandrov-Fenchel type inequalities and an affine isoperimetric inequality for the vector form of the Kullback Leibler divergence for log concave functions.

Special cases of f-divergences are mixed L_λ-affine surface areas for log concave functions. For those, we establish various affine isoperimetric inequalities as well as a vector Blaschke-Santaló type inequality. (Received January 15, 2016)

47 ► Operator theory

1117-47-161 **Maksym Derevyagin*** (mderevya@olemiss.edu). *The Jacobi matrix approach to Nevanlinna-Pick problems.*

Some mathematical models are described by probability measures that do not necessarily have finite moments of all orders. Therefore, one cannot always use the powerful tools from the theory of orthogonal polynomials and moment problems to study these models. However, this obstacle can be overcome by dealing with an interpolation problem for the Cauchy transform of a measure rather than a moment problem.

The main goal of the talk will be to demonstrate how to handle the situation for any probability measure. Namely, it'll be shown that starting with the interpolation data corresponding to Nevanlinna-Pick interpolation problems, one can get generalized eigenvalue problems that involve two Jacobi matrices. It turns out that the corresponding eigenvectors have orthogonal rational functions as entries. So, the underlying spectral object is a linear pencil of two Jacobi matrices and such pencils can be used to study Nevanlinna-Pick problems. For instance, the uniqueness criteria for solutions of Nevanlinna-Pick problems will be presented.

Finally, an explicit example related to the Cauchy distribution will be discussed. (Received January 12, 2016)

1117-47-181 **Maria Cristina Pereyra*** (crisp@math.unm.edu), Department of Mathematics and Statistics, MSC01 1115, 1 University of New Mexico, Albuquerque, NM 87131, and **Oleksandra Beznosova**, **Jean Carlo Moraes** and **Daewon Chung**. *Two weight inequalities for dyadic operators.*

We will discuss, compare, and contrast a two-weight quantitative estimate for the dyadic paraproduct obtained by the authors and the results obtained by Holmes, Lacey and Wick. We will also discuss quantitative two weight estimates for the dyadic square function. (Received January 13, 2016)

1117-47-260 **Fritz Gesztesy** and **Michael M.H. Pang*** (pangm@missouri.edu). *On (Conditional) Positive Semidefiniteness in a Matrix-Valued Context.* Preliminary report.

We extend Schoenberg's classical theorem connecting conditionally positive semidefinite functions $F\colon \mathbb{R}^n \to \mathbb{C}$, $n \in \mathbb{N}$, and their positive semidefinite exponentials $\exp(tF)$, $t > 0$, to the case of matrix-valued conditionally positive functions $F\colon \mathbb{R}^n \to \mathbb{C}^{m\times m}$, $m \in \mathbb{N}$. Moreover, we study the closely associated property that $\exp(tF(-i\nabla))$, $t > 0$, is positivity preserving and its failure to extend directly in the matrix-valued context. (Received January 15, 2016)

1117-47-289 **Konstantin A. Makarov***, Department of Mathematics, University of Missouri, Department of Mathematics, University of Miss, Columbia, MO 65211, and **Eduard Tsekanovskiĭ** (tsekanov@niagra.edu), Department of Mathematics, Niagara University, Lewiston, NY 14109. *On dissipative and non-unitary solutions to operator commutation relations.*

We study the (generalized) semi-Weyl commutation relations $U_g A U_g^* = g(A)$, where A is a densely defined operator and $G \ni g \mapsto U_g$ is a unitary representation of the subgroup G of the group of affine transformations of the real axis preserving the orientation. If A is a symmetric operator, the group G induces an action/flow on the operator unit ball of contractive transformations from $\mathrm{Ker}(A^* - iI)$ to $\mathrm{Ker}(A^* + iI)$. We establish several fixed point theorems for this flow. In the case of one-parameter continuous subgroups of linear transformations, self-adjoint (maximal dissipative) operators associated with the fixed points of the flow give rise to solutions of the (restricted) generalized Weyl commutation relations. We show that in the dissipative setting, the restricted Weyl relations admit a variety of non-unitarily equivalent representations. (Received January 16, 2016)

1117-47-349 **Kelly Bickel*** (kelly.bickel@bucknell.edu), **Stefanie Petermichl** and **Brett Wick**. *Operators on Matrix Weighted L^2 Spaces.*

Every Calderón-Zygmund operator is bounded on $L^2(w)$ if w is a scalar A_2 weight and any such operator's norm depends (at most) linearly on the A_2 characteristic of w. For matrix weights W, the matrix A_2 conjecture, namely whether operator norms depend linearly on the A_2 characteristic of W, is open even for simple operators. In this talk, we will discuss results related to the matrix A_2 conjecture. These include improved bounds for the

norms of certain Calderón-Zygmund operators, such as the Hilbert transform, on matrix weighted L^2 spaces and a two-weight $T(1)$ theorem for band operators on matrix weighted L^2 spaces. (Received January 17, 2016)

1117-47-375 **Olena Kozhushkina***, Department of Mathematics, Lafayette College, Easton, PA 18042. *The Bishop-Phelps-Bollobás Property for Operators.*

The celebrated Bishop-Phelps theorem states that the set of norm-attaining functionals on a Banach space X is dense in its topological dual X^*. We are interested in a certain operator version of this result, called the Bishop-Phelps-Bollobás property, which deals with the denseness of norm-attaining operators on Banach spaces. In this talk, we will discuss recent developments in this area, in particular, for operators on spaces of continuous functions $C(K)$, where K is a compact Hausdorff space. (Received January 18, 2016)

1117-47-466 **Alex Kasman*** (kasmana@cofc.edu), Charleston, SC 29464. *On factoring an operator using elements of its kernel.*

Just as one can factor a polynomial given some of its roots, a well-known theorem allows the factorization of an ordinary differential operator acting on scalar functions given a set of linearly independent functions in its kernel. This talk presents a generalization to other types of operators. In particular, in place of the differential operator ∂ acting on a ring of functions we consider the more general situation of an endomorphism $\mathcal{D}$ acting on a unital associative algebra. It turns out that a simple assumption about the way $\mathcal{D}$ composes with multiplication operators is sufficient for an analogous result that factors operators written in terms of its powers. The talk will conclude with examples that illustrate the use of this result in three different contexts. (Received January 19, 2016)

51 ► Geometry

1117-51-233 **Samuel C Dent*** (samuel.dent@eagles.usm.edu), 504 Winding Hills Drive, Clinton, MS 39056. *Applications of the Sierpiński Triangle to Music Composition.* Preliminary report.

The present paper builds on the idea of composing music via fractals, specifically the Sierpiński Triangle and Sierpiński Pedal Triangle. The resulting methods intend to produce not just a series of random notes, but a series that pleases the ear. One such method is a geometric composition system with the configuration of the Sierpiński Triangle to generate a string of notes or chords. Other methods include a bottom-up composition technique of designing a piece of music around three notes and distributing this pattern throughout various levels of the music. A counterpart top-down approach utilizes the iterative process of generating the Sierpiński Triangle and Sierpiński Pedal Triangle via matrix multiplication by applying this process to music composition. This technique designs the largest components of the musical work first, then creates subsequent layers with each layer adding more detail. The effect is to perform Schenkerian Analysis in reverse order to compose music. (Received January 15, 2016)

1117-51-428 **Elisheva Adina Gamse*** (gamse.e@husky.neu.edu). *Vanishing relations in the cohomology of the moduli space of parabolic bundles.*

Let Σ be a compact connected oriented 2-manfiold of genus g, and let p be a point on Σ. We define a space $S_g(t)$ consisting of certain irreducible representations of the fundamental group of $\Sigma \setminus p$, modulo conjugation by $SU(N)$. This space has interpretations in algebraic geometry, gauge theory and topological quantum field theory; in particular if Σ has a Kähler structure then $S_g(t)$ is the moduli space of parabolic vector bundles of rank N over Σ. We construct tautological line bundles on $S_g(t)$ and prove that the ring generated by their Chern classes vanishes above a certain degree. This is joint work with Jonathan Weitsman. (Received January 18, 2016)

1117-51-497 **Eric Burgess*** (ericdb@gmail.com), 219B Buchanan Terrace, Decatur, GA 30030. *Encoding knotted surfaces in $\mathbb{C}P^2$ with triple grid diagrams.*

A *triple grid diagram* is a grid diagram (i.e., a square grid with exactly two marks in each row and column) with the additional requirement that each slope-1 diagonal (considering the grid as a torus) also has exactly two marks. Such a diagram encodes three links which, following Meier and Zupan, specify a bridge trisection of a knotted surface. (Received January 19, 2016)

1117-51-521 **Rebecca Goldin*** (rgoldin@gmu.edu), 4400 University Drive, MS 3F2, Fairfax, VA 22039. *Positive formulas for Schubert calculus and generalizations in the symplectic category.*

Schubert calculus is the study of (complex) intersections of a specific set of varieties in the flag manifold; the intersection numbers and their generalizations to equivariant cohomology and K-theory are *manifestly positive*,

defined in an appropriate sense. I will present results toward finding positive formulas for the structure constants in the corresponding rings, with generalizations to the symplectic category. (Received January 19, 2016)

52 ► Convex and discrete geometry

1117-52-32 **Arnaud Marsiglietti*** (arnaud.marsiglietti@ima.umn.edu), IMA, 207 Church Street SE, 306 Lind Hall, Minneapolis, MN 55455. *On the monotonicity of Minkowski sums towards convexity.*

Let us define for a compact set $A \subset \mathbb{R}^n$ the sequence

$$A(k) = \left\{ \frac{a_1 + \cdots + a_k}{k} : a_1, \ldots, a_k \in A \right\} = \frac{1}{k}\Big(\underbrace{A + \cdots + A}_{k \text{ times}}\Big).$$

By a theorem of Shapley, Folkmann and Starr (1969), $A(k)$ tends to the convex hull of A in Hausdorff distance as k goes to ∞. Bobkov, Madiman and Wang (2011) conjectured that when one has convergence in the Shapley-Folkmann-Starr theorem in terms of a volume deficit, then this convergence is actually monotone. In this talk, we show that this conjecture holds true in dimension 1 but fails in dimension $n \geq 12$. We also consider whether one can have monotonicity when measured using alternate measures of non-convexity, including the Hausdorff distance, effective standard deviation, and a non-convexity index of Schneider.
Joint work with Matthieu Fradelizi, Mokshay Madiman and Artem Zvavitch. (Received December 17, 2015)

1117-52-66 **Mokshay Madiman*** (madiman@udel.edu). *Optimal concentration of information for convex measures.*

Together with Matthieu Fradelizi and Jiange Li, we obtain sharp exponential deviation estimates of the information content as well as a sharp bound on the varentropy for convex measures, extending the development for log-concave measures in recent work of Fradelizi, Madiman and Wang. (Received December 31, 2015)

1117-52-82 **Michael T Lacey***, Mathematics, Georgia Institute of Technology, Atlanta, GA 30332, and **Dmitriy Bilyk**, Mathematics, University of Minnestoa, Minneapolis, MN 55455. *One Bit Sensing, Discrepancy, and Empirical Processes.*

A signal is a high dimensional vector x, and a measurement is the inner product $\langle x, y\rangle$. A one-bit measurement is the sign of $\langle x, y\rangle$. These are basic objects in that (1) liking a page on Facebook is a very common example of a one bit measurement, (2) one can make impressive tradeoffs between the size of measurements, and their frequency, and (3) it is a canonical example of a non-linearity in measurement. The import of this talk is that one bit measurements can be as effective as the measurements themselves. Joint work with Dimtriy Bilyk. (Received January 04, 2016)

1117-52-91 **Valeriu Soltan***, 4400 University Drive, Fairfax, VA 22030. *On characterizations of ellipses.* Preliminary report.

We will discuss various characterizations of ellipses among convex curves in terms of properties of their midcurves and a new conjecture dealing with an affine version of a "rectangular" property of circles. (Received January 05, 2016)

1117-52-115 **Steven D. Hoehner**, **Carsten H. Schuett*** (schuett@math.uni-kiel.de) and **Elisabeth M. Werner**. *The Surface Area Deviation of the Euclidean Ball and a Polytope.*

While there is extensive literature on approximation of convex bodies by inscribed or circumscribed polytopes, much less is known in the case of generally positioned polytopes. Here we give upper and lower bounds for approximation of convex bodies by arbitrarily positioned polytopes with a fixed number of vertices in the symmetric surface area deviation. (Received January 07, 2016)

1117-52-154 **Romanos Diogenes Malikiosis** (malikios@math.tu-berlin.de), **Sinai Robins*** (sinai_robins@brown.edu) and **Yichi Zhang** (yczhang@ntu.edu.sg). *Polyhedral Gauss sums, and polytopes with symmetry.*

We define certain natural finite sums of n'th roots of unity that are associated to each convex integer polytope P, and which generalize the classical 1-dimensional Gauss sum $G(n)$ defined over $\mathbb{Z}/n\mathbb{Z}$, to integer polytopes. We call these finite exponential sums which $G_P(n)$. It is therefore natural to ask: for which convex integer polytopes do we get closed forms for $G_P(n)$, analogous to the 1-dim'l Gauss case? We consider the finite Weyl group W, generated by the reflections with respect to the coordinate hyperplanes, as well as all permutations of the coordinates, and we let G be the group generated by W as well as all integer vector translations.

We prove that if P multi-tiles $\mathbb{R}^d$ under the action of the group G, then we have the closed form $G_P(n) = vol(P)G(n)$.

Conversely, we also prove that if the closed form expression $G_P(n) = vol(P)G(n)$ is true for $n \in \{1, 2, 3, 4\}$, and P is a lattice tetrahedron in $\mathbb{R}^3$ of (minimal) volume $1/6$, then there is an element $g \in G$ such that $g(P)$ is the fundamental tetrahedron with vertices $(0, 0, 0), (1, 0, 0), (1, 1, 0)$, and $(1, 1, 1)$. We will mention lots of open questions that arise naturally. (Received January 12, 2016)

1117-52-155 **Tin-Yau Tam*** (tamtiny@auburn.edu), Department of Mathematics and Statistics, 221 Parker Hall, Auburn University, Auburn, AL 36830. *Hyperbolic geometry of positive definite matrices associated with geometric mean.*

In this talk we will discuss the geometry and inequalities associated with the geometric mean of positive definite matrices. The space P_n of $n \times n$ positive definite matrices of determinant 1 is a Riemannian manifold. It turns out that the geometry associated with the Riemannian structure is hyperbolic. We show that geodesic convexity emerges when a natural pre-order call log majorization is introduced to P_n. We also derive several inequalities for the geometric mean. Some inequalities reflect the hyperbolic geometry. (Received January 12, 2016)

1117-52-163 **Liping Yuan*** (lpyuan88@yahoo.com), College of Mathematics & Information Science, Hebei Normal University, Shijiazhuang, Hebei 050024, Peoples Rep of China. *On $\mathcal{F}$-Convexity.*

Let $\mathcal{F}$ be a family of sets in $\mathbb{R}^d$. A set $M \subset \mathbb{R}^d$ is called *$\mathcal{F}$-convex* if for any pair of distinct points $x, y \in M$ there is a set $F \in \mathcal{F}$ such that $x, y \in F$ and $F \subset M$. In this talk we'll present some properties of some *$\mathcal{F}$-convex* sets. (Received January 12, 2016)

1117-52-167 **Sergii Myroshnychenko*** (smyroshn@kent.edu). *On the equation related to projections of convex bodies.*

Let S^2 be the unit sphere in $\mathbb{R}^3$. We consider the following question. Let f and g be two continuous functions on S^2 such that for any unit vector $\xi \in S^2$ their restrictions onto any great circle $\xi^\perp \cap S^2$ satisfy $f(\varphi_\xi(u)) + a(\xi) \cdot u = g(u)$ for all $u \in \xi^\perp \cap S^2$, where the vector $a(\xi)$ is in $\xi^\perp$ and φ_ξ is a rotation in $\xi^\perp$. Does it follow that $g(u) = f(u) + b \cdot u$ or $g(u) = f(-u) + b \cdot u$ for all $u \in S^2$ and some vector $b \in \mathbb{R}^3$?

Using a geometrical approach suggested by V.P.Golubyatnikov, we show that the answer is affirmative, provided f and g satisfy a certain smoothness condition and the map $\varphi : S^2 \to SO(3), \varphi(\xi) = \varphi_\xi$ is continuous. In this case, f and g can be thought of as support functions of hedgehogs in $\mathbb{R}^3$. (Received January 12, 2016)

1117-52-171 **Matthias Reitzner*** (matthias.reitzner@uos.de), University of Osnabrueck, Institute for Mathematics, Albrechtstr. 28A, 49076 Osnabrueck, Germany. *Random Points on a Halfsphere.*

Choose n random points on a halfsphere and denote by P_n the spherical convex hull of these points. Combinatorial and metric properties of the random polytope P_n are investigated as the number n of points tends to infinity. Of particular interest are the number of vertices and facets, the volume, and the Hausdorff distance of P_n to the halfsphere. (Received January 12, 2016)

1117-52-179 **Alina Stancu*** (alina.stancu@concordia.ca), Department of Mathematics and Statistics, 1455 Blvd Maisonneuve West, Montreal, Quebec H3G 1M8, Canada. *A discrete version of centro-affine curvature.* Preliminary report.

We introduce a notion of centro-affine curvature for convex polytopes which can be further used to define global, non-trivial, centro-affine invariants for such polytopes. These invariants satisfy many of the properties of the p-affine areas for smooth convex bodies, including several geometric inequalities, some of which we will present here. (Received January 12, 2016)

1117-52-185 **Robert Connelly*** (connelly@math.cornell.edu), Cornell University, Malott Hall, Ithaca, NY 14853, **Matthew Funkhouser** (mjf298@cornell.edu), Cornell University, Department of Mathematics, Malott Hall, Ithaca, NY 14853, **Vivian Kuperberg** (vzk2@cornell.edu), Cornell University, Department of Mathematics, Malott Hall, Ithaca, NY 14853, and **Evan Solomonides** (egs73@cornell.edu), Cornell University, Malott Hall, Department of Mathematics, Ithaca, NY 14853. *Packings of equal disks in a square torus, I.*

Packings of equal disks in the plane are known to have density at most 0.906.., and it is known that this is never achieved in the square torus. (We provide our own proof in the appendix.) We find packings of disks in a square torus we conjecture to be the most dense for certain numbers of packing disks, using continued fractions to approximate one-third the square root of 3 and 3 minus the square root of 3. We also define a constant to measure the efficiency of a packing motivated by a related constant due to Markov for continued fractions,

and we show, using the unique factorization of Gaussian integers, that there is an upper bound for the Markov constant for grid-like packings. (Received January 13, 2016)

1117-52-186 **Robert Connelly** (connelly@math.cornell.edu), Cornell University, Malot Hall, Department of Mathematics, Ithaca, NY 14853, **Matthew Funkhouser** (mjf298@cornell.edu), Cornell University, Malott Hall, Department of Mathematics, Ithaca, NY 14853, **Vivian Kuperberg*** (vzk2@cornell.edu), Department of Mathematics, Malott Hall, Cornell University, Ithaca, NY 14853, and **Evan Solomonides** (egs73@cornell.edu), Department of Mathematics, Malott hall, Cornell University, Ithaca, NY 14853. *Packings of equal disks in a square torus, II.*

Packings of equal disks in the plane are known to have density at most $\pi/\sqrt{12}$, and it is known that this is never achieved in the square torus. We provide a new proof of this, and a proof that when the container is a planar square polygon the the error is on the order of $1/\sqrt{N}$, whereas for a square torus the error is on the order of $1/N$. We also show an algorithm that converges to a dense packing of equal disks in a square torus with pictures that show the convergence. (Received January 13, 2016)

1117-52-220 **T. Bisztriczky*** (tbisztri@ucalgary.ca). *Separation in Polytopes.*

The problem concerns the minimum number of hyperplanes necessary to strictly separate an arbitrary interior point of a convex d-polytope from each facet of the polytope. We examine the problem for neighbourly 4-polytopes. (Received January 14, 2016)

1117-52-224 **Florian Besau*** (florian.besau@case.edu) and **Elisabeth M. Werner**. *The Floating Body in Real Space Forms.*

We carry out a systematic investigation of floating bodies in real space forms. A new unifying approach not only allows us to treat the important classic case of Euclidean space as well as the recent extension to the Euclidean unit sphere, but also the new extension of floating bodies to hyperbolic space.

In our main result we establish a relation between the derivative of the volume of the floating body and a certain surface area measure, which is called the floating area. In the Euclidean setting the floating area coincides with the well known affine surface area, a powerful tool in the affine geometry of convex bodies. (Received January 14, 2016)

1117-52-229 **Deborah Oliveros*** (dolivero@matem.unam.mx), Instituto de Matemáticas, UNAM, Circuito Exterior, Area de la Investigación Científica, C.U., 04510 México, Mexico, and **Clemens Huemer**, **Pablo Pérez-Lantero** and **Birgit Vogtenhuber**. *Alternating sums of polygons in planar point sets.* Preliminary report.

Given a set of points S in general position, we will show some known and unknown results about the behavior of alternating sums on the number of empty and none empty convex polygones with vertices in S. (Received January 14, 2016)

1117-52-231 **Elizaveta Rebrova*** (erebrova@umich.edu) and **Konstantin Tikhomirov**. *Coverings of random ellipsoids, and invertibility of matrices with i.i.d. heavy-tailed entries.*

I will talk about a generalization of Rudelson-Vershynin theorem, showing that the smallest singular value of an $n \times n$ random matrix with i.i.d. subgaussian entries is at least of order $n^{-1/2}$ with high probability ($\mathbb{P}\{s_n < \varepsilon n^{-1/2}\} \le C\varepsilon + c^n$ for some $C > 0$, $c \in (0,1)$ and all $\varepsilon \ge 0$). It turns out that the same bound holds for heavy-tailed matrices, namely, all random matrices having i.i.d. entries with zero mean and bounded variance.

This generalization was obtained as an application of the following geometric result: we've shown that with the probability exponentially close to one there is enough to take $\exp(\delta n)$ translates of a Euclidean ball $C\sqrt{n}\delta^{-1}B_2^n$ in order to cover the random ellipsoid $A(B_2^n)$ (where A is a heavy-tailed matrix described above, and C is a universal constant). (Received January 14, 2016)

1117-52-259 **Michael J. Mossinghoff*** (mimossinghoff@davidson.edu), Davidson College, Box 6996, Davidson, NC 28035-6996. *Constructing Reinhardt polygons.* Preliminary report.

A *Reinhardt polygon* is a convex n-gon that is optimal in a number of geometric extremal problems in the plane, for example, they have maximal perimeter relative to their diameter. It is known that many distinct Reinhardt polygons exist with a fixed number of sides n, for almost every positive integer n. Some of these polygons exhibit a particular periodic structure and are relatively straightforward to generate; others are known as sporadic and are more challenging to construct. We describe a number of algorithms for constructing sporadic Reinhardt polygons with n sides, which employ some properties of the principal ideal generated by the $2n$th cyclotomic

polynomial. Some of the methods we describe were investigated by students at a summer REU program at the Institute for Computational and Experimental Research in Mathematics. (Received January 15, 2016)

1117-52-283 **Luis Montejano***, National University of Mexico at Quertaro, Juriquilla, 76230 Queretaro, Juriquilla, Mexico. *Constant width, constant minimum width and reduced convex bodies.*

In the literature of convex bodies there are three close related notions: constant width body, constant minimum width body and reduced body. We shall prove that for strictly convex body the notions of constant minimum width body and reduced body coincide. In fact, we shall see that the three notions coincide for smooth convex bodies, almost spherical convex bodies or strictly convex bodies with only regular or vertex points at it boundary.

For strictly convex plane figures the three notions coincide, while in general, every constant width figure is a reduced figure which has constant minimum width. The triangle is reduced but has not constant width and the square has constant minimum width but is not reduced.

We shall also prove that for dimension greater than 2 and diameter h, a convex body which either has constant width h, constant minimum width h or is reduced can not be h-spherical convex and consequently that a body of constant width h, of constant minimum width h or reduced is not the intersection of finitely many solid spheres of radius h.

Finally, will be discuss how to construct constant width bodies in higher dimensions. (Received January 16, 2016)

1117-52-302 **Oleg R. Musin*** (oleg.musin@utrgv.edu), UTRGV, SMSS, One West University Boulevard, Brownsville, TX 78520. *Optimal configurations on spheres and majorizations.*

We consider optimal distributions of N points on spheres interacting via convex decreasing potentials. The majorization (or Karamata) inequality implies that the set of distances between points of an optimal configuration is (weakly) majorized by distance sets of other distributions. Therefore, we have that the sets of minimums of majorizations on spheres contain optimal configurations. We will discuss several results in this direction that are related to the optimal Riesz s-energy configurations, Thomson's and Tammes' problems. (Received January 16, 2016)

1117-52-316 **Wöden Kusner*** (wkusner@gmail.com), Graz University of Technology, Institute for Analysis and Number Theory, Steyrergasse 30/II, Graz, 8010. *Configurations of points with respect to discrepancy and uniform distribution.* Preliminary report.

In the theory of uniform distribution, one important measure of the quality of a point set is its discrepancy. This quantifies how well the counting measure of a point set can approximate volume with respect to some collection of regions. For the purposes of Quasi-Monte Carlo integration, we would like to find point sets with low discrepancy. We'll look at the implementation of some algorithms for explicitly computing discrepancy, analyze some problems related to high quality point sets in the compact setting and discuss some of the open questions that go with them. (Received January 17, 2016)

1117-52-322 **Jie Xiao** (jxiao@mun.ca), Department of Mathematics and Statistics, Memorial University of Newfoundland, St. John's, NL A1C5S7, Canada, and **Deping Ye*** (deping.ye@mun.ca), Department of Mathematics and Statistics, Memorial University of Newfoundland, St. John's, NL A1C5S7, Canada. *Anisotropic Sobolev Capacity with Fractional Order.*

In this talk, I will present the recent progress of the anisotropic Sobolev capacity with fractional order, in particular its connection with convex geometry.

I will also talk about the related isocapacitary inequalities and the anisotropic fractional Sobolev embedding. (Received January 17, 2016)

1117-52-337 **Dmitry Ryabogin*** (ryabogin@math.kent.edu), 122 Chesterton ln, Aurora, OH 44202. *On symmetries of projections and sections of convex bodies.* Preliminary report.

We will discuss several questions of uniqueness related to the problem about pairs of convex bodies having congruent projections onto corresponding subspaces. (Received January 17, 2016)

1117-52-338 **Petros Valettas*** (valettasp@missouri.edu), Columbia, MO 65203, and **Grigoris Pouris** and **Joel Zinn**. *Remarks on the dependence on ε in Dvoretzky's theorem.*

We discuss the dependence on ε in the random version of Dvoretzky's theorem for the classical spaces. In order to do so we prove optimal gaussian concentration estimates for the ℓ_p norms. Our estimates recover the sharp estimates for the extreme values $p = 1$ and $p = \infty$.

This is joint work with G. Paouris and J. Zinn from Texas A& M. (Received January 17, 2016)

1117-52-347 **Michael N. Bleicher*** (bleicher@math.wisc.edu), PMB 4369 PO BOX 2428, Pensacola, FL 32513. *Efficient partitioning of the plane or a fixed domain into cells of given area.* Preliminary report.

It is frequently necessary to divide a domain into a number of cells (rooms) where the separation cost varies according to which cells are juxtaposed. We present a number of necessary conditions for a configuration to be optimal. One must know the cost of separating any two cells from one another. If it is a free standing construction without a given domain one must know the cost of separating each cell from the exterior of the collection. Some examples will also be given. (Received January 17, 2016)

1117-52-360 **Peter Pivovarov*** (pivovarovp@missouri.edu) and **G. Paouris**. *Randomized isoperimetric inequalities.*

I will discuss randomized versions of isoperimetric inequalities for convex sets. (Received January 18, 2016)

1117-52-363 **Ferenc Fodor*** (fodorf@math.u-szeged.hu), Department of Geometry, Bolyai Institute, University of Szeged, Aradi vertanuk tere 1, Szeged, 6720, Hungary. *On some covering and extremal problems on the sphere.*

We will consider some covering and extremal problems on the unit sphere in 3-space. In particular, we will prove a lower bound for the minimum width of n equal zones (spherical segments symmetric with respect to the centre of the sphere) that can cover the sphere. We will also find an upper bound for the maximum of the sum of the pairwise angles of n unoriented lines in 3-dimensional space. These two results are joint with V. Vígh (University of Szeged, Hungary) and T. Zarnócz (University of Szeged, Hungary). Moreover, we will investigate the approximation properties of a spherical convex disc by convex n-gons with respect to various measures of distance. (Received January 18, 2016)

1117-52-421 **Joseph Anderson**, **Navin Goyal**, **Anupama Nandi** and **Luis Rademacher*** (lrademac@cse.ohio-state.edu), Dreese Labs 495, 2015 North High St., Columbus, OH 43210. *The centroid body: algorithms and statistical estimation for heavy-tailed distributions.*

Independent component analysis (ICA) is the problem of efficiently recovering a matrix A in $\mathbb{R}^{n\times n}$ from i.i.d. observations of $X = AS$ where $S \in \mathbb{R}^n$ is a random vector with independent coordinates. All existing efficient algorithms with provable guarantees require that the coordinates of S have finite fourth moments. We give a provably efficient algorithm that works under the assumption that for constant γ, each S_i has finite $(1+\gamma)$-moment. Our techniques are based on a new application of the centroid body from convex geometry. (Received January 18, 2016)

1117-52-448 **Carlos M. Nicolas*** (cnicolas@ferrum.edu). *A super-linear lower bound for the number of empty convex pentagons in planar point sets.*

Let S be a set of points in general position in the plane. A subset P of S is called an empty convex pentagon of S if $|P| = 5$, P is in convex position and the convex hull of P does not contain any other points of S. Let $G(S)$ be the number of empty convex pentagons of S and $g(n)$ the minimum value of $G(S)$ over all sets S with n points in general position. In this talk I show that $n/g(n)$ goes to zero as n goes to infinity. This improves the current linear lower bound on $g(n)$. (Received January 18, 2016)

1117-52-455 **Karoly Bezdek*** (bezdek@math.ucalgary.ca), University of Calgary, Calgary, Alberta , Canada, and **Alexander E. Litvak**, University of Alberta, Edmonton, Alberta , Canada. *Packing convex bodies by cylinders.*

In K. Bezdek and A. E. Litvak (J Geom Anal 19:233–243, 2009) in relation to the unsolved Bang's plank problem (Bang in Proc Am Math Soc 2:990–993, 1951) we obtained a lower bound for the sum of relevant measures of cylinders covering a given d-dimensional convex body. In this talk we provide the packing counterpart of these estimates. We also extend bounds to the case of r-fold covering and packing and show a packing analog of Falconer's results (Falconer in Math Proc Camb Philos Soc 87:81–96, 1980). (Received January 18, 2016)

1117-52-479 **Megan Owen*** (megan.owen@lehman.cuny.edu), **Anna Lubiw** and **Daniela Maftuleac**. *Convex hulls in tree space.*

The space of metric phylogenetic trees, as constructed by Billera, Holmes, and Vogtmann, is a polyhedral cone complex. This space is non-positively curved, so the geodesic (shortest path) between two trees is unique. Based on this property, a number of statistical methods in Euclidean space can be analogously defined for tree space. One such concept is that of convex hulls, which can be used for computing both quartiles of data and data points

of maximal depth. We give an algorithm for computing convex hulls in the space of trees with 5 leaves. This algorithm extends to any 2D CAT(0) polyhedral complex with a single-vertex. (Received January 19, 2016)

1117-52-489 **Osman Yardimci*** (ozy0003@auburn.edu), Auburn University, Parker Hall, Office 138-B, Auburn, AL 36849. *On polyhedronizations of parallel polygons.* Preliminary report.

We study a specific existence question: given two parallel polygons in R^3, under what conditions is it possible to find a polyhedron that has these polygons as faces, and whose vertices are precisely the vertices of the two polygons. The general question 'Can every two parallel polygons be polyhedronized?' was answered negatively by C. Gitlin, J. O'rourke and V. Subramanian. In this talk we survey the known partial results and prove some new ones: The following statement illustrates the form of our new partial results. Two parallel monotone polygons, which can have different directional monotonicities, but one of them has an edge whose extension is a line which does not split the polygon into two or more parts, can be polyhedronized. Variations of the original question include polyhedronizations of a finite planar point set and a polygon contained by a parallel plane. Among others we give a positive answer when the polygon is a so called a serpentine polygon. (Received January 19, 2016)

53 ► Differential geometry

1117-53-4 **Rodrigo Ristow Montes*** (ristow@ufpr.nbr), Amazonas St, 818 ap 32, Curitiba, 80610030, Brazil. *Constant Contact Angle Surfaces in the Lorentz Group L^3.*

In this paper we establish the equation for the Gaussian Curvature and Laplacian equation of a constant mean curvature surface in the Lorentz Group $\mathbb{L}^3$. Using the Gauss equation we prove that constant mean curvature surfaces in $\mathbb{L}^3$ with constant contact angle have constant Gaussian curvature. Also, we provide a congruence theorem for constant mean curvature surfaces immersed in the Lorentz space $\mathbb{L}^3$. (Received May 28, 2015)

1117-53-16 **Xiang Ji*** (xxj104@psu.edu). *Deformations in Extended Poisson Geometry.*

We consider the problem of deforming a coisotropic submanifold S in an extended Poisson manifold (X, H). Under the assumption that S has a holomorphic tubular neighborhood, we can associate S with an L_∞-algebra. Although in general this L_∞-algebra does not control the deformations of S, in the case that (X, H) is holomorphic Poisson, an L_∞-subalgebra of it does control the deformations of S. With the help of a result of Y. Frégier and M. Zambon, this L_∞-algebra can be combined with a differential graded Lie algebra to control the simultaneous deformations of the holomorphic Poisson structure H and the coisotropic submanifold S. (Received November 10, 2015)

1117-53-65 **Joshua Cape**, **Hans-Christian Herbig**, **Daniel Herden**, **Gerald Schwarz** and **Christopher Seaton*** (seatonc@rhodes.edu), Rhodes College, Department of Mathematics & Computer Science, 2000 N. Parkway, Memphis, TN 38112. *The ring of regular functions on a linear symplectic quotient.*

Let G be a compact Lie group and let V be a unitary G-module. Considering V as a real symplectic manifold and choosing the homogeneous quadratic moment map J, let M_0 denote the singular symplectic quotient $M_0 = Z/G$ where $Z := J^{-1}(0)$ is the zero fiber of the moment map. The space M_0 has several structures, including that of a symplectic stratified space and a semialgebraic set, and its algebra of smooth functions has a graded Poisson subalgebra $\mathbb{R}[M_0]$ of regular functions defined as the quotient of the real polynomial invariants of the G-action on V by the vanishing ideal of Z.

We will discuss recent results concerning the properties of $\mathbb{R}[M_0]$ and its use in the study of the smooth structure of M_0. We will in particular discuss using $\mathbb{R}[M_0]$ to construct symplectomorphisms between symplectic quotients and symplectic orbifolds. Cases considered will include that where G is a torus or $SU(2)$ as well as the representations of the orthogonal group corresponding to k particles in $\mathbb{R}^n$ with zero angular momentum. (Received December 31, 2015)

1117-53-193 **Tara S Holm*** (tsh@math.cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853, and **Liat Kessler** (liatke.math@gmail.com), Department of Mathematics, Physics and CS, University of Haifa at Oranim, 36006 Tivon, Israel. *Circle actions on symplectic four-manifolds.* Preliminary report.

We characterize Hamiltonian circle actions on blowups of ruled symplectic manifolds of positive genus, up to (possibly non-equivariant) symplectomorphism. As a by-product, we provide an algorithm that determines the reduced form of a blowup form and which also provides a method for computing the Gromov width. Finally, we compute the equivariant cohomology of these spaces. Our work is a combination of "soft" equivariant and

combinatorial techniques, using the momentum map and related data, with "hard" holomorphic techniques, including Gromov-Witten invariants. (Received January 13, 2016)

1117-53-198 **Rui Wang*** (ruiw10@math.uci.edu), 340 Rowland Hall (Bldg.# 400), University of California, Irvine, Irvine, CA 92697. *On the morphisms between lHGW and GW for symplectic reductions.*

Recently, Bohui Chen and Bai-Ling Wang introduced a new Gromov-Witten type of invariants for symplectic reductions using moduli spaces of symplectic vortex equations on punctured Riemann surfaces with cylindrical ends. In my talk, I will explain how to construct morphisms from this new type of topological invariants to the well-known Gromov-Witten invariants for symplectic reductions at regular values. This is a joint work with Bohui Chen and Bai-Ling Wang. (Received January 13, 2016)

1117-53-210 **Diana Hubbard*** (diana.hubbard@bc.edu) and **Adam Saltz**. *An annular refinement of the transverse element in Khovanov homology.*

In 2006, Plamenevskaya proved that the homology class of a certain distinguished element in Khovanov homology is an invariant of transverse links. In this talk we will present an annular refinement of this element, κ, and will show that while κ is not an invariant of transverse links, it is a conjugacy class invariant of braids. We will see applications of κ relating to transverse links, braid destabilization, and the word problem in the braid group. (Received January 14, 2016)

1117-53-290 **Yanli Song*** (ylsong@me.com), 40 St. George Street, Toronto, ON M5t1K%, Canada. *K-multiplicities of discrete series representation and quantization of coadjoint orbit.*

For real connected semi-simple Lie group, it is well-known that the discrete series representations can be geometrically realized as quantization of coadjoint orbit. In this talk, I will explain how to calculate the K-multiplicities of discrete series representation using the quantization commutes with reduction principle from symplectic geometry. (Received January 16, 2016)

1117-53-317 **Dan Cristofaro-Gardiner**, **Tara Holm**, **Alessia Mandini** and **Ana Rita Pires*** (apissarrapires@fordham.edu). *Infinite staircases in symplectic embedding problems.* Preliminary report.

McDuff and Schlenk determined when a four-dimensional symplectic ellipsoid can be symplectically embedded into a four-dimensional ball, and found that if the ellipsoid is close to round, the answer is given by an "infinite staircase" determined by the odd index Fibonacci numbers, while if the ellipsoid is sufficiently stretched, all obstructions vanish except for the volume obstruction. Infinite staircases have also been found when embedding ellipsoids into polydisks (Frenkel–Muller) and into the ellipsoid E(2,3) (Cristofaro-Gardiner–Kleinman). In this talk, we will see how the sharpness of ECH capacities for embedding of ellipsoids implies the existence of infinite staircases for these and three other domains. (Received January 17, 2016)

1117-53-332 **Jonathan Simone*** (js3fv@virginia.edu). *2-replaceability.*

It is known that if $p = n^2$ and $q = nm - 1$, where n and m are coprime, then the lens space $(L(p, q), \xi_{st})$, where ξ_{st} is the canonical contact structure, has a symplectic filling of Euler characteristic 1. In this talk, we will produce a complete list of linear plumbings whose boundary lens spaces, equipped with the canonical contact structure, have minimal symplectic fillings of Euler characteristic 2. We call such plumbings "2-replaceable." We will then use these linear plumbings to build "2-replaceable trees" and finally use symplectic cut and paste to produce an exotic rational surface. (Received January 17, 2016)

1117-53-345 **Jennifer Vaughan*** (jennifer.vaughan@mail.utoronto.ca). *Dynamical Invariance of a New Metaplectic-c Quantization Condition.*

Metaplectic-c quantization was developed by Robinson and Rawnsley as an alternative to the classical Kostant-Souriau quantization procedure with half-form correction. Given a metaplectic-c quantizable symplectic manifold (M, ω) and a real-valued function H on M, we propose a condition under which a regular value E of H is a quantized energy level for the system (M, ω, H). This condition is dynamically invariant: if there are two functions on M that share a level set, then the quantization condition over that level set is identical for both functions. We can generalize from one function H to a family of k Poisson commuting functions on M. In the special case of a completely integrable system, the quantization condition is equivalent to a Bohr-Sommerfeld condition. (Received January 17, 2016)

1117-53-355 **Samuel T Lisi*** (stlisi@olemiss.edu), University of Mississippi, PO Box 1848, Oxford, MS 38677, and **Jeremy Van Horn-Morris** and **Chris Wendl**. *Spinal open book decompositions and symplectic fillings.* Preliminary report.

I will discuss the notion of spinal open book decomposition, which is a partial generalization of Giroux's open book decomposition for a contact 3-manifold. I will present some results on fillings of contact manifolds that admit spinal open book decompositions with prescribed combinatorics, giving a classification of fillings of Lutz's S^1 invariant contact structures on circle bundles. Time permitting, I will also mention a few words about higher dimensional generalizations, connecting these ideas to work in progress with Niederkrüger and Perisic. (Received January 17, 2016)

1117-53-424 **Li-Sheng Tseng*** (lstseng@math.uci.edu) and **Lihan Wang**. *Analysis of symplectic differential operators.*

On symplectic manifolds, there are two first-order linear differential operators (∂_+, ∂_-) that are intrinsically symplectic and have good properties. The operators were identified and used by Tseng-Yau to define novel symplectic invariants based on cohomology of differential forms. These operators can be thought of as the natural building blocks for constructing symplectic elliptic operators and differential systems. This talk will present some of recent results on the analysis of these operators and show how they can lead to some new invariants for symplectic manifolds with boundary. (Received January 18, 2016)

1117-53-435 **Christian Duval*** (duval@cpt.univ-mrs.fr). *A new integrable system on the sphere and conformally equivariant quantization.*

I will introduce a new Liouville-integrable system, namely the "dual Jacobi-Moser system", associated with the geodesic flow of the n-sphere, endowed with a conformally flat metric which is projectively equivalent to that of the generic Jacobi n-ellipsoid. I will go on proving that quantum integrability of both dual Jacobi-Moser and Neumann-Uhlenbeck systems is ensured by means of conformally equivariant quantization. This is joint work with G. Valent. (Received January 18, 2016)

1117-53-509 **Mark D. Hamilton*** (mhamilton@mta.ca), 67 York St., Sackville, NB E4L 1E6, Canada. *Classical and quantum monodromy via action-angle variables.*

The monodromy of a completely integrable system is one obstruction to the existence of global action-angle variables. Monodromy is also observed in quantum systems, where the quantum spectrum has a local but not global lattice structure. We give an elementary description of the relationship between classical and quantum monodromy as a consequence of the construction of action-angle variables. (Received January 19, 2016)

54 ► General topology

1117-54-166 **Alejandro Illanes*** (illanes@matem.unam.mx), Instituto de Matemáticas, Circuito Exterior, Ciudad Universitaria, 04510 Distrito Federal, Mexico. *Some new results on the pseudo-arc.*

The pseudo-arc is the only chainable hereditarily indecomposable continuum. This is one of hte most interesting objects in Continuum Theory. In this talk we will present some new results on the pseudo.arc, related to products, compactifications of the ray and symmetric products. (Received January 12, 2016)

1117-54-170 **Steven C Clontz*** (steven.clontz@gmail.com), 380G Fretwell Hall, UNC Charlotte, Charlotte, NC 28223. *Generalized inverse limits indexed by arbitrary linear orders.*

Call an idempotent uppersemicontinuous continuum-valued surjective relation on X^2 a V-map. The presenter and S. Varagona showed that an inverse limit of a linearly ordered compactum indexed by an ordinal and bonded with a single V-map is metrizable if and only if the ordinal is countable. This result may be generalized to any linearly ordered index. To demonstrate this, the presenter will give a simple characterization for the inverse limit bonded by the simple V-map γ in terms of the lexicographic product of the factor space and linearly ordered index. (Received January 12, 2016)

1117-54-183 **Kyle Stephen Austin*** (ksaustin88@gmail.com), Department of Mathematics, Ben Gurion University of the Negev, P.O.B. 653, 8410501 Beer Sheva, Israel. *Dimension Raising and the Higson Corona Functor.*

Takahisa Miyata and Ziga Virk introduced a version of n-to-1 maps in large scale geometry and prove various analogues of the classical dimension raising theorems. They prove the following variant of the Hurewicz dimension

raising theorem for asymptotic dimension (asdim): If $f : X \to Y$ is coarse and coarsely n-to-1 then $asdim(Y) \leq (asdim(X) + 1)n - 1$.

Recall that the classical Hurewicz dimension raising theorem is much stronger: If $f : X \to Y$ is a closed n-to-1 map of metric spaces then $dim(Y) \leq dim(X) + (n - 1)$. It has been a matter of some debate since the aforementioned publication as to whether the estimate of Miyata and Virk can be sharpened to be the same as the classical version. This is exactly what Z. Virk and I managed to prove: If $f : X \to Y$ is coarse and coarsely n-to-1 then $asdim(Y) \leq asdim(X) + (n - 1)$. Moreover, our proof relies on the classical Hurewicz theorem via the Higson compactification.

In my talk, I plan to give a brief introduction to all the necessary prerequisite materials to understanding the result, as well as an outline of the proof. (Received January 13, 2016)

1117-54-324 **Stewart Baldwin*** (baldwsl@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849-5310. *A nontrivial uniquely homogenous subset of the plane, all of whose homeomorphisms are rigid motions.* Preliminary report.

We show that for every positive even integer n, there is a dense uniquely homogeneous subspace X of $\mathbb{R}^n$, all of whose non-constant continuous functions are rigid motions. In the case $n = 2$, X can be constructed to be Bernstein, i.e., Both X and $\mathbb{R}^2 \setminus X$ intersect every Cantor set in $\mathbb{R}^2$. The construction uses certain facts about complex arithmetic to get a Bernstein example for the complex plane $\mathbb{C}$, and then uses a well-known trick involving products to get (non-Bernstein) examples for $\mathbb{C}^n$, so the proof as it currently exists will not generalize easily to $\mathbb{R}^n$ for odd n, but it is conjectured that the result also holds for odd n. (Received January 17, 2016)

1117-54-380 **Alexander Blokh**, UAB, Birmingham, AL 35294, **Lex Oversteegen*** (overstee@math.uab.edu), UAB, Birmingham, AL 35294, **Ross Ptacek**, UF, Gainsville, FL 32611, and **Vladlen Timorin**, Moscow, Russia. *The combinatorial Mandelbrot set as the quotient of the space of geolaminations.*

We interpret the combinatorial Mandelbrot set in terms of *quadratic laminations* (equivalence relations $\sim$ on the unit circle invariant under σ_2). To each lamination we associate a particular *geolamination* (a collection $\mathcal{L}_\sim$ of points of the circle and edges of convex hulls of $\sim$-equivalence classes) so that the closure of the set of all of them is a compact metric space with the Hausdorff metric. Two such geolaminations are said to be *minor equivalent* if their *minors* (images of their longest chords) intersect. We show that the corresponding quotient space of this topological space is homeomorphic to the boundary of the combinatorial Mandelbrot set. To each equivalence class of these geolaminations we associate a unique lamination and its topological polynomial so that this interpretation can be viewed as a way to endow the space of all quadratic topological polynomials with a suitable topology. (Received January 18, 2016)

1117-54-441 **Jason Yust*** (jason.yust@gmail.com), 39 Northbourne Rd, Jamaica Plain, MA 02130. *A three-dimensional model of tonality.*

This talk proposes a spatial model of tonality using the discrete Fourier transform on characteristic functions of pitch-class sets. I define a three-dimensional torus using phases of the second, third, and fifth coefficients of the DFT (Ph_2, Ph_3, and Ph_5). Ph_5 represents diatonicity, Ph_3 represents triadic voice-leading properties, and Ph_2 tracks the structural counterpoint of fifths. I show that common tonal sets (including triads, perfect fifths, unisons, and diatonic scales) lie on or close to the "tonal plane" defined by $Ph_2 + Ph_3 - Ph_5 = 0$. The arrangement of tonal regions on this plane closely resembles the empirically derived Krumhansl-Kessler space, and as a distributional model it suggests a key-finding algorithm similar to Krumhansl-Schmuckler's and Temperley's. However, the added dimension motivates refinements to concept of key, where deviations from the tonal plane (indexed by $Ph_2 + Ph_3 - Ph_5$) measure tonal stability. Small deviations may indicate dominant and subdominant functions, while regions further from the plane are tonally ambiguous. The space also has a rich fundamental group, with the different homotopy classes (i.e., cycles in different dimensions) associated with different types of sequential routines in music. (Received January 18, 2016)

55 ► Algebraic topology

1117-55-184 **Seung Yeop Yang*** (syyang@gwu.edu) and **Józef H. Przytycki** (przytyck@gwu.edu). *Geometric interpretations of distributive structure homology.*

In 1993, Fenn, Rourke, and Sanderson introduced the rack space to define rack homotopy invariants and a modification to the quandle space and quandle homotopy invariants of classical links was introduced by Nosaka

in 2011. In analogy to rack and quandle spaces, we define the Cayley-type graph and CW complex of distributive structures and study a relation with homology theory of distributive structures. (Received January 13, 2016)

1117-55-273 **Michael S Willis*** (msw3ka@virginia.edu), 141 Cabell Drive, Kerchof Hall, PO Box 400137, Charlottesville, VA 229044137. *The Khovanov Homotopy Type of Infinite Torus Links.*

Both the Jones polynomial and its categorification, the Khovanov homology, are known to stabilize for torus links $T(n,m)$ as $m \to \infty$. In recent work, Robert Lipshitz and Sucharit Sarkar constructed the Khovanov homotopy type $\chi(L)$ for a link L, a spectrum whose reduced cohomology gives the Khovanov homology of L. In this talk I will discuss the stability of $\chi(T(n,m))$ as $m \to \infty$. One corollary will be the existence of nontrivial Steenrod Sq^2 action on $\chi(T(3,m))$ for $m \geq 3$. (Received January 16, 2016)

1117-55-284 **Paul Fabel*** (apf3@msstate.edu), Dept. of Mathematics and Statistics, Drawer MA, Mississipi State, MS 39762. *Fundamental groups of continua and categorical topology.* Preliminary report.

If X, p is a based metric continuum, the familiar fundamental group $\pi_1(X,p)$ becomes naturally a topological space, the topological quotient of the space of based loops $L(X,p)$ under the equivalence relation 'path homotopic'.

Understanding basic structural properties of $\pi_1(X,p)$ is impeded by the general failure in the topological category of products to commute with quotients.

For example, metric continua illustrate that each of the following questions has a negative answer.

(1) If $\pi_1(X,p)$ is a T_4 topological group must $\pi_1(X,p)$ be metrizable? Must $\pi_1(X,p)$ be zero dimensional?

(2) If X has a basis such that each component of each basic open set is an open arc, must $\pi_1(X,p)$ be a topological group?

If the definition of continuum is relaxed to allow compact connected spaces X whose compact subspaces are closed,

3. If $\pi_1(X,p)$ is T_1 must $\pi_1(X,p)$ be T_2?

A standard response to such pathology is to work within a 'better' category such as $CGWH$, the category of compactly generated weakly Hausdorff spaces.

Within $CGWH$, the Kolmogorov quotient of $\pi_1(X,p)$ is a weakly Hausdorff topological group. (Received January 16, 2016)

1117-55-412 **Yu Pan*** (yp37@math.duke.edu), Duke University, P.O.box 90320, 117 Physics BLOG, Math Department, Durham, NC 27708. *The long exact sequence associated to exact Lagrangian cobordisms.* Preliminary report.

To a Legendrian knot, one can associate an $\mathcal{A}_\infty$category, the augmentation category. An exact Lagrangian cobordism between two Legendrian knots gives a functor of the augmentation categories of the two ends. We study the functor and establish a long exact sequence relating the corresponding Legendrian cohomology categories of the two ends. As applications, we prove that the functor between augmentation categories is injective on objects, and find new obstructions to the existence of exact Lagrangian cobordisms. The main technique is a recent work of Chantraine, Dimitroglou Rizell, Ghiggini and Golovko on Cthulhu homology. (Received January 18, 2016)

1117-55-482 **Jesse T. Prince-Lubawy*** (jprincelubawy@una.edu), One Harrison Plaza, Florence, AL 35632. *Equivalence of cyclic p-squared actions on handlebodies.* Preliminary report.

We consider all orientation-preserving $\mathbb{Z}_{p^2}$-actions on 3-dimensional handlebodies V_g of genus $g > 0$ for p an odd prime. To do so, we examine particular graphs of groups $(\Gamma(\mathrm{v}), \mathbf{G}(\mathbf{v}))$ in canonical form for some 5-tuple $\mathrm{v} = (r,s,t,m,n)$ with $r+s+t+m > 0$. These graphs of groups correspond to the handlebody orbifolds $V(\Gamma(\mathrm{v}), \mathbf{G}(\mathbf{v}))$ that are homeomorphic to the quotient spaces $V_g/\mathbb{Z}_{p^2}$ of genus less than or equal to g. This algebraic characterization is used to enumerate the total number of $\mathbb{Z}_{p^2}$-actions on such handlebodies, up to equivalence. (Received January 19, 2016)

57 ► Manifolds and cell complexes

1117-57-97 **John Etnyre*** (etnyre@math.gatech.edu) and **Ryo Furukawa**. *Embeddings of contact manifolds.*

I will discuss recent results concerning embeddings and isotopies of one contact manifold into another. Such embeddings should be thought of as generalizations of transverse knots in 3-dimensional contact manifolds (where they have been instrumental in the development of our understanding of contact geometry). I will mainly focus on embeddings of contact 3-manifolds into contact 5-manifolds. In this talk I will discuss joint work with Ryo Furukawa aimed at using braiding techniques to study contact embeddings. Braided embeddings give an explicit way to represent some (maybe all) smooth embeddings and should be useful in computing various invariants. If time permits I will also discuss other methods for embedding and constructions one may perform on contact submanifolds. (Received January 05, 2016)

1117-57-98 **John Etnyre*** (etnyre@math.gatech.edu) and **Bulent Tosun**. *Solid tori and the classification of contact structures on small Seifert fibered spaces.* Preliminary report.

Tight contact structures have been classified on most small Seifert fibered spaces, but there are infinite families that have resisted classification despite many attempts. These are the most interesting families in that they contain examples that do not admit tight contact structures and examples of tight but non-fillable contact structures. In this talk I will discuss an approach to the classification on new infinite subsets of these families and illustrates how studying embeddings of solid tori in contact manifolds can be used to construct and distinguish tight contact structures. (Received January 05, 2016)

1117-57-100 **Kenneth L. Baker*** (kenken@math.miami.edu), Department of Mathematics, Ungar 515, University of Miami, 1365 Memorial Drive, Coral Gables, FL 33146, and **R. Sean Bowman** and **John Luecke**. *Boundary-reducing surgeries and bridge number.*

Let M be a 3–dimensional handlebody of genus g. For each integer $g > 1$ we construct hyperbolic knots in M with arbitrarily large genus g bridge number which admit a cosmetic surgery, i.e. a non-trivial Dehn surgery to a genus g handlebody. This sharply contrasts what occurs when $g = 1$. (Received January 05, 2016)

1117-57-136 **Louis H. Kauffman*** (kauffman@uic.edu), Louis H. Kauffman, Math, UIC, 851 South Morgan Street, Chicago, IL 60607-7045, and **Christopher Gomes** (cgomes2@uic.edu), Christopher Gomes, Math, UIC, 851 South Morgan Street, Chicago, IL 60607-7045. *The Dold-Kan Theorem and the Homotopy Theory of Khovanov Homology.*

The well-known Dold-Kan constructon in simplicial homotopy theory can be fruitfully applied to convert link homology theories into homotopy theories. In particular, in the case of Khovanov homology, the Dold-Kan construction can be replaced directly with a simplicial abelian group associated with the usual presheaf on the Khovanov category with target a category of Frobenius modules that is associated to a given knot or link. (Received January 10, 2016)

1117-57-140 **W. Edwin Clark** and **Masahico Saito*** (saito@usf.edu). *Quandle identities and homology.*

Quandle homology was defined from rack homology as the quotient by a subcomplex corresponding to the idempotency, that reflects the invariance under the type I Reidemeister move. Similar subcomplexes have been considered for various identities of quandles and moves on diagrams. We observe common aspects; a quandle identity gives rise to a 2-cycle, the corresponding 2-cocycle extension inherits the identity, and the identity leads to a subcomplex. We apply this principle to some other specific identities. Quandles with these identities are constructed by Alexander quandles, and also listed from the table of quandles. (Received January 10, 2016)

1117-57-141 **Jason Cantarella***, UGA Math Department, Athens, GA 30602, and **Harrison Chapman** and **Matt Mastin**. *Random Knot Diagrams.*

There has been increasing interest in using randomly generated diagrams to make constructions in knot theory. In this talk, we discuss results from a recent enumeration of all the knot diagrams with 10 and fewer crossings (about 1.6 billion diagrams). The data reveals some interesting features of the space of knot diagrams; for instance, a surprisingly large fraction of the low-crossing knot diagrams are “treelike” curves which are unknotted with any assignment of crossing information. (Received January 10, 2016)

1117-57-201 **Pedro Lopes*** (pelopes@math.tecnico.ulisboa.pt), Department of Mathematics, IST - University of Lisbon, Av. Rovisco Pais, 1049-001 Lisbon, Portugal. *Generalized palette graphs.* Preliminary report.

The palette graph was introduced by Nakamura, Nakanishi and Satoh in the context of Fox colorings. A palette graph takes a set of colors as vertices of a graph, and an edge connecting two colors stands for the coloring condition being satisfied. Considerations on palette graphs and associated matrices leads to a lower bound for the minimum number of colors. In this talk we report on generalizing these notions to colorings by other linear Alexander quandles. This is joint work with Louis H. Kauffman. (Received January 13, 2016)

1117-57-213 **Jonathan Hanselman*** (hanselman@math.utexas.edu), **Jacob Rasmussen** and **Liam Watson**. *Bordered Floer homology via immersed curves in the punctured torus.*

We call a 3-manifold M with torus boundary *loop type* if its bordered Floer homology satisfies a mild technical assumption. In this setting, we give a geometric interpretation of the bordered Floer invariants of M: they can be represented as a collection of immersed curves in ∂M. When two loop type manifolds are glued together, the Heegaard Floer homology of the glued manifold can be obtained from the intersection of these immersed curves. Among other applications, this description of bordered Floer theory leads to a simple reproof of an L-space gluing result which was recently used to show that the conditions of being a non-L-space, admitting a coorientable taut foliation, and having left-orderable fundamental group are equivalent for graph manifolds. (Received January 14, 2016)

1117-57-246 **Nicolas Petit*** (nicolas.petit.gr@dartmouth.edu), Dept of Mathematics, Hanover, NH 03755. *Order One Vassiliev Invariants for Long Virtual Knots.* Preliminary report.

We extend the construction of A. Henrich's three finite-type invariants of order one to the long virtual knot case. To do so, we will review the interpretation of long virtual knots as knots in thickened surfaces with boundary, and mention how to reconstruct the notion of a based matrix for a flat long virtual knot. (Received January 15, 2016)

1117-57-248 **Huygens Ravelomanana*** (ravelomanana@uga.edu). *Exceptional Cosmetic Surgeries on S^3.*

Two distinct Dehn surgeries on the same knot are called cosmetic if they produces homeomorphic 3-manifolds. The knot cosmetic surgery problem asks if cosmetic surgeries do exist. One of my result is that the slope of an exceptional truly cosmetic surgery (if it exists) on a hyperbolic knot in S^3 must be ± 1 and the surgery must be toroidal but not Seifert fibred. I will talk about this and some of it consequences. (Received January 15, 2016)

1117-57-266 **Alissa S. Crans** (acrans@lmu.edu), **Sujoy Mukherjee*** (sujoymukherjee@gwu.edu) and **Jozef H. Przytycki** (przytyck@gwu.edu). *Associative Shelves.* Preliminary report.

A shelf is a magma satisfying right self-distributivity which is the algebraic encoding of the third Reidemeister move in knot theory. We will discuss, in particular, properties of shelves with unit element and their one-term and two-term (rack) homologies. (Received January 15, 2016)

1117-57-281 **Zhiyun Cheng*** (czy@bnu.edu.cn), School of Mathematical Sciences, Beijing Normal University, Beijing, 100875, Peoples Rep of China. *Applications of chord index in virtual knot theory.*

Parity of real crossing plays an important role in the study of virtual knot theory. In this talk we will introduce the chord index for each real crossing, which can be regarded as a generalization of the parity. Several applications of the chord index will be discussed. (Received January 16, 2016)

1117-57-287 **Zhiyun Cheng**, **Sujoy Mukherjee**, **Jozef H. Przytycki**, **Xiao Wang*** (wangxiao@gwu.edu) and **Seung Yeop Yang**. *Strict unimodality of q-polynomials of rooted trees.*

We classify rooted trees which have strictly unimodal q-polynomials (plucking polynomial). We also give criteria for a trapezoidal shape of a plucking polynomial. We generalize results of Pak and Panova on strict unimodality of q-binomial coefficients. We discuss which polynomials can be realized as plucking polynomials and whether or not different rooted trees can have the same plucking polynomial. (Received January 16, 2016)

1117-57-307 **James R. Hughes***, One Alpha Drive, Elizabethtown, PA 17022. *Mathematical Models for Voice Leading: Dealing with Doubling.*

Voice leading refers to the interplay of melody and harmony in music. More precisely, voice leading is the specific means by which one harmonic situation changes to another through specific part assignments. Voice leading has been modeled mathematically in various ways. After giving a brief survey of the main approaches, we will

focus on the use of paths in chord spaces. In particular, we will explore how the orbifold fundamental group and groupoid of a chord space can be especially useful for modeling voice leading situations in which more than one part is assigned to a given pitch class. (Received January 16, 2016)

1117-57-309 **Yewon Joung*** (yjoung@math.msu.edu), **Seiichi Kamada** (skamada@sci.osaka-cu.ac.jp) and **Sang Youl Lee** (sangyoul@pusan.ac.kr). *Applying Lipson's state models to marked graph diagrams of surface-links.*

A surface-link of n components is n mutually disjoint connected and closed (possibly orientable or non-orientable) 2-manifolds smoothly (or piecewise linearly and locally flatly) embedded in the oriented 4-space. In 1992, A. S. Lipson constructed two state models yielding the same classical link invariant obtained from the Kauffman polynomial F(a;z). In this talk, we apply Lipson's state models to marked graph diagrams of surface-links, and observe when they induce surface-link invariants. This is a joint work with Seiichi Kamada and Sang Youl Lee. (Received January 16, 2016)

1117-57-328 **Thomas A. Ivey*** (iveyt@cofc.edu). *Remarks on the Geometry of Chords.* Preliminary report.

In a sequence of publications Dmitri Tymoczko and collaborators have developed the notion of chord and voice-leading spaces constructed by applying various musically relevant equivalence relations (generated by group actions) to cubic lattices in n-dimensional pitch spaces. The quotient lattices are naturally embedded in topological spaces which are typically orbifolds, but it is difficult to formulate a mathematically valid notion of geometry for these spaces that is also musically meaningful.

Nonetheless, a mathematical examination of the literature on the geometry of chords (including Tymoczko's 2011 book "The Geometry of Music") leads to several interesting avenues: many continuous chord spaces have non-trivial topology that has musical significance (e.g., homotopy generators in the orbifold lift to modulatory sequences of chords); the orbifold points within these spaces often represent chords that maximize tonal ambiguity; and it may be possible to apply more sophisticated models (e.g., Finsler metrics) to endow these spaces with a path geometry that reflects the dominant features of certain stylistic corpora.

This talk is based in part on a summer research project conducted with College of Charleston undergraduate Omar Valencia. (Received January 17, 2016)

1117-57-335 **Adam M Lowrance*** (adlowrance@vassar.edu). *Knots of Turaev genus one.* Preliminary report.

We give a diagrammatic classification of knots of Turaev genus one and discuss invariants for such knots. (Received January 17, 2016)

1117-57-339 **Mustafa Hajij*** (mustafahajij@gmail.com), Tampa, FL 33647, and **Mohamed Elhamdadi**. *A one variable generalization of the Kauffman and Vogel polynomial.*

Kauffman and Vogel's polynomial is an invariant for unoriented four-valent graphs embedded in three dimensional space. In this talk we give a one variable generalization of this invariant. This generalization is given as a sequence of invariants in which its first term is the Kauffman and Vogel's polynomial. (Received January 17, 2016)

1117-57-359 **Radmila Sazdanovic*** (rsazdanovic@math.ncsu.edu), NCSU Department of Mathematics, SAS Hall PO Box 8205, Raleigh, NC 27695-8295, and **Adam 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 January 18, 2016)

1117-57-376 **Margaret F Symington*** (symington_mf@mercer.edu), Department of Mathematics, Mercer University, 1501 Mercer University Drive, Macon, GA 31207, and **Sonja Hohloch**, **Silvia Sabatini** and **Daniele Sepe**. *From Hamiltonian S^1-spaces to semi-toric systems.* Preliminary report.

A Hamiltonian S^1-space is a compact four-manifold equipped with an effective Hamiltonian S^1-action. Karshon classified such manifolds and determined necessary and sufficient conditions for the circle action to extend to an effective Hamiltonian T^2-action, thereby defining a completely integrable system that is toric. When such an extension fails to exist, it may still be possible for the Hamiltonian S^1-action to underlie a semi-toric system, as defined by Pelayo and Vũ Ngọc. In this talk, I will describe necessary and sufficient conditions for the S^1-action

to extend to an $S^1 \times \mathbb{R}$-action that defines a semi-toric system on the manifold. I will also describe a blow-up in the semi-toric category that we use to prove the result. This is joint work with Hohloch, Sabatini and Sepe. (Received January 18, 2016)

1117-57-382 **Thomas E Mark** and **Bulent Tosun*** (bt5t@virginia.edu), 141 Cabell Drive Kerchof Hall, Charlottesville, VA 22904. *Naturality of Heegaard Floer Invariants Under Positive Contact Surgery.*

One of the fundamental open question in three dimensional contact topology is the determination of which closed oriented three manifolds support a tight contact structure. One powerful way to approach this problem is provided by Heegaard Floer homology. In this talk, we will describe some recent work that shows the contact invariant in Heegaard Floer homology behaves "naturally" under certain contact surgery operations. As an application we give a complete description of the contact invariant of a contact structure obtained by positive rational contact surgery on a Legendrian knot in the standard three sphere. This is joint work with Tom Mark. (Received January 18, 2016)

1117-57-391 **Patricia Cahn*** (pcahn@mpim-bonn.mpg.de) and **Vladimir Chernov**. *Knots transverse to a vector field and the classification of Legendrian knots.*

We study knots transverse to a fixed vector field V on a 3-manifold M up to the corresponding isotopy relation. Such knots are equipped with a natural framing. Motivated by questions in contact topology, it is natural to ask whether two V-transverse knots which are isotopic as framed knots and homotopic through V-transverse immersed curves must be isotopic through V-transverse knots. When M is R^3 and V is the vertical vector field the answer is yes. However, we construct examples which show the answer to this question can be no in other 3-manifolds, specifically S^1-fibrations over surfaces of genus at least 2. We also give a general classification of knots transverse to a vector field in an arbitrary closed oriented 3-manifold M. We show this classification is particularly simple when V is the co-orienting vector field of a tight contact structure, or when M is irreducible and atoroidal. Lastly, we apply our results to study loose Legendrian knots in overtwisted contact manifolds, and generalize results of Dymara and Ding-Geiges. This work is joint with Vladimir Chernov. If time permits we will also discuss applications to the coarse classification of Legendrian knots which are homologically nontrivial, joint with Bulent Tosun. (Received January 18, 2016)

1117-57-393 **Bo-hyun Kwon*** (bortire74@gmail.com), 280 East Creek bend, Athens, GA 30605. *Rectangle Condition on n-bridge presentation of knots.* Preliminary report.

In this paper, we define the rectangle condition for n-bridge presentation of knots whose definition is analogous to the definition of the rectangle condition for Heegaard splittings of 3-manifolds. We show that the satisfaction of the rectangle condition for n-bridge presentation can guarantee that the Hempel distance for the n-bridge presentation is greater than or equal to two. Especially, we find a certain condition of 6-plat presentations to be alternating 3-bridge knots by using the rectangle condition and train track argument. (Received January 18, 2016)

1117-57-437 **Jim Hoste*** (jhoste@pitzer.edu), Pitzer College, Claremont, CA 91711. *2-variable Alexander polynomials of 2-bridge links.* Preliminary report.

We extend an old result regarding Alexander polynomials of 2-bridge knots to the multi-variable Alexander polynomial of 2-bridge links. This leads naturally to the question of which 2-variable polynomials can occur as Alexander polynomials of 2-bridge links. We discuss some results in this direction. (Received January 18, 2016)

1117-57-439 **Juanita Pinzón Caicedo*** (jpinzon@uga.edu). *An Overview of Relative Trisections.*

In 2012 Gay and Kirby developed the notion of trisections of closed 4–manifolds and briefly mentioned relative trisections as a way to adapt their definition to include 4–manifolds with boundary. In this talk I will introduce a rigorous definition of relative trisections, describe their relationship with open book decompositions, introduce the notion of diagrams of relative trisections, and present a few representative examples. This is joint work with Nick Castro. (Received January 18, 2016)

1117-57-451 **James Conway*** (conway@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30332. *Heegaard Floer Homology and Negative Transverse Surgery.*

We focus on the question of when negative surgeries on transverse knots in overtwisted contact manifolds produce tight contact structures. We use Heegaard Floer homology to find large classes of examples. For fibred knots

supporting the contact structure, we define an invariant (which we call the dual contact set) of a related contact structure that detects the non-vanishing of the contact invariants of surgeries on the fibred knot. (Received January 19, 2016)

1117-57-456 **Alan Diaz***, adiaz@math.gatech.edu, and **John Etnyre**. *Strong quasipositivity of fibered satellite knots.* Preliminary report.

A link is strongly quasipositive if it admits a Seifert surface consisting of disks connected by positively twisted bands. We investigate whether a satellite knot S must share this property with its pattern P and companion C. It is straightforward to show that if P and C are strongly quasipositive, then S must be also. We use tools from contact geometry to show that the converse holds when restricting to the fibered case. (Received January 18, 2016)

1117-57-465 **Adam R Saltz*** (saltz.adam@gmail.com), Boston College, Dept of Mathematics, Maloney Hall 538, Chestnut Hill, MA 02467. *A Khovanov-theoretic invariant of knotted surfaces.* Preliminary report.

Khovanov homology is a powerful invariant of knots and links in S^3, but has not had much to say about knotted surfaces in S^4. We construct a non-trivial Khovanov-theoretic invariant of surfaces in S^4 using Meier and Zupan's bridge trisections of surfaces. We will also discuss applications. (Received January 19, 2016)

1117-57-474 **Jeremy Van Horn-Morris*** (jvhm@uark.edu), 1 University of Arkansas, Fayetteville, AR 72701, and **Sam Lisi** (stlisi@olemiss.edu) and **Chris Wendl** (c.wendl@ucl.ac.uk). *A quick introduction to spinal open books.*

We'll explain what a spinal open book is, how to describe and work with one, and why you should care. (Received January 19, 2016)

1117-57-488 **Andy Wand*** (andy.wand@glasgow.ac.uk). *Tight, non-fillable contact structures on 3-manifolds.*

The modern development of contact geometry in 3 dimensions has seen several (due to Giroux, Wendl, Latschev and Wendl, Hutchings, and others) invariants of contact structures meant in some sense to measure non-(Stein/symplectic)-fillability of the structure. Time permitting, we will discuss two new approaches, which rely on Giroux's theory of open book decompositions: the first a more topological construction generalizing a characterization of tightness in terms of open book decompostions, the second (in joint work with Kutluhan, Matic, and Van Horn-Morris) a refinement of the Heegaard-Floer contact class, inspired by the 'algebraic torsion' of Latschev and Wendl, and Hutchings. (Received January 19, 2016)

1117-57-490 **J. Scott Carter*** (carter@southalabama.edu), Department of Mathematics and Statistics, ILB 325, Mobile, AL 36688. *Moves to 2-foams and their chart realizations.*

Moves to 2-foams as realized by means of of moves to the corresponding charts. As such, several posited movie moves for foams can be realized as consequences of the original set of foam moves together with some natural moves to charts and equivalences. (Received January 19, 2016)

1117-57-492 **Christopher Cornwell*** (cornwell@cirget.ca). *Character varieties of branched double covers via knot contact homology.*

I will discuss recent results on obtaining information about the SL(2,C) character variety of the double branched cover over a knot from augmentations of its knot contact homology. Some applications include determining when a knot complement has a simple SU(2) character variety and if the fundamental group of the double branched cover has a left-invariant ordering. (Received January 19, 2016)

1117-57-494 **John Baldwin** and **David Shea Vela-Vick*** (shea@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *A refinement of the contact invariant in Heegaard Floer theory.*

We present a refinement of Ozsvath and Szabo's contact invariant in Heegaard Floer theory. This invariant, denoted b, takes values in the positive integers union infinity, and extends the usual contact invariant in the sense that if $c(Y,\xi)$ is nonzero, then b is infinity. We further show that if (Y,ξ) is overtwisted, then $b(Y,\xi)=1$, reflecting the usual vanishing of the usual contact invariant for such contact structures. In this talk, we will focus on the construction of b and discuss some of its basic properties and applications. (Received January 20, 2016)

1117-57-503 **Alexander Ellis**, **Ina Petkova*** (ina@math.columbia.edu) and **Vera Vertesi**. *Tangle Floer homology and quantum $gl(1|1)$.*

The Reshetikhin-Turaev construction for the standard representation of the quantum group $gl(1|1)$ sends tangles to $\mathbb{C}(q)$-linear maps in such a way that a knot is sent to its Alexander polynomial. After a brief review of this construction, I will give an introduction to tangle Floer homology — a combinatorial generalization of knot Floer homology which sends tangles to (homotopy equivalence classes of) bigraded dg bimodules. Finally, I will discuss how to see tangle Floer homology as a categorification of the Reshetikhin-Turaev invariant. This is joint work with Alexander Ellis and Vera Vertesi. (Received January 19, 2016)

1117-57-523 **Nickolas A. Castro***, ncastro@math.uga.edu. *Gluing and Stabilizing Relative Trisections.*

A trisection of a smooth, oriented, compact 4-manifold is a decomposition analogous to a Heegaard splittings of a 3-manifold. I will discuss a gluing theorem which ties together trisections of closed manifolds and trisections of manifolds with connected boundary, known as relative trisections. I will also introduce a stabilization operation of relative trisections which induces a stabilization on the induced open book decomposition of the bounding 3-manifold. Finally, I will show that this stabilization is compatible with gluing, which yields interesting results relating trisections and embeddings of separating 3-manifolds. (Received January 19, 2016)

58 ► Global analysis, analysis on manifolds

1117-58-180 **Peter Spaeth*** (peter.spaeth@ge.com), One Research Circle, 5B-2FE, Niskayuna, NY 12309. *The symplectic displacement energy.*

To begin we will recall Banyaga's Hofer-like metric on the group of symplectic diffeomorphisms, and explain its conjugation invariance up to a factor. From there we will prove the positivity of the symplectic displacement energy of open subsets in compact symplectic manifolds, and then present examples of subsets with finite symplectic displacement energy but infinite Hofer displacement energy. Based on a joint project with Augustin Banyaga and David Hurtubise. (Received January 12, 2016)

1117-58-442 **Ely Kerman*** (ekerman@illinois.edu). *On primes and period growth for Hamiltonian diffeomorphisms.*

In this talk I will describe how one can use Vinogradov's famous prime distribution theorem and a multidimensional generalization due to Harman to strengthen some recent results concerning the periodic points of Hamiltonian diffeomorphisms. (Received January 18, 2016)

1117-58-528 **Paul M. N. Feehan*** (paul.feehan@rutgers.edu), Department of Mathematics, Rutgers University, 110 Frelinghuysen Road, Piscataway, NY 08854-8019, and **Manos Maridakis** (manousos.maridakis@rutgers.edu), Department of Mathematics, Rutgers University, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. *The Lojasiewicz-Simon gradient inequality and its applications to differential geometry, topology, and mathematical physics.*

The Lojasiewicz-Simon gradient inequality is a generalization, due to Leon Simon (1983), to analytic or Morse-Bott functionals on Banach manifolds of the finite-dimensional gradient inequality, due to Stanislaw Lojasiewicz (1963), for analytic functions on Euclidean space. In this talk, we shall discuss several generalizations of the Lojasiewicz-Simon gradient inequality and a selection of their applications, including global existence and convergence of Yang-Mills gradient flow over 4-manifolds, discreteness of energies of Yang-Mills connections over 4-manifolds, and discreteness of energies of harmonic maps from Riemann surfaces into analytic Riemannian manifolds. (Received January 19, 2016)

1117-58-534 **Phillip Andreae*** (pandreae@math.duke.edu). *Analytic torsion: generalized metric invariance.*

We study the Ray-Singer analytic torsion associated to a flat vector bundle over an odd-dimensional compact manifold. A theorem of Ray-Singer states that in the acyclic case (and, with the appropriate interpretation, more generally), analytic torsion is independent of the metrics used to define it, i.e., it is a topological invariant. We generalize this metric independence theorem to a larger class of metrics, and we explain the metric independence in terms of a certain closed one-form on the space of metrics using a Stokes' theorem argument. (Received January 19, 2016)

60 ► Probability theory and stochastic processes

1117-60-10 **Andrew L Papanicolaou*** (andrew.papanicolaou@nyu.edu), 6 Metrotech Center RH519, Brooklyn, CA 11201. *Numerical Methods for Backward SDEs for Control with Partial Information.*

This talk considers a non-Markov control problem arising in a financial market where asset returns depend on unobserved factors. Latency of the factors requires the investor to maintain an up-to-date posterior distribution, which is a stochastic probability measure that is of infinite dimension. Infinite dimensionality of the posterior means this optimization problem involves conditioning on a state that cannot be differentiated in the traditional sense, and hence cannot be solved using HJB equations.This talk will show how the problem is analyzed and solved using backward stochastic differential equations (BSDEs), and present non-PDE-based algorithms for obtaining numerical solutions. In financial applications, this problem is relevant to managing portfolios of commodities ETFs where the pretext for uncertainty is the latency of convenience yields that affect ETF returns. (Received October 15, 2015)

1117-60-103 **Dan Pirjol*** (dpirjol@gmail.com), New York City, NY , and **Lingjiong Zhu** (ling@cims.nyu.edu), Department of Mathematics, Florida State University, Tallahassee, FL. *Moment explosions in discrete time stochastic processes.*

The talk describes a class of stochastic processes in discrete time which display moment explosions. Under certain conditions the moments of the stochastic variable remain finite but have a rapid increase which is observed in simulations as an explosion. This phenomenon appears in stochastic growth processes, and Euler discretized versions of stochastic volatility models where the volatility follows a geometric Brownian motion. The moment explosions are related to phase transitions in Lyapunov exponents of the moments. They Lyapunov exponents are computed exactly using large deviations theory, and explosion conditions are obtained. (Received January 05, 2016)

1117-60-106 **Bahman Angoshtari*** (bango@umich.edu), Department of Mathematics, University of Michigan, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109-1043, and **Thaleia Zariphopoulou** and **Xun Yu Zhou**. *Predictable Forward Investment Preferences.*

We introduce a new class of investment preferences called Predictable Forward Investment Preferences (PFIP). These preference are motivated by the so-called Forward Investment Preferences (FIP) introduced by Musiela and Zariphopoulou (2006), in the sense that the risk preferences are stochastic and updated forward in time. However, unlike FIP, the updating of PFIP occurs in discrete-time.

In the binomial market setting, we establish the existence of PFIP through a constructive argument. In particular, we show that in the interval between two subsequent updating of preferences, the investor faces the inverse of the classical Merton investment problem, i.e. when the value function is given and the terminal utility function is to be found. We reduce this inverse problem to an iterative (i.e. single variable) functional equation and provide existence and uniqueness conditions for the its solution. This functional equation is the counterpart of the stochastic partial differential equation that characterizes FIP. (Received January 06, 2016)

1117-60-108 **Gordan Žitković*** (gordanz@math.utexas.edu), The University of Texas at Austin, and **Hao Xing**, London School of Economics. *A class of globally solvable systems of BSDE and incomplete stochastic equilibria.*

We give new sufficient conditions on the driver and the terminal condition of a system of BSDE (Backward Stochastic Differential Equations) so that it admits a global (in time) solution. As a corollary, we establish existence and uniqueness of a class of stochastic equilibria in incomplete financial markets. Joint work with Hao Xing (London School of Economics). (Received January 06, 2016)

1117-60-135 **Ambar N Sengupta*** (ambarnsg@gmail.com), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70803. *Mathematical modeling of portfolios with default risk.*

Mathematical aspects of portfolios comprised of assets with default risk will be discussed. Sensitivity of the portfolio loss with respect to model parameters will be examined. (Received January 09, 2016)

1117-60-148 **Mihai Sirbu*** (srbu@math.utexas.edu), Austin, TX 78712. *On modeling and analysis of continuous-time stochastic games.*

We present a new look at the modeling and dynamic programming analysis of zero-sum stochastic differential games. We consider both symmetric and non-symmetric strong formulations of games and analyze their relation with control problems under model uncertainty, that appear in Finance. (Received January 11, 2016)

1117-60-150 **Kim Weston*** (kimberly@andrew.cmu.edu). *Stability of Utility Maximization in Nonequivalent Markets.*

Consider a contingent claim whose underlying is not replicable yet is highly correlated with a traded asset. As the correlation between the underlying and traded asset increases to 1, do the claim's indifference prices converge to the arbitrage-free price? In this talk, I will first present a simple counterexample in a Brownian setting with power utility where the indifference prices do not converge. The counterexample's degeneracies are alleviated for utility functions on the real line, and a positive convergence result will be presented in this case. (Received January 11, 2016)

1117-60-189 **Alexander E. Litvak**, **Anna Lytova*** (anna.lytova@gmail.com), **Konstantin Tikhomirov**, **Nicole Tomczak-Jaegermann** and **Pierre Youssef**. *On invertibility of adjacency matrices of random d-regular directed graphs.*

We consider the set $\mathcal{D}_{n,d}$ of all d-regular directed graphs on n vertices. Let G be a graph chosen uniformly at random from $\mathcal{D}_{n,d}$ and M_n be its adjacency matrix. We show that M_n is invertible with probability at least $1 - C\ln^3 d/\sqrt{d}$ for $C \le d \le cn/\ln^2 n$, where c, C are positive absolute constants. To this end, we establish a few properties of d-regular directed graphs. One of them, a Littlewood–Offord type anti-concentration property, is of independent interest. Let J be a subset of vertices of G with $|J| \approx n/d$. Let δ_i be the indicator of the event that the vertex i is connected to J and define $\delta = (\delta_1, \delta_2, ..., \delta_n) \in \{0,1\}^n$. Then for every $v \in \{0,1\}^n$ the probability that $\delta = v$ is exponentially small. This property holds even if a part of the graph is "frozen." (Received January 13, 2016)

1117-60-208 **Prasad Tetali*** (tetali@math.gatech.edu). *Characterization of a class of weak transport-entropy inequalities on the line.*

We study an optimal weak transport cost related to the notion of convex order between probability measures. On the real line, we show that this weak transport cost is reached for a coupling that does not depend on the underlying cost function. As an application, we give a necessary and sufficient condition for weak transport-entropy inequalities (related to concentration of convex/concave functions) to hold on the line. In particular, we obtain a weak transport-entropy form of the convex Poincaré inequality in dimension one. (This is joint work with Nathael Gozlan, Cyril Roberto, Paul-Marie Samson, and Yan Shu.) (Received January 14, 2016)

1117-60-249 **Chun-Yuan Chiu*** (cc12s@my.fsu.edu), 3041 Dickinson Drive, Tallahassee, FL 32311. *Analytically Tractable Structural Credit Risk Model — A New Framework.*

We propose a new framework of structural credit risk model that is flexible and analytically tractable. In this framework, the asset value of a company can be modeled by a wide range of stochastic processes while the default time distribution is still known in closed form. As an example we take into consideration the stochastic volatility of the asset value of a company. In the special case where a company's debt ratio is a constant, the joint default time distribution can be obtained analytically in any dimensions. (Received January 15, 2016)

1117-60-348 **Ionel Popescu*** (ipopescu@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30332, and **Mihai Pascu**. *Deterministic couplings of Brownian motions on the boundary of convex sets.*

Motivated by the Hot Spots Conjecture we will show some intriguing couplings of Brownian motions on the surface of a smooth convex body. For instance we show that there are fixed distance couplings and in the case of the Euliclidean ball we can completely characterize all couplings of deterministic distance. (Received January 17, 2016)

1117-60-385 **Vladimir Koltchinskii*** (vlad@math.gatech.edu). *Concentration bounds for sample covariance operators.*

We will discuss moment bounds and concentration inequalities for sample covariance operators based on n i.i.d. Gaussian random variables with values in a separable Banach space. These bounds provide a dimension-free characterization of the operator norm of the deviation of the sample covariance from the true covariance in terms of two parameters of the true covariance: its operator norm and its so called "effective rank". Most of the results are based on a joint work with Karim Lounici. (Received January 18, 2016)

1117-60-545 **Ibukun O Amusan*** (ibukun.amusan@kysu.edu). *Option pricing under a stochastic volatility model with two noises and transaction cost.*

This paper considers option pricing that incorporates transaction cost. The pricing is done under a stochastic volatility model with coupled additive and multiplicative noises. Some numerical results obtained for some options are presented and a comparison is made between pricing with and without transaction cost. (Received January 20, 2016)

62 ► Statistics

1117-62-182 **Danush K Wijekularathna*** (dwijekularathna@troy.edu), Mathematics Department, Troy University, Troy, AL 36082, and **Hossein Mansouri** (hossein.mansouri@ttu.edu), Dept. of Mathematics, Texas Tech University, Lubbock, TX 79409. *Rank Procedures for Testing Sub Hypotheses in Repeated Measures Design.*

The term repeated-measures refers to an experiment that collects multiple measurements from each subject. Repeated measures data has its own challenges. Since we repeatedly take the same type of measurement across time on the subjects, data are not independent. So the major problem of this model is covariance structure among these repeated measurements and we must account for the dependency in data using more complex or complicated statistical methods. Often it is of interest to test hypotheses concerning the parameters of a linear model for such data. The problem of testing linear hypothesis in linear models based on rank statistics has received a considerable interest in statistical literature as a result of its robustness against outliers. Several tests based on ranks are also available. In this presentation, a class of rank tests for testing linear hypotheses for parameters of a linear model for repeated measures data will be formulated. Some results on small sample properties of the rank tests will also be presented and compared them with their parametric competitors. (Received January 13, 2016)

1117-62-282 **Karim Lounici***, Georgia Inst. of Technology, School of Mathematics, 686 Cherry St Ne, Atlanta, GA 30332. *Concentration bounds and asymptotic distribution for the empirical spectral projectors of sample covariance operators.*

Let $X, X_1, \dots, X_n$ be i.i.d. Gaussian random variables in a separable Hilbert space $\mathbb{H}$ with zero mean and covariance operator $\Sigma = \mathbb{E}(X \otimes X)$, and let $\hat{\Sigma} := n^{-1} \sum_{j=1}^{n} (X_j \otimes X_j)$ be the sample (empirical) covariance operator based on $(X_1, \dots, X_n)$. Denote by P_r the spectral projector of Σ corresponding to its r-th eigenvalue μ_r and by $\hat{P}_r$ the empirical counterpart of P_r. Our goal is to obtain tight bounds on

$$\sup_{x \in \mathbb{R}} \left| \mathbb{P} \left\{ \frac{\|\hat{P}_r - P_r\|_2^2 - \mathbb{E}\|\hat{P}_r - P_r\|_2^2}{\mathrm{Var}^{1/2}(\|\hat{P}_r - P_r\|_2^2)} \le x \right\} - \Phi(x) \right|,$$

where $\|\cdot\|_2$ denotes the Hilbert–Schmidt norm and Φ is the standard normal distribution function. Such accuracy of normal approximation of the distribution of squared Hilbert–Schmidt error is characterized in terms of so called effective rank of Σ defined as $\mathbf{r}(\Sigma) = \frac{\mathrm{tr}(\Sigma)}{\|\Sigma\|_\infty}$, where $\mathrm{tr}(\Sigma)$ is the trace of Σ and $\|\Sigma\|_\infty$ is its operator norm, as well as another parameter characterizing the size of $\mathrm{Var}(\|\hat{P}_r - P_r\|_2^2)$.

Joint work with Vladimir Koltchinskii (Received January 16, 2016)

1117-62-443 **Huijun Yi*** (hyi146574@troy.edu) and **Bhaskar Bhattacharya**. *Contingency Table Analysis Under Linear Inequality Constraints.*

When analyzing I x J contingency tables, there are four established methods for estimating the cell probabilities with known margins (equal constraints), namely, raking (RAKE), maximum likelihood under random sampling (MLRS), minimum chi-squared (MCSQ), and least squares (LSQ). Under the situation where sampled and target populations are different, sets of general linear inequality restrictions can be considered as the prior information. It is of interest to present new models related to the above four methods of estimation subject to inequality constraints. Four methods are compared in a simulation study and data from a health and nutrition survey data. It shows that four methods rank differently under inequality than with equality.

Considering the difficulty of numerically solving primal problem due to large dimensions, we use the algorithm of Khun-Tucker conditions to exploit the duality for each method. It shows the dual problems could be substantially easier to solve than the primal problem for large I, J. (Received January 18, 2016)

65 ► Numerical analysis

1117-65-53 **Seong Jun Kim*** (skim396@math.gatech.edu), 686 Cherry Street, Atlanta, GA 30332, and **Sung Ha Kang** and **Haomin Zhou**. *A computational strategy for optimal path planning with limited sensing ability.*

In applications, the optimal solution is extremely important because it directly impacts the efficiency of allocated resources. This talk focuses on establishing a numerical method for path planning problems under limited sensing ability which arises as an essential part in many scientific fields, e.g., robotic path planning, unmanned automatic vehicles. We formulate the problem using the level set framework and find the solution using an optimization method with SDEs. (Received December 28, 2015)

1117-65-62 **Michele Benzi***, Dept. of Mathematics and Computer Science, Emory University, 400 Dowman Drive, Atlanta, GA 30322. *Numerical Analysis of Quantum Graphs.*

We consider the numerical solution of eigenvalue and boundary-value problems for differential equations posed on graphs or networks. More specifically, the talk is concerned with quantum graphs, which are metric graphs endowed with a self-adjoint differential operator (Hamiltonian) acting on functions defined on the graph's edges with suitable side conditions. We describe and analyze the use of a linear finite element method for discretizing a class of simple Hamiltonians.

The solution of the discrete equations is achieved by means of a (non-overlapping) domain decomposition approach. For model elliptic problems and a wide class of graphs, we show that a combination of Schur complement reduction and diagonally preconditioned conjugate gradients results in optimal complexity. We also discuss the solution of parabolic diffusion-type problems. Numerical results are presented for both simple and complex graph topologies.

This is joint work with Mario Arioli (University of Wuppertal, Germany). (Received December 30, 2015)

1117-65-83 **Lea Jenkins*** (lea@clemson.edu) and **Anastasia Wilson**. *The Math of Chemistry: Using Scientific Computing to Understand Filtration and Separations Processes.*

Filtration and separations processes are ubiquitous in our everyday lives. They are involved in a wide range of production environments, including polymer fiber production and production of biopharmaceuticals. Filtration devices also provide us access to clean water, and they help our car engines run smoothly. Our body also uses filtration processes to efficiently trap and remove impurities. In this talk, I will present an overview of filtration processes used in the polymer fiber and biopharmaceutical industries, including a synopsis of several mathematical problems that arise in the context of modeling these processes. I will also describe theoretical work and numerical results associated with our efforts to develop simulation frameworks for engineers interested in optimizing their manufacturing capabilities based on effective filtration. (Received January 04, 2016)

1117-65-92 **Massimiliano Lupo Pasini*** (mlupopa@emory.edu), **Michele Benzi** (benzi@mathcs.emory.edu), **Thomas M. Evans** (evanstm@ornl.gov), **Steven P. Hamilton** (hamiltonsp@ornl.gov)) and **Stuart R. Slattery** (slatterysr@ornl.gov). *Monte Carlo Acceleration of Iterative Solvers for Sparse Linear Systems.*

We consider hybrid deterministic-stochastic iterative algorithms for the solution of large, sparse linear systems. Starting from a convergent splitting of the coefficient matrix, we analyze various types of Monte Carlo acceleration schemes applied to the original preconditioned Richardson (stationary) iteration. These methods are expected to have considerable potential for resiliency to faults when implemented on massively parallel machines.

We establish sufficient conditions for the convergence of the hybrid schemes, and we investigate different types of preconditioners including sparse approximate inverses. Numerical experiments on linear systems arising from the discretization of partial differential equations are presented. (Received January 05, 2016)

1117-65-296 **Mahboub Baccouch*** (mbaccouch@unomaha.edu), 6001 dodge st., DSC 233, omaha, NE 68182. *A superconvergent local discontinuous Galerkin method for the sine-Gordon equation.*

In this talk, we present a superconvergent and energy-conserving local discontinuous Galerkin (LDG) method for the sine-Gordon equation. We prove the L^2 stability, the energy conserving property, and error estimates for the LDG scheme. The L^2 errors are shown to converge with the optimal order $O(h^{p+1})$, when piecewise polynomials of degree at most p are used. We further identify a special numerical flux and a suitable projection of the initial conditions for the LDG scheme to prove superconvergence toward particular projections of the exact solutions. We apply our superconvergence results to prove that the significant parts of the discretization errors for the LDG solution and its spatial derivative are proportional to (p+1)-degree right and left Radau

polynomials, respectively. This result is used to construct asymptotically exact a posteriori error estimates by solving a local steady problem on each element. Finally, we prove that these a posterior error estimates for the solution and its derivative converge to the true spatial errors in the L^2-norm under mesh refinement. Several numerical results are presented to validate the superconvergence results and the asymptotic exactness of our a posteriori error estimates under mesh refinement. (Received January 16, 2016)

1117-65-399 **fidele ngwane***, USC Salkehatchie, 807 Hampton Street, Walterboro, SC 29488. *A block hybrid method for directly solving second order initial value problems.*

We derive a block hybrid trigonometric fitted continuous method for directly solving second order initial value problems. The implementation of this numerical method is in block form. Stability properties are discussed and numerical examples are presented to illustrate the accuracy of the method. (Received January 18, 2016)

1117-65-411 **Jason S Howell*** (howelljs@cofc.edu), Department of Mathematics, 66 George St., Charleston, SC 29424. *Prestructuring sparse matrices with dense rows for direct solvers.*

The presence of a dense row in an otherwise sparse coefficient matrix may significantly affect the performance of modern direct solvers for large sparse linear systems. In this work we describe how an unconventional application of a null space method can be utilized to eliminate a small number of dense rows while preserving the overall sparsity of the matrix. This results in a prestructuring technique, i.e. a method that seeks to modify the nonzero structure of the matrix with the intent of realizing gains in direct solver performance. (Received January 18, 2016)

1117-65-422 **Vani Cheruvu*** (vani.cheruvu@utoledo.edu), Dept of Mathematics and Statistics, MS 942, The University of Toledo, 2801 W Bancroft Street, Toledo, OH 43606. *Numerical solution of Laplace equation in an arbitrary shaped domain.*

Dirichlet problem for the two-dimensional Laplace equation in an arbitrary shaped bounded domain is considered. This domain is embedded in a circular domain using analytic continuation. This leads to an inverse problem for the boundary values of the unknown function on the circular domain. Wavelet regularization is used to solve the resulting ill-conditioned system. In this talk, we present the idea and conclude with couple of numerical results. (Received January 18, 2016)

1117-65-471 **Abhinandan Chowdhury*** (chowdhury@savannahstate.edu), Department of Mathematics, Savannah State University, Savannah, GA 31404, and **Mark Delcambre**. *A Numerical Modelling for the Potential Flow Around Two Non-overlapping Spheres in Arbitrary Motion through an Ideal Fluid.* Preliminary report.

The velocity potential of an ideal fluid around two spheres having constant velocity is considered. Bi-spherical coordinates are used, together with a transformation of the dependent variable that leads to separation of variables. Then the solution can be sought in Legendre series with respect to one of the bi-spherical coordinates. An important element of the proposed work is the effective way to reduce an essentially 3D problem to a set of three 2D problems. The Legendre spectral method is shown to have an exponential convergence which is confirmed by the computations. The efficiency is so high that even for the hard cases of two closely situated spheres, an accuracy of $10^{(-15)}$ is achieved with as few as 20 terms in the expansion. (Received January 19, 2016)

1117-65-533 **Alina Chertock**, **Alexander Kurganov**, **Maria Lukacova** and **Seyma Nur Ozcan***, snozcan@ncsu.edu. *An Asymptotic Preserving Simulation for Kinetic Equations of Chemotaxis.*

Chemotaxis models describe the cell movements in relation to the chemical substance in the medium. It is known that the most common PDE based chemotaxis models, so-called (Patlak) Keller-Segel models, can be derived as a drift-diffusion limit of corresponding kinetic equation. These diffusive limits are obtained by rescaling the kinetic models. We develop an Asymptotic Preserving numerical method to solve the kinetic models, in which the new scheme yields to the scheme of the limit problem. (Received January 19, 2016)

68 ► Computer science

1117-68-207 **Paul Robert Stallings*** (paul@kubotekusa.com), 1506 Fisk Ct., Longmont, CO 80503. *A New Boundary Representation Boolean Algorithm.*

Abstract. One of the most useful ways to both create and modify parts is to unite, subtract or intersect one part with another, or Boolean them. The data structure I use in the paper is a boundary representation, or b-rep

model. I have used a b-rep definition that is part way between the many formats in commercial use and inclusive of all the major format properties. Current Boolean algorithms, that operative on b-rep models, have not yet reached the formal level of proof that the well-defined algorithms of Computational geometry have. However, there is still a need to solve this very difficult problem along with the other difficult algorithms of blending, shelling, and surface creation that are needed in CAD to name a few. Since a Boolean algorithm depends on the use of several other algorithms, which together make up what is called a geometric modeler, this is a problem that academia does not have the resources to address and quite often the commercial world does not have the time to address. The algorithm presented here was developed by Kubotek Corporation over the last ten years at the cost of millions of. How the algorithm works, was developed and tested is presented. (Received January 14, 2016)

1117-68-257 **Scott C. Batson*** (scott.batson@navy.mil), **Bryan Williams** (bryan.l.williams1@navy.mil), **Evan Austin** (evan.austin@navy.mil) and **Adam Wazzan** (adam.wazzan@navy.mil). *On Automated Verification of Security Proofs in Elliptic Curve Cryptography.* Preliminary report.

Modern cryptography is rapidly evolving to include elaborate functionalities, and cryptographic proofs of security have become significantly more complicated as a result. The use of automated tools to assist in constructing these proofs would potentially increase the confidence in them, and address the difficulty in verifying implementations. In 2014, Barthe et. al. introduced EasyCrypt, a tool that supports game-based verification of security for cryptographic constructions in generic group models. The aim of our work is to extend the EasyCrypt results to elliptic curve cryptographic schemes. We first present the intuition behind the automated verification of elliptic curve ElGamal in EasyCrypt, and discuss how one may adapt these ideas to additional elliptic curve schemes. (Received January 15, 2016)

1117-68-299 **Diego Cifuentes*** (diegcif@mit.edu), 77 Massachussets Avenue, 32-D760, Cambridge, MA 02139, and **Pablo A Parrilo** (parrilo@mit.edu), 77 Massachusetts Avenue, 32D-726, Cambridge, MA 02139. *Chordal structure and polynomial systems.*

Techniques based on chordal structure and bounded treewidth have been extensively studied in linear algebra, graphical models, constraint satisfaction, database theory, and many other areas. It is natural then to analyze to what extent chordality might also help in computational algebraic geometry. To this end, we propose new techniques for solving polynomial equations by means of Gröbner bases and triangular sets. By maintaining the graphical structure of the input polynomial system in all computations, our methods can outperform standard algorithms in many cases. In particular, for a restricted class of ideals, the computational complexity is linear in the number of variables. Our methods can be used to tackle several important computational problems for polynomial ideals, such as feasibility, dimension, counting isolated solutions and radical ideal membership. Besides the theoretical developments, we illustrate the suitability of our methods in examples arising from graph colorings, cryptography and sensor localization. (Received January 16, 2016)

1117-68-502 **Jingsai Liang*** (jl4z@mtmail.mtsu.edu), 2850 Middle Tennessee Blvd, Apt A12, Murfreesboro, TN 37130, and **Don Hong**. *Non-Gaussian Penalized PARAFAC Analysis of fMRI(Functional Magnetic Resonance Imaging) Data.*

Independent Component Analysis(ICA) has been used successfully in Functional Magnetic Resonance Imaging(fMRI) data analysis. As an extension of the ICA, Tensorial Probabilistic ICA(TPICA) is to decompose the fMRI data into three-mode(subject $\times$ temporal $\times$ spatial). Parallel Factor Analysis(PARAFAC) is another method to process three-mode data. While only the spatial mode has the priority to be processed in TPICA, three modes are equally and simultaneously processed in PARAFAC. One drawback of PARAFAC is that it will converge to some degenerate solutions if the data does not meet the requirements of full rank in three-mode matrices. Meanwhile TPICA can not perform well in the presence of overlapping of activation patterns in the spatial mode. So both of TPICA and PARAFAC can not process three-mode fMRI data perfectly. In this paper, via adding a penalty term to PARAFAC, we impose the constraint of the non-Gaussian character on the calculation step of the spatial mode. This penalized PARAFAC algorithm can drive the spatial sources as non-Gaussian as possible to avoid the degenerate solutions and does not need the independent constraint of the spatial sources. fMRI data analysis examples show that the proposed method outperforms both the TPICA and PARAFAC methods. (Received January 19, 2016)

1117-68-547 **Erik Demaine*** (edemaine@mit.edu). *Fun with Fonts: Mathematical Typography.*

Over the past decade, my father and I have designed several typefaces based on mathematical theorems and open problems. These typefaces expose the general public in a unique way to intriguing results and hard problems

in hinged dissections, geometric tours, origami design, computer-aided glass design, physical simulation, protein folding, juggling, and card shuffling. Most of our typefaces include puzzle fonts, where reading the intended message requires engaging in the mathematics itself, solving a series of puzzles which illustrate the challenge of the underlying mathematical problem.

To play with the fonts, visit http://erikdemaine.org/fonts/. (Received January 20, 2016)

74 ► Mechanics of deformable solids

1117-74-156 **David Swigon*** (swigon@pitt.edu), Department of Mathematics, University of Pittsburgh, 301 Thackeray Hall, Pittsburgh, PA 15215, and **Sookkyung Lim** (sookkyung.lim@uc.edu), Department of Mathematical Sciences, 4199 French Hall West, University of Cincinnati, Cincinnatti, OH 45221. *Dynamics of DNA supercoiling, knotting, and compaction.*

Recent experiments on electrostatically induced migration of DNA in nanochanels reveal an intricate phenomenon of compaction of migrating DNA that promotes knotting of the molecule. Subsequent relaxation of the molecule proceeds along several distinct kinetic regimes. The structural details of DNA configurations in different stages of the process are yet unknown. We investigate this and other related phenomena of DNA dynamics using a model in which DNA is represented by a charged elastic rod immersed in a viscous incompressible fluid and the governing equations of the system are solved numerically using the generalized immersed boundary method. The equations of motion of the rod include the fluid–structure interaction, rod elasticity and a combination of two interactions that prevent self-contact, namely the electrostatic interaction and hard-core repulsion. Presented will be results on the effects of electrostatics, steric repulsion, and thermal fluctuations on DNA supercoiling and knotting dynamics. (Received January 12, 2016)

76 ► Fluid mechanics

1117-76-88 **K. Choi*** (kchoi@unist.ac.kr), Ulsan, 689798, South Korea, **T. Hou** (hou@cms.caltech.edu), Pasadena, CA 91125, **A. Kiselev** (kiselev@rice.edu), Houston, TX 77005, **G. Luo** (guoluo@cityu.edu.hk), Hong Kong, N/A, Hong Kong, **V. Sverak** (sverak@math.umn.edu), Minneapolis, MN 55455, and **Y. Yao** (yaoyao@math.gatech.edu), Atlanta, GA 30332. *A Finite time blow up for 1D models for 2D Boussinesq system / 3D Axi-symmetric Euler equations.*

In connection with the recent proposal for possible singularity formation at the boundary for solutions of 3d axi-symmetric incompressible Euler's equations (Luo and Hou, 2013), we study some models for the dynamics at the boundary and show that they exhibit a finite-time blow-up from smooth data. (Received January 04, 2016)

80 ► Classical thermodynamics, heat transfer

1117-80-526 **Anilkumar Devarapu*** (anilkumar.devarapu@asurams.edu), Department of Mathematics and Computer Scienc, 504 College Dr, Albany, GA 31705. *Non-similar solution of an Unsteady Mixed Convection Heat Transfer.*

Unsteady mixed convection heat transfer equations do not necessarily admit self-similarity solutions in many practical situations. A general analysis has been developed to study heat transfer characteristics of an unsteady mixed convection on a continuously moving vertical slender cylinder. We formulated this problem in a more general settings by using the parameter λ. When $\lambda = 0$, we have the case of stationary cylinder in a moving stream, whereas when$\lambda = 1$ we have the case of moving cylinder with no external motion imposed on the free stream. For the intermediate values of λ we have the case of simultaneous motion of the slender cylinder and the free stream. The governing unsteady boundary layer equations are solved by the implicit finite difference method. Heat transfer characteristics for a variety of accelerating and decelerating situations are presented graphically and discussed. (Received January 19, 2016)

82 ► Statistical mechanics, structure of matter

1117-82-89 **Houssam Abdul-Rahman*** (houssam@uab.edu), UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294-1170, and **Günter Stolz** (stolz@uab.edu), UAB Department of Mathematics, Campbell Hall, 1300 University Boulevard, Birmingham, AL 35294. *Entanglement Dynamics in the Disordered Quantum XY Chain.*

We consider the dynamics of the quantum XY chain in the presence of a transversal random magnetic field under the assumption of eigenfunction correlator localization of the corresponding effective single particle Hamiltonian. We show that, starting from a broad class of product initial states, bipartite entanglement remains bounded for all times. For the disordered XX chain we also derived bounds for the particle number transport. These results demonstrate the fact that the disordered XY chains are fully many-body localized. (Received January 04, 2016)

1117-82-104 **Houssam Abdul-Rahman**, **Bruno Nachtergaele**, **Robert Sims** and **Gunter Stolz*** (stolz@uab.edu). *Manifestations of Many-Body Localization.*

In the most recent decade the topic of many-body localization has seen strong attention and rapid development in the physics and quantum information literature. The physical understanding of relevant concepts is still in flux, while mathematically rigorous approaches remain a wide open challenge. Here we will survey some of the accepted manifestations of MBL such as absence of many-body transport, exponential decay of ground and thermal state correlations, as well as area laws for the (stationary and dynamical) entanglement of states. Among the few models where mathematical results have been obtained are disordered oscillator systems and some examples of quantum spin chains. Recent work on the latter will be presented in the talk by H. Abdul-Rahman. (Received January 05, 2016)

1117-82-173 **Shannon L Starr*** (slstarr@uab.edu), UAB Department of Mathematics, 1300 University Boulevard, Birmingham, AL 35294-1170. *Comparing Graphs.* Preliminary report.

A graph is a pair G=(V,E). One may define a discrete Laplacian on a graph. Then there are natural elementary inequalities to compare the eigenvalues of the discrete Laplacians on pairs of such graphs. For us a key example is the graph associated to the quantum Heisenberg ferromagnetic spin system, with n spins down and the rest of the spins up. This is close to a product graph but with some vertices removed. Obtaining upper and lower bounds in terms of the product graph gives a partial verification of the physicists' linear spin wave approximation. This type of analysis has been done before by Correggi, Giuliani and Seiringer, as part of more general results they obtained. But we also have some new results not previously obtained by them, in dimensions d=1 and d=2. (Received January 12, 2016)

1117-82-515 **Lei Zhang*** (lzhang98@math.gatech.edu), **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 the-orem 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 January 19, 2016)

90 ► Operations research, mathematical programming

1117-90-17 **Jon Lee** (jonxlee@umich.edu) and **Daphne Skipper*** (daphne.skipper@gmail.com). *Virtuous smoothing for global optimization.*

Virtually all exact solvers for global-optimization and mixed-integer nonlinear-optimization (like SCIP, for example) rely on nonlinear-programming (NLP) solvers, both to generate good feasible solutions (yielding upper bounds) and to solve relaxations (yielding lower bounds). Convergence of most NLP solvers requires that functions be twice continuously differentiable. Yet many models naturally utilize functions with some limited

nondifferentiability. One approach to handle limited nondifferentiability is smoothing based. We propose a method, mostly aimed at (concave) root functions ($f(x) = x^p$, with $0 < p < 1$) that provides a tighter lower bound than the obvious shift ($g(x) = (x+\epsilon)^p - \epsilon^p$), and is smooth and globally concave, so it works well with local and global solvers. Importantly, lower bounding is critical when root functions appear in inequality constraints [upper bounds are also important, but they are obtained more easily for concave functions]. We lower-bound the derivative via a parameter, so as to accommodate any working precision. A new (hidden) feature of SCIP makes our methodology easy to incorporate. (Received November 12, 2015)

1117-90-330 **Alexander Mafusalov*** (mafusalov@ufl.edu), 303 Weil Hall, University of Florida, Gainesville, FL 32611, and **Stan Uryasev** (uryasev@ufl.edu), 303 Weil Hall, University of Florida, Gainesville, FL 32611. *Risk-averse chance optimization with buffered probability of exceedance.*

The Probability of Exceedance (POE), a probability that a random loss exceeds a certain threshold, is one of the key performance measures in many applications, including finance. However, POE optimization is not convex and computationally challenging. Additionally, POE estimates are not risk-averse. This paper uses a new probabilistic characteristic called buffered Probability of Exceedance (bPOE) to provide an alternative convex optimization problem formulation. This bPOE minimization problem is a conservative version of POE minimization, as bPOE is the smallest quasi-convex upper bound for POE. A case study with a cash flow matching problem where bPOE is used to control risk of shortfalls was performed. (Received January 17, 2016)

1117-90-462 **Lakmali P Weerasena***, lweeras@g.clemson.edu, and **Banu Soylu** and **Margaret Wiecek**. *An algorithm to approximate the solutions of the multiobjective set covering problem.*

The multiobjective set covering problem (MOSCP) is a challenging multiobjective combinatorial optimization problem. An algorithm is proposed to approximate/compute elements in the solution set of the MOSCP. Unlike other approaches in the literature, the algorithm estimates the cost of each set when constructing a feasible solution to the problem. Numerical experiments are conducted on small and large-sized bi-objective and three-objective set covering problems. The experiments confirm that the proposed algorithm performs well on the MOSCP. (Received January 19, 2016)

91 ► Game theory, economics, social and behavioral sciences

1117-91-109 **Shiyu Ye** and **Berna Karali***, 315 Conner Hall, Dept. of Ag. and Applied Economics, The University of Georgia, Athens, GA 30602-7509. *The Informational Content of Inventory Announcements: Intraday Evidence from Crude Oil Futures Market.*

This study examines the behavior of intraday return and volatility in crude oil futures market and their response to weekly inventory announcements by the American Petroleum Institute (API) and Energy Information Administration (EIA). First, a nonparametric method is applied to identify intraday jumps surrounding API and EIA report releases. Then, the impacts of unexpected changes in petroleum products' inventories on five-minute futures returns and their volatility are explored using a two-step weighted least squares method. Results show that both API and EIA inventory surprises exert an immediate negative impact on crude oil futures returns and a positive impact on return volatility. However, the duration and magnitude of inventory effects differ between the two reports. Further, asymmetric effects are found in the instantaneous return response to EIA inventory surprises. (Received January 06, 2016)

1117-91-250 **Arash Fahim** and **Lingjiong Zhu*** (zhu@math.fsu.edu). *Optimal Investment in a Dual Risk Model.*

Dual risk models are popular for modeling a venture capital or high tech company, for which the running cost is deterministic and the profits arrive stochastically over time. Most of the existing literature on dual risk models concentrated on the optimal dividend strategies. In this paper, we propose to study the optimal investment strategy on research and development for the dual risk models to minimize the ruin probability of the underlying company. We will also study the optimization problem when in addition the investment in a risky asset is allowed. (Received January 15, 2016)

1117-91-327 **Vishwakant Malladi**, **Rafael Mendoza-Arriaga** and **Stathis Tompaidis*** (stathis.tompaidis@mccombs.utexas.edu). *Modeling Dependent Outages of Electricity Generators.*

We present a framework for modeling dependence in outages of electricity generators based on time changed stochastic processes. We provide an algorithm for the calibration of our model and illustrate it for the case of two regions in North America using actual outage data. We use our calibrated results to quantify the impact of dependence in outages to the reliability of the electricity system. (Received January 17, 2016)

92 ► Biology and other natural sciences

1117-92-13 **Lihong Zhao*** (lzhao@louisiana.edu), lzhao@louisiana.edu, and **Karyn L. Sutton** and **Jacoby Carter**. *Growth Dynamics for Pomacea maculata.*

Pomacea maculata is a relatively new invasive species to the Gulf Coast region and potentially threatens local agriculture (rice) and ecosystems (aquatic vegetation). The population dynamics of *Pomacea maculata* have largely been unquantified. We directly measured the growth rates of individually marked snails grown in a common tank to quantify their growth patterns. But due to large intra- and inter- individual variability and sample size, we were not able to get statistically supported estimates (i.e., tight confidence intervals) on overall growth dynamics. However, we were able to use a model comparison statistic to determine that there are distinct growth stages. Further, these data strongly suggest that male and female growth dynamics, size distributions, and overall weights, are notably different with females being generally larger. We performed simulation studies based on observed variability, and designed additional lab experiments and field studies. We were able to get a large sample size data set, which allows us to better characterize the variability in the population, but only over one time interval. Analysis of this data set suggests that variability in growth rates is significant, which is important for an accurate model of the population dynamics. (Received November 10, 2015)

1117-92-27 **Alan Veliz-Cuba***, 300 College Park, University of Dayton, Dayton, OH 45431. *On the perfect reconstruction of the topology of dynamic networks.*

The network inference problem consists in reconstructing the topology or wiring diagram of a dynamic network from time-series data. Even though this problem has been studied in the past, there is no algorithm that guarantees perfect reconstruction of the topology of a dynamic network. In this talk I will present a framework and algorithm to solve the network inference problem for discrete-time networks that, given enough data, is guaranteed to reconstruct the topology of a dynamic network perfectly. The framework uses tools from algebraic geometry. (Received December 16, 2015)

1117-92-42 **Luis David Garcia-Puente*** (lgarcia@shsu.edu), **Iliana De La Cruz**, **Taylor Spino**, **Melissa Stadt** and **Catherine Sullivan**. *Algebraic Statistics Applications in Epidemiology.* Preliminary report.

Interactions between single nucleotide polymorphisms (SNPs) and complex diseases have been an important topic throughout epidemiological studies. Previous studies have mostly focused on gene variables at a single locus. In this talk, I will discuss a focused candidate gene study to test the interaction of multiple SNPs with the risk of different types of cancer. Using the R package algstat, developed by Kahle, Garcia-Puente, and Yoshida, we implemented an algebraic statistics method that can test for independence between several variables and the desease. We applied our methods to the study of gene-gene interaction on cancer data obtained from the European case-control study Gen-Air extending previous work by Ricceri, Fassino, Matullo, Roggero, Torrente, Vineis, and Terracini. (Received December 22, 2015)

1117-92-59 **Elizabeth Allman**, **John Rhodes** and **Seth Sullivant*** (smsulli2@ncsu.edu). *Statistically-consistent k-mer methods for phylogenetic tree reconstruction.*

Frequencies of k-mers in sequences are sometimes used as a basis for inferring phylogenetic trees without first obtaining a multiple sequence alignment. We show that a standard approach of using the squared-Euclidean distance between k-mer vectors to approximate a tree metric can be statistically inconsistent. To remedy this, we derive model-based distance corrections for orthologous sequences without gaps, which lead to consistent tree inference. The identifiability of model parameters from k-mer frequencies is also studied. Finally, we report simulations showing the corrected distance out-performs many other k-mer methods, even when sequences are generated with an insertion and deletion process. These results have implications for multiple sequence alignment as well, since k-mer methods are usually the first step in constructing a guide tree for such algorithms. (Received December 29, 2015)

1117-92-86 **Peter Hinow*** (hinow@uwm.edu), Department of Mathematical Sciences, University of Wisconsin - Milwaukee, PO Box 413, Milwaukee, WI 53201. *Algebraic and Topological Indices of Molecular Pathway Networks in Human Cancers.*

Biological networks have been an active area of research for some years, in particular protein-protein interaction (PPI) networks. We retrieve the protein-protein interaction networks of 11 human cancers from the Kyoto Encyclopedia of Genes and Genomes (KEGG) and determine their relative automorphism group sizes and the dimensions of their cycle spaces. These quantities are commonly taken to be measures of network complexity in physics and computer science. We find evidence that greater network complexity is associated with lower five year survival probabilities. Moreover, we identify several protein families (PIK, ITG, AKT) that are repeated motives in many of the cancer pathways. Our results can aide in identification of promising targets for anti-cancer drugs.

This is joint work with Jack A. Tuszyński (Cross Cancer Institute and Department of Physics, University of Alberta, Edmonton, AB, Canada) and Edward A. Rietman (Center for Cancer Systems Biology, Tufts University School of Medicine, Boston, MA, USA). (Received January 04, 2016)

1117-92-121 **Ronald D Hagan*** (rhagan@utk.edu) and **Michael A Langston**. *Computational Tools for the Analysis of DNA Methylation Data.*

The genetic code contained in a person's DNA is far from the only determining factor in actual gene expression. Epigenetic mechanisms such as DNA methylation and histone modifications also play a prominent role. In fact, aberrant methylation patterns have been linked to nearly all forms of cancer. In this talk we present an overview of an innovative set of computational tools with a foundation in statistical analysis and graph theory for analyzing methylation data. In addition, we explore a variety of use cases demonstrating the utility of our tools for methylation biomarker discovery in disease, tissue differentiation, mutation status, and outlier detection. (Received January 07, 2016)

1117-92-128 **Andy Jenkins** (leej@clemson.edu), Department of Mathematical Sciences, Martin Hall, Clemson University, Clemson, SC 29634-0975, and **Matthew Macauley*** (macaule@clemson.edu), Department of Mathematical Sciences, Martin Hall, Clemson University, Clemson, SC 29634-0975. *A Boolean network model of the L-arabinose operon.* Preliminary report.

In genetics, an operon is a segment of DNA that contains several co-transcribed genes, which together form a functional regulatory unit. Operons have primarily been studied in prokaryotes, with both the lactose (lac) and tryptophan (trp) operons in E. coli having been classically modeled with differential equations and more recently, with Boolean networks. The L-arabinose (ara) operon in E. coli encodes proteins that function in the catabolism of arabinose. It differs from the lac and trp operons in that it exhibits both positive and negative gene regulation within a single operon. In this talk, we will describe our proposed Boolean network model for the ara operon, which consists of both a physical wiring diagram, and the logical functions that govern each node. Additionally, we will describe the results of model validation and current and future research. (Received January 08, 2016)

1117-92-147 **Shi-Jie Chen*** (chenshi@missouri.edu), Departments of Physics and Biochemistry, University of Missouri Informatics Institute, University of Missouri, Columbia, MO 65211. *RNA Folding: From Statistical Mechanics to Therapeutic Applications.*

The current experiments on structural determination cannot keep up the pace with the steadily emerging RNA sequences and new functions. This underscores the request for an accurate model for RNA three-dimensional (3D) structural prediction. Considerable progress has been made in mechanistic studies, but accurate prediction for RNA tertiary structural folding from sequence remains an unsolved problem. The first and most important requirement for predicting of RNA structure from physical principles is an accurate free energy landscape model. I will introduce a multiscale RNA folding theory recently developed in my lab. A key advantage of this new theory is the use of rigorous physical principles for chain entropies/free energies for RNA tertiary folds. I will present several biomedical applications of the theory including microRNA-gene target interactions and RNA-related therapeutic design (Received January 11, 2016)

1117-92-217 **Zhan Chen*** (zchen@georgiasouthern.edu). *Differential geometry based multiscale solvation models.*

Solvation is an elementary process in nature and is of paramount importance to many sophisticated chemical, biological and biomolecular processes. The understanding of solvation is an essential prerequisite for the quantitative description and analysis of biomolecular systems. Implicit solvent models, particularly those based on the

Poisson-Boltzmann (PB) equation for electrostatic analysis, are established approaches for solvation analysis. However, ad hoc solvent-solute interfaces and complex solutions of nonlinear post some severe limitations on the applications.We will present differential geometry (DG) based multiscale solvation models which allow the solvent-solute interface, electrostatic potential, and even electron densities to be determined by the variation of a total free energy functional. Our models have been utilized to the blind prediction of the solvation free energies, calculation of protein-protein binding affinities, and the multiscale modeling of ion channel charge transport etc. (Received January 14, 2016)

1117-92-232 **Chi-Jen Wang*** (cwang463@math.gatech.edu), 686 Cherry Street, School of Mathematics, Atlanta, GA 30332, and **Hao-Min Zhou**, **Shui-Nee Chow** and **Christine E. Heitsch**. *Helix dependent variable improves the thermodynamic prediction accuracy of RNA secondary structure. (preliminary).* Preliminary report.

Dynamic programming algorithm predicts the RNA secondary structure by free energy minimization. The accuracy of prediction varies by the type of RNA. We add an additional helix dependent variable to indicate the RNA secondary structure under the situation native structure were included in the pool of possible structures by dynamic programming, which improves the accuracy of structure predictions. (Received January 15, 2016)

1117-92-234 **Joseph Rusinko*** (rusinko@hws.edu). *Combinatorics of the Kimura-3 Polytope.*

The Kimura three parameter model of evolution along a tree can be described as a toric variety. We provide a facet description for the polytope associated this toric variety for any choice of a claw tree. The combinatorial structure behind these facet descriptions provide an interesting example of how applied mathematics can motivate new and interesting pure algebraic geometry. (Received January 15, 2016)

1117-92-271 **Badal Joshi** and **Anne Shiu*** (annejls@math.tamu.edu). *Which biochemical reaction networks are multistationary?*

Many dynamical systems arising in applications (in systems biology, for instance) are multistationary, and yet the following question is open: when taken with mass-action kinetics, which reaction networks admit multiple steady states? Mathematically, this question is: among certain parametrized families of polynomial systems, which families admit multiple positive roots (for some parameter values)? No complete answer is known, although various criteria now exist—some to answer the question in the affirmative and some in the negative. In this talk, we answer these questions for the smallest networks—those with only a few chemical species or reactions. Our results highlight the role played by the Newton polytope of a network (the convex hull of the reactant vectors). Finally, our work is motivated by recent results that connect the capacity for multistationarity of a given network to that of certain related networks which are typically smaller: we are therefore interested in classifying small multistationary networks, and our results form the first step in this direction. (Received January 15, 2016)

1117-92-280 **Julie C Mitchell*** (jcmitchell@wisc.edu), 480 Lincoln Dr, Madison, WI 53706. *Data Driven Approaches to Molecular Biophysics.*

The data science revolution is transforming the field of molecular modeling. In this talk, we present several examples from our work that demonstrate the value of machine learning in predictive modeling of biomolecules. Using features derived from domain knowledge combined with supervised learning, one can achieve highly accurate models for important biophysical questions, such as the prediction of nucleic acid binding sites and the impact of amino acid substitutions on protein-protein interaction. (Received January 16, 2016)

1117-92-286 **David Murrugarra*** (murrugarra@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506. *Estimating Propensity Parameters using Google PageRank and Genetic Algorithms.*

Stochastic Boolean networks, or more generally stochastic discrete networks, are an important class of computational models for molecular interaction networks. The stochasticity stems from the updating schedule. The standard updating schedules include the synchronous update, where all the nodes are updated at the same time and gives a deterministic dynamic, and the asynchronous update, where a random node is updated at each time step that gives a stochastic dynamics. A more general stochastic setting considers propensity parameters for updating each node. SDDS is a modeling framework that considers two propensity values for updating each node, one when the update has a positive impact on the variable, that is, when the update causes the variable to increase its value, and the other when the update is negative, that is, when the update causes it to decrease its value. This extension adds a complexity in parameter estimation of the propensity parameters. This talk presents a method for estimating the propensity parameters for SDDS. The method is based on adding noise to the system using the Google PageRank approach to make the system ergodic and and then with the use of a genetic algorithm the propensity parameters are estimated. (Received January 16, 2016)

1117-92-312 **Nataša Jonoska***, Department of Mathematics and Statistics, 4202 E. Fowler Av. CMC 342, Tampa, FL 33620, and **Masahiko Saito**. *Detecting reoccurring patterns of scrambled genes.* Preliminary report.

DNA recombination occurs at both evolutionary and developmental levels, and is often studied through model organisms such as ciliate species *Oxytricha* and *Stylonychia*. These species undergo massive genome rearrangements during their development of a somatic macronucleus from a zygotic micronucleus. We use graphs and words to represent the rearrangement process and we investigate genome-wide the range of scrambled gene architectures that describe the precursor-product relationships. We find that there are two general patterns, reoccurring genome wide, that describe over 90% of the *Oxytricha's* scrambled genes. We further investigate the patterns of interleaving genes and find that there are specific star-like graph structures that describe most complex interleaving patterns. (Received January 17, 2016)

1117-92-343 **Meera Sitharam*** (sitharam@cise.ufl.edu), University of Florida, CSE bldg, P.O. box 11-6120, Gainesville, FL 32611-6120. *Geometrization, Stratification and Convexification for Atlasing Molecular Assembly Configuration Spaces.*

Abstract: We present a versatile, powerful and efficiently computable representation of the topology and geometry of molecular assembly configuration spaces under short-ranged potentials, using the standard concept of Geometrization, a classical concept of Stratification and a new concept of Convexification using Cayley or distance parameters (abbr: CayCon technique). The representation makes search and the computation of path, volumes and other measures (needed for free energy, configurational entropy, and kinetics pathways of assembly) amenable to state-of-the art developments in convex analysis, semidefinite programming, combinatorial rigidity, and algebraic topology/geometry of configuration spaces. EASAL (Efficient Analysis and Search of Assembly Landscapes) is a method that has been successfully used in predicting crucial interactions driving assembly of 3 types of viruses, and in computing path, area and volume integrals useful for kinetics of assembly of hard-sphere clusters. Detailed studies comparing its performance and resource usage with standard MC-based sampling clearly demonstrate its efficacy. We anticipate that hybrids of EASAL/CayCon with currently standard MC/MD based methods will soon become de rigeur for predictions related to assembly. (Received January 17, 2016)

1117-92-398 **Svetlana Poznanović*** (spoznan@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634. *Parametric analysis of models for RNA secondary structure prediction.* Preliminary report.

The scientific view of RNA molecules as passive transmitters of the genetic code has drastically changed during the last few decades and the known biological functions of RNA continue to grow in number and expand in scope. To perform the necessary function, the RNA nucleotide chain must fold into a specific three-dimensional functional shape. Thus, understanding the ways RNA performs its function is tightly related to knowing its structure. Since experimental determination of the structure is expensive and time consuming, the problem of predicting the structure of the RNA molecule is an important problem in computational biology.

The prevalent method for structure prediction, which minimizes free energy, is based on a model that depends on hundreds of thermodynamic parameters. Other methods are based on language theoretic approaches and depend on probability parameters derived by training grammars. We performed parametric analysis of some models in order to elucidate the dependancies of the predictions on these parameters. In this talk we will discuss our findings. (Received January 18, 2016)

1117-92-408 **Carina Curto**, **Elizabeth Gross**, **Jack Jeffries**, **Katherine Morrison**, **Mohamed Omar**, **Zvi Rosen**, **Anne Shiu** and **Nora Youngs*** (nyoungs@g.hmc.edu). *What makes a neural code convex?*

Neural codes allow the brain to represent, process, and store information about the world. Combinatorial codes, comprised of binary patterns of neural activity, encode information via the collective behavior of populations of neurons. A code is called convex if its codewords correspond to regions defined by an arrangement of convex open sets in Euclidean space. Convex codes have been observed experimentally in many brain areas, including sensory cortices and the hippocampus, where neurons exhibit convex receptive fields. What makes a neural code convex? That is, how can we tell from the intrinsic structure of a code if there exists a corresponding arrangement of convex open sets? Using tools from combinatorics and commutative algebra, we uncover a variety of signatures of convex and non-convex codes. In many cases, these features are sufficient to determine convexity, and reveal bounds on the minimal dimension of the underlying Euclidean space. (Received January 18, 2016)

1117-92-445 **Nicolette Meshkat*** (nmeshkat@scu.edu) and **Seth Sullivant**. *An algebraic approach to the structural (un-)identifiability problem in systems biology.*

The problem of parameter identifiability for a mathematical model is about finding which unknown parameters can be determined from known data. If all of the parameters can be determined, uniquely or finitely, the model is said to be identifiable. Otherwise, the model is said to be unidentifiable. Many models in systems biology are unidentifiable and thus the question that arises is what should one do with an unidentifiable model? One approach is to find identifiable functions of the parameters and attempt to reparameterize the model over these identifiable functions. We will discuss some methods to find these identifiable functions of parameters using algebraic techniques. (Received January 18, 2016)

1117-92-457 **Daniel J. Bates**, **Brent Davis**, **Elizabeth Gross*** (elizabeth.gross@sjsu.edu), **Kenneth L. Ho** and **Heather A. Harrington**. *Model selection in systems biology with numerical algebraic geometry.*

Researchers from scientific and medical disciplines are often interested in whether their hypotheses, translated into mathematical models, are compatible with available data. Model selection and hypothesis testing requires knowledge of parameter and variable values which are usually unavailable. Estimation of such parameters and hidden variables is a nonlinear optimization problem, which amounts to solving a system of polynomial equations. In this talk, we will present a systematic framework for determining if a mathematical model given by a polynomial system of first-order differential equations is compatible with limited data (i.e., unknown parameters or variables, and noisy data) using methods from numerical algebraic geometry. (Received January 19, 2016)

1117-92-467 **Scott A McKinley*** (scott.mckinley@tulane.edu) and **J Darby Smith**. *Intracellular transport: The paradox of codependence among antagonistic motors.*

Transport in neurons is intrinsically bidirectional, with each movement modality carried out by molecular motors in either the kinesin (anterograde) or the dynein (retrograde) families. Because all motors are present at a given time there must be competition and/or cooperation among motors that simultaneously bind a single vesicle to nearby microtubules. The prevailing tug-of-war model captures this dynamic, but fails to account for a recently recognized phenomenon: that in many situations, disabling one family of motors somehow inhibits the performance of motors that are working in the opposite direction. In this talk we will survey a few proposed mechanisms that may account for this behavior and will look at recent work that focuses on a potential role played by the helper protein dynactin. (Received January 19, 2016)

1117-92-506 **Christine E Heitsch*** (heitsch@math.gatech.edu). *Branching polytopes for RNA sequences.*

The branching of an RNA secondary structure is an important molecular characteristic, yet often difficult to predict correctly by optimizing under the nearest-neighbor thermodynamic model (NNTM). Prior results for a combinatorial model of RNA folding analyzed the expected degree of branching, and demonstrated that changes in the NNTM parameters can significantly affect this distribution. This insight was fully developed using methods from geometric combinatorics to give a parametric analysis of the optimal configurations, addressing the dependence of prediction results on the objective function parameters. Furthermore, it is now possible to compute a branching polytope and associated normal fan subdivision of the dual space for any RNA sequence, yielding new insights into the accuracy and robustness of RNA secondary structure prediction. (Received January 19, 2016)

1117-92-514 **Carina Curto***, ccurto@psu.edu. *Convex neural codes.*

Cracking the neural code is one of the central challenges of neuroscience. Typically, this has been understood as finding the relationship between single neurons and the stimuli they represent. More generally, neural activity must also reflect relationships between stimuli, such as proximity between locations in an environment. Convex codes, comprised of activity patterns for neurons with classical receptive fields, may be the brain's solution to this problem. These codes have been observed in many areas, including sensory cortices and the hippocampus. What makes a code convex? Using algebra, we can uncover intrinsic signatures of convexity and dimension in neural codes. I will report on some recent results by multiple authors, including participants in a 2014 AMS Math Research Community. (Received January 19, 2016)

1117-92-548 **Caner Kazanci*** (caner@uga.edu), Department of Mathematics, 200 D W Brook dr., Athens, GA 30602. *Decomposing networks representing living systems without breaking connections.*

Living systems are often represented by networks, with links representing relations (e.g. biochemical reactions, regulation, feeding) among entities (e.g. molecules, genes, tissues, organisms, species). Such networks can be

fairly large and complex. Decomposing a system into smaller sub-networks for detailed analysis is often tempting. However, essential system-wide behavior may be lost by breaking connections, or excluding nodes.

Motivated by flux based analysis and metabolic control analysis, we propose an alternative building block for such networks: a minimal set of sub-networks that can theoretically sustain themselves. Since connections are not totally lost during such decomposition, complex system-wide properties may still be analyzed with little to no information loss. Furthermore, any result obtained using such decomposition will hold regardless of size or complexity of the model.

In this talk, we define the minimal set of sub-networks for a given network model, and discuss how system-wide properties of an entire system can be studied using only these sub-networks, and demonstrate this on a specific model using a Beta version of an online modeling, simulation and analysis software we developed. (Received January 20, 2016)

93 ► Systems theory; control

1117-93-25 **Thaleia Zariphopoulou*** (zariphop@math.utexas.edu), 2515 Speedway, Dpt. of Mathematics, The University of Texas at Austin, Austin, TX 78759. *Long-term behavior of optimal investments under forward performance criteria.*

The long-term behavior of optimal portfolios is examined under time-monotone forward performance criteria. It is shown that in contrast to the classical (backward) paradigm, the spatial and temporal limits of the local risk tolerance function do not coincide. Examples and asymptotic expansions will be discussed for a family of forward processes, and their optimal wealth and portfolio processes. (Received December 08, 2015)

1117-93-123 **Jiongmin Yong*** (jiongmin.yong@ucf.edu), 4000 Central Florida Blvd, Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Time-Inconsistent Optimal Control Problems.*

In classical situations, Bellman's principle of optimality implies that an optimal control chosen at a time moment will stay optimal afterwards. This is called the time-consistency of the problem. However, in reality, more than often, this seems not to be the case. This is called the time-inconsistency of the problems under consideration. This talk will present some results in finding time-consistent equilibrium strategies for time-inconsistent problems. (Received January 08, 2016)

97 ► Mathematics education

1117-97-26 **Caleb L Adams*** (cadams5@radford.edu), Department of Mathematics and Statistics, Radford, VA 24142. *Learning by Teaching: An Instructor's View of Active Learning Mathematics in a Flipped Calculus 1 Course.* Preliminary report.

Active learning is an instructional method which engages the student in the learning process, often involving activities within a class session that not only requires students to complete the activities, but also reflect on what they have done. This student-centered approach allows for more active learning within the classroom and allows the instructor to provide feedback in real-time manner to promote the students' conceptual understanding of material. With this process open to both individual understanding as well as peer-mediated learning, a variety of cognitive levels of learning can be reached. This manner of instruction and learning has been analyzed and found to be a very effective method within the STEM fields. The project presented is the second year of a multiyear study on examining how the implementation of the flipped classroom approach in Calculus influenced students' math achievement and attitudes about math and learning. Additionally presented is a personal review of the process, including changes made from the first year to the second which has led to a higher impact on student learning. (Received December 10, 2015)

1117-97-28 **Kadian M Callahan*** (kmcallahan@kennesaw.edu), Department of Mathematics, Clendenin Building Rm 3035 (MD1102), 275 Kennesaw State University Rd NW, Kennesaw, GA 30144. *Prospective Teachers' Generalizing Actions as They Reason about Algebraic and Geometric Representations in an Undergraduate Mathematics Content Course.*

The abilities to reason about and generalize mathematical relationships and make sense of different representations are important facets of knowledge for proficiency in teaching middle school mathematics (e.g., Allen, et. al., 2008; Izsak & Sherin, 2003; Morris, 2007; National Research Council, 2001). Teacher preparation programs

provide an avenue to develop these skills by engaging prospective middle school teachers (PMSTs) in reasoning, generalizing, and representational experiences as they study mathematics content (CBMS, 2001, 2012). This study examined the actions of one group of PMSTs as they reasoned about algebraic generalizations and geometric representations of even and odd numbers in an undergraduate mathematics content course. Results indicated that "Relating" and "Encouraging Generalizing: Encouraging Relating" (Ellis, 2007) were central in PMSTs' collective reasoning about the different representations. Three of the remaining five generalizing-promoting action categories – "Publicly Sharing a Generalization or Idea"; "Encouraging Justification or Clarification"; and "Focusing Attention on Mathematical Relationships" (Ellis, 2007) – were frequently used as PMSTs made sense of how the algebraic generalizations and geometric representations were related. (Received January 06, 2016)

1117-97-29 **Greg Mayer*** (greg.mayer@gatech.edu), Skiles Building, Room 116, School of Mathematics, Georgia Institute of Technology, Atlanta, GA 30332. *Developing Community and Collaboration through Active Learning in Synchronous Online Linear Algebra and Multivariable Calculus Courses.*

This presentation will offer a brief overview of three recent studies, conducted between 2012 to 2015, that characterized the learning environment afforded by the use of web conferencing software in synchronous online recitation sessions for linear algebra and multivariable calculus courses. Participants in these studies were geographically isolated and advanced high school students enrolled in Georgia Tech's Distance Calculus Program. One of the primary goals of incorporating web conferencing software into these courses was to foster online community among students through active learning. Research findings from these studies were based on results from a qualitative content analysis of student discussions held during recitations, interview and focus group data, validated survey instrument data, and final grade data. Study findings characterize the development of online community among students, and how they engaged in these sessions using different technologies and different learning activities, including collaborative group work. Findings include evidence that students were able to develop online community, and that, relative to whole group discussions, small group work activities resulted in an increase in student engagement in academic and task-oriented discussion. (Received December 17, 2015)

1117-97-78 **Belinda P. Edwards*** (bedwards@kennesaw.edu), Kennesaw State University, 236 Mathematics/Statistics Bldg, Kennesaw, GA 30152. *Implementing Student-Centered Teaching Strategies in STEM Gateway Courses: Examples, Challenges and Successes.* Preliminary report.

There is an increasing body of evidence supporting the effectiveness of student-centered teaching approaches in developing deep learning and understanding (Bransford, Brown, & Cocking, 2000; Weimar, 2013). Student-centered teaching can be implemented in many mathematics courses using a variety of methods, some of which are more effective than others. Many faculty face notable challenges when implementing reformed teaching approaches in their courses. There are numerous benefits to implementing student centered strategies; however, the benefits are not always immediate or automatic. The challenges or problems associated with implementing student-centered teaching are solvable. The support of a Faculty Learning Community (FLC) can provide a venue for expanding the student-centered teaching strategies of faculty members with a range of comfort levels, drawing from the pedagogical experiences of faculty from diverse disciplines. The benefit of a FLC as an enabler of lasting change in mathematics courses is well documented (Cox, 2001; 2003; 2004). In this session, student-centered strategies that have been implemented in mathematics courses will be shared, along with the challenges and successes associated with implementation, as well as applications to your own practice. (Received January 03, 2016)

1117-97-105 **Andrew D. Jones*** (andrew.d.jones@yale.edu) and **Richard Cohn**. ***Geometry, consonance, and the non-specialist:*** Pedagogical interdisciplinarity and math/music undergraduates.

Undergraduate mathematics and music theory both challenge students to formalize their intuitions using terms and concepts foreign to them. This paper describes the authors' attempts to produce an interdisciplinary pedagogy which works back and forth across this intuitive boundary, leveraging musical intuitions to exemplify formal mathematics and employing mathematical concepts, both formal and intuitive, to describe and define complex music theoretical relationships.

Offered in 2013 to 35 Yale undergraduates, the course based on this pedagogy pairs introductory concepts from modular arithmetic, graph theory, geometry, and topology with music theoretical analogues. Musical scales and octave equivalence render intuitive modular arithmetic, the mathematical formalization of which extends students' cyclic intuitions to the rhythmic domain. Treating chords as harmonic objects embedded in graphs and geometric spaces motivates investigating relations and metrics; terms and images from graph theory and

geometry allow students to formalize new insights into extended harmonies and progressions. A textbook-in-progress contains these and other materials designed to give students a cross-domain vocabulary for describing patterns of relationships between musical and mathematical objects. (Received January 06, 2016)

1117-97-142 **Rebecca L Rizzo, Ph.D.***, Georgia State University, Dept. of Mathematics and Statistics, P.O. Box 4110, Atlanta, GA 30303. *BioCalculus – A Flipped Classroom that is Reflective.*

APOS theory emphasizes that learning through reflection is the key to strengthening critical thinking skills and achieving a higher order of thinking. This presentation examines the reflection strategies used in the GSU BioCalculus course sequence to gain increased student engagement, conceptual knowledge and hence overall success rates in the course. Using a combination of lecture, grading, and pedagogical shifts, it has become possible to create a flipped classroom that is reflective for students while measuring the students' analysis skills and ability to apply their learning to their lives. (Received January 10, 2016)

1117-97-151 **Jennifer Kindle*** (jlovell@flpoly.org) and **Thanos Gentimis** (agentimis@flpoly.org). *Florida Poly Primers: Calculus.* Preliminary report.

At Florida Polytechnic University, a STEM University founded in 2014, Calculus I is the first math course required by students in every major. Unfortunately, many students are unprepared due to lack of necessary prerequisites or a time gap in their schooling. In order to ensure students received the support necessary for the rigorous work of Calculus I, an online Primer course was developed. The course, which is housed in the online platform CANVAS, targets specific topics and skills necessary for students to achieve success in Calculus I. In this paper, we present the effect of the primer on the retention rate and pass rate for Calculus I. (Received January 11, 2016)

1117-97-152 **Langley M Payton*** (lpayton3512@flpoly.org) and **Thanos Gentimis** (agentimis@flpoly.org). *Improving Pedagogy with Modules in Calculus I.* Preliminary report.

As a STEM University, it is important for Florida Polytechnic to ensure student success in basic undergraduate math courses, particularly in Calculus I. We assessed the effectiveness of two types of Calculus I courses: (1) a "traditional" course and (2) a modified hybrid-online curriculum with modules. This analysis looks at the techniques involved in teaching this modified class and further discusses its benefits for students. Student data has been collected and analyzed over a period of a few semesters. Student pre-calculus experience, withdrawal rates, final Calculus grades, among other variables, are assessed in comparison with those from traditional Calculus classes. Results will be provided to the university to help better prepare the students for higher level math courses. (Received January 11, 2016)

1117-97-223 **Iman C Chahine*** (ichahine@gsu.edu), 30 Pryor Street, Atlanta, GA 30303. *Teaching modeling in Algebra and Geometry using Musical Rhythms: Teachers' Perceptions on Effectiveness.*

The study was conducted within a summer institute program that trained 15 mathematics teachers from two high need school districts in facilitating students' understanding of mathematical modeling using musical rhythms. Qualitative and quantitative data was collected and triangulated using different sources. This study showed that when teachers are engaged in inter-disciplinary experiences situating mathematics in the context of music, they were confident that such experiences can be effective in stimulating student learning. Furthermore, the study argues that introducing teachers to creative ways of linking mathematical ideas with musical rhythms will not only impact their teaching outcome expectancy but will also strengthen their self-efficacy to teach mathematics in less traditional ways. (Received January 14, 2016)

1117-97-306 **Natalie L.F. Hobson*** (nhobson@uga.edu), **Kevin C. Moore**, **Irma E. Stevens**, **Biyao Liang** and **Kathryn D. Mauldin**. *Providing Students Experiences to Model Novel Situations.* Preliminary report.

Numerous researchers and policy makers have argued the importance of providing students opportunities to model dynamic situations via quantitative and covariational reasoning. Quantitative reasoning—conceiving a situation constituted by measurable attributes—and covariational reasoning—the conception of how two quantities change in tandem—are essential to problem solving topics in undergraduate mathematics. Through our research on student thinking, we have developed a series of technology-supported tasks designed to engender students' quantitative and covariational reasoning as they experience a dynamic situations. In this presentation we reveal some of these tasks, the accompanying instructional goals of the tasks, and illustrations of student

thinking on the tasks. Our study continues to lead to new insights into students' reasoning and ways of thinking about quantities, covariation, and representations, and we share some of these emerging findings. (Received January 16, 2016)

1117-97-318 **Richard Cohn*** (richard.cohn@yale.edu), 63 Ogden St, New Haven, CT 06511. *The Pedagogy of Beat-Class Theory Modulo Small.*

Many of the difficulties of learning atonal pitch-class theory are attributable to the large size of the 12-tone cyclic universe. This paper sketches a pedagogical program that begins with the smallest cycles and leads incrementally upward toward twelve. The power set of small universes is easily mastered, allowing focus on properties of individual sets, and relations among them. Those properties are inherited by larger universes, each of which supplies new and curious possibilities that in turn are inherited by the 12-tone universe. Musicians come pre-loaded with ready intuitions about these smaller universes, in the form of knowledge about metered rhythm, easily translatable in terms of cycles of 3, 4, 6,, and 8 beats, and of quasi-even pentatonic and diatonic scales. This presentation pays special attention to the structure of modulo 6 beat-class space, which is small enough to lexically control, but large enough to host aesthetic and structural variety. (Received January 17, 2016)

1117-97-354 **Kimbeni H Mansion*** (kmansion1@student.gsu.edu), Lawrenceville, GA 30045. *The Inclusion of Culture in the Mathematics Classroom by Implementing Ethnomathematics.* Preliminary report.

This presentation examines how ethnomathematics, cultural mathematics, provides students in the mathematics classroom opportunities to explore the human aspect, including the creation and discovery of mathematics, from different perspectives around the world. This presentation will also discuss how educators can employ a variety of cultural inputs, such as those used to identify individuals, families, communities, and schools to engage students in mathematics classrooms through the teaching of ethnomathematics. Ethnomathematics acknowledges the connection between mathematics and culture and, as a result, shares with others the many applications of mathematics. By observing and appreciating cultural practices of others and oneself, students are able to self-identify with the study at hand and position mathematics in academic relevance. Recognizing and appreciating the diversity of students' cultures validates the mathematical practices students often wonder about. (Received January 17, 2016)

1117-97-423 **Darryl Jim Chamberlain*** (dchamberlain2@student.gsu.edu), **Aubrey Kemp**, **Leslie Meadows**, **Harrison Stalvey**, **Draga Vidakovic** and **Annie Burns**. *The Emporium Model for Elementary Statistics: A Preliminary Report.* Preliminary report.

The Emporium Model pedagogy is designed to actively engage students in the process of learning and teaching by utilizing interactive computer software for a personalized experience. While the Emporium Model originated from Virginia Tech, numerous universities have implemented this pedagogy with varying degrees of success. This presentation will describe how Georgia State University has adapted this model/pedagogy in three courses: College Algebra, Precalculus, and Elementary Statistics. Additionally, we will present Elementary Statistics students' perceptions of this model and describe how students are actively engaged within this model. (Received January 18, 2016)

1117-97-541 **Kemal Akoglu*** (kakoglu@ncsu.edu), 3147 B Kings Ct, Raleigh, NC 27606. *A Framework about Using Digital Simulation Tools and Task Development to Overcome the Cognitive Issues about Learning of Conditional Probability.*

Using research-based suggestions and previous frameworks, a new framework about creating conditional probability tasks via simulation tools has been constructed for others to use. Two tasks are presented as examples in which task content and problems are aligned with the framework.

Because of its uncertain nature there have been serious cognitive issues in teaching and learning of probability. Conditional probability is specifically difficult for students to learn and it is also difficult for teachers to teach. Research showed that cognitive issues are often increased by age and education (Fischbein & Schnarch, 1997). With the help of simulation tools, students can participate in the process of building probability models and collecting data generated from those models, creating opportunities to improve teaching and learning of conditional probability.

The framework for creating worthwhile conditional probability tasks, two simulation tasks in which task content and problems embody aspects of the framework, and reflection on research issues will be presented in the poster. (Received January 19, 2016)

00 ► General

1118-00-109 **Iancu Dima** and **Rachel Popp*** (rachel.popp@gmail.com), 216 East 111th Street Apt. 4F, New York, NY 10029, and **Robert Strichartz**. *A convex surface with fractal curvature.* Preliminary report.

A convex surface in space has a well-defined curvature which is a measure. Can the measure be a fractal one? Yes! We construct a surface that is obtained from the octahedron by pushing out 4 of the faces so that the curvature is supported in a copy of the Sierpinski gasket in each of them, and is essentially the self similar measure on SG. We then compute the bottom of the spectrum of the associated Laplacian using the finite element method on polyhedral approximations of our surface, and speculate on the behavior of the entire spectrum. (Received January 26, 2016)

1118-00-112 **Elif Tan*** (etan@ankara.edu.tr), Ankara University, Department of Mathematics, Tandogan, 06100 Ankara, Turkey. *Bi-periodic Fibonacci quaternions.*

In this talk, we present a new generalization of the Fibonacci quaternions $\{Q_n\}$ as:

$$Q_n = \sum_{l=0}^{3} q_{n+l} e_l$$

where q_n is the n-th bi-periodic Fibonacci number and defined by

$$q_n = \begin{cases} aq_{n-1} + q_{n-2}, & \text{if } n \text{ is even} \\ bq_{n-1} + q_{n-2}, & \text{if } n \text{ is odd} \end{cases}, \ n \geq 2$$

with initial values $q_0 = 0$, $q_1 = 1$ and a, b are nonzero numbers. They are emerged as a generalization of the best known quaternions in the literature, such as classical Fibonacci quaternions, Pell quaternions, k-Fibonacci quaternions. We give the generating function and the Binet formula for these quaternions. By using Binet formula, we obtain some well-known results. (Received January 26, 2016)

1118-00-186 **Christopher Robert Bennett*** (bennettc5@mail.sacredheart.edu), 23 Jones Road, Wallingford, CT 06492. *An efficient algorithm for a variation of the Gold Grabbing Game.* Preliminary report.

In order to provide a winning strategy form the Gold Grabbing Game as posed by Moshe Rosenfeld, we developed an algorithm for player one to provide him/her with a total score that is greater than or equal to player two's score once the algorithm terminates given a tree of even order. As inspired by existing work, we apply concepts from graph theory in order to develop the algorithm which we show is efficient and prove its validity. (Received January 31, 2016)

1118-00-259 **Nathan P Vander Werf*** (nvanderw@nd.edu), 1225 Bissell st., South Bend, IN 46617. *Special pairs of screening operators and certain subalgebras of a rank d lattice vertex operator algebra.*

We discuss the notion of special pairs of screening operators for a rank d lattice vertex operator superalgebra. Such screening pairs $(\tilde{Q}, Q)$ in the rank 1 case proved to be useful machinery in studying the internal structure of the $\mathcal{W}$-algebra $\mathcal{W}(p) = \ker \tilde{Q}$ and proving the C_2-cofinite property. From an analysis of screening pairs that can arise, one can construct a large number of subalgebras of V_L by considering the intersection of the kernels of certain screening operators that share a common Virasoro element. Some subalgebras that emerge share features similar to the $\mathcal{W}(p)$-algebra in the rank 1 setting while others do not as much. If time permits, we will show in the rank 2 setting how the kernel of a long screening operator $\ker \tilde{Q}$ (and in some cases the intersection of the kernels of two screening operators) can be computed. With such decompositions, the problem of studying the internal structure of $\ker \tilde{Q}$, such as finding a strongly generating set for $\ker \tilde{Q}$ and proving the C_2-cofinite property, as well as determining the representation theory, all become tractable. (Received February 02, 2016)

05 ► Combinatorics

1118-05-61 **Emanuele Delucchi*** (emanuele.delucchi@unifr.ch), Département de mathématiques, Université de Fribourg, Chemin du musée 23, 1700 Fribourg, FR, Switzerland. *Toric arrangements and group actions on semimatroids.*

Recent work of De Concini, Procesi and Vergne on vector partition functions gave a fresh impulse to the study of toric arrangements from an algebraic, topological and combinatorial point of view. In this context, many new combinatorial structures have recently appeared in the literature, each tailored to one of the different facets of the subject.

As a unifying framework, in this talk I will propose the study of "group actions on semimatroids" and of their polynomial invariants, recently introduced in joint work with Sonja Riedel. (Received January 19, 2016)

1118-05-70 **Joseph Kung*** (kung@unt.edu), 4563 Coyote Point, Denton, TX 762208-323. *The $\mathcal{G}$-invariant and catenary data of a matroid.*

The $\mathcal{G}$-invariant is a universal valuative invariant on decompositions of matroid base polytopes (Derksen and Fink); in particular, the Tutte polynomial is one of its specializations. The catenary data of a matroid is a vector containing numerical information about flags of flats of the matroid. The caternary data and the $\mathcal{G}$-invariant are "cryptomorphic", in the sense that they contain the same information about the matroid. We will talk about the catenary data. (Received January 20, 2016)

1118-05-71 **Aori Nevo*** (aorinevo@gmail.com), **Douglas Bauer** and **Edward Schmeichel**. *Best Monotone Theorem for 1-binding implies 1-factor.*

Let G be a graph with vertex set V. The *neighborhood* $N(S)$ *of* $S \subseteq V$ is the set of vertices adjacent to some vertex of S. The *binding number* of a graph G, denoted $\mathrm{bind}(G)$, is the minimum of the ratio $|N(S)|/|S|$, taken over all non-empty $S \subseteq V$ such that $N(S) \neq V$. A *k-factor* of a graph is a spanning k-regular subgraph. In particular, a 1-factor is a perfect matching. We give a vertex degree condition to guarantee that a 1-binding graph contains a 1-factor, which is best in the same sense as Chvátal's well-known hamiltonian degree condition. (Received January 20, 2016)

1118-05-83 **Louis Petingi*** (louis.petingi@cai.cuny.edu), 2800 Victory Blvd. 1N, Staten Island, NY 10314. *Diameter-constrained network reliability, a generalization of the classical reliability.* Preliminary report.

Consider a probabilistic graph $G = (V, E)$, where edges fail independently with known probabilities (vertices are perfectly reliable), and given a set of terminal nodes $K \subseteq V$, the classical reliability, $R_K(G)$, introduced in the 1960s, is the probability that for each pair of terminal nodes $a, b \in K$, there exists an operational path connecting a and b.

In 2001, the Diameter-constrained reliability (**DCR**), $R_K(G, D)$, was introduced to measure the probability that each pair of terminal nodes is connected by a path of length D or less, given some diameter bound D. As the maximum length of any path in a network is of at most $n-1$ edges (n is the number of nodes), then $R_K(G, n-1) = R_K(G)$, thus the DCR represents a generalization of the classical reliability. This new reliability model measures performing objectives of a network in which short-enough paths connecting the terminal nodes would guarantee the network's functionality.

In this talk we present a survey of combinatorial and computational-complexity results shown for the DCR, in relationship to well-known properties established for the classical reliability, as well as open problems. (Received January 23, 2016)

1118-05-97 **M Jaradat*** (mmjst4@qu.edu.qa), Department of mathematics, Statistics and phy, Doha, Qatar. *On the basis number and the minimum cycle bases of the Lexicographic product of graphs.*

For a graph G, let $e_1, e_2, \ldots, e_{|E(G)|}$ be an ordering of its edges. Then a subset S of $E(G)$ corresponds to a $(0,1)$-vector $(b_1, b_2, \ldots, b_{|E(G)|})$ in the usual way with $b_i = 1$ if $e_i \in S$, and $b_i = 0$ if $e_i \notin S$. These vectors form an $|E(G)|$-dimensional vector space, denoted by $(Z_2)^{|E(G)|}$, over the field of integers modulo 2. The vectors in $(Z_2)^{|E(G)|}$ which correspond to the cycles in G generate a subspace called the cycle space of G denoted by $\mathcal{C}(G)$. The *basis number*, $b(G)$, of G is the least non-negative integer d such that each edge of G appears in at most d edges of the basis. A basis $\mathcal{B}$ is called *a minimum cycle basis* if its total length is minimum among all bases of $\mathcal{C}(G)$. The Lexicographic product $G[H]$ of two graphs G and H is the graph with vertex set is$V(G) \times V(H)$ and the edge set is $\{(u_1, v_1)(u_2, v_2) | u_1u_2 \in E(G)$ or $u_1 = u_2$ and $v_1v_2 \in E(H)\}$. In this work, we give an

upper bound of the basis number and construct a minimum cycle bases of the lexicographic product of graphs. Further, we give examples to show that the upper bound is optimal. (Received January 26, 2016)

1118-05-143 **Pauline Bailet*** (pauline.bailet@uni-bremen.de), Department Mathematics and Computer Science, University of Bremen, 28359 Bremen, Germany, and **Masahiko Yoshinaga** (yoshinaga@math.sci.hokudai.ac.jp), Department of Mathematics, Hokkaido University, Sapporo, 060-0810, Japan. *Vanishing results for the Aomoto complex of real hyperplane arrangements via minimality.* Preliminary report.

Reference: P. Bailet, M. Yoshinaga: Vanishing results for the Aomoto complex of real hyperplane arrangements via minimality; arXiv:1512.05318

Let $\mathcal{A} = \{H_1, \dots, H_n\} \subset \mathbb{R}^l$ be an essential arrangement of affine hyperplanes, and $M(\mathcal{A}) = \mathbb{C}^l \setminus \bigcup_{H\in\mathcal{A}} H_{\mathbb{C}}$ be the complement of the complexified arrangement. Let $A^\bullet_R(\mathcal{A})$ be the Orlik-Solomon algebra of $\mathcal{A}$, with generators $e_i, 1 \le i \le n$, and coefficients in a commutative unitary ring R. Consider the Aomoto complex $(A^\bullet_R(\mathcal{A}), \omega\wedge)$ induced by $\omega = \sum_{i=1}^n \lambda_i e_i$. Aomoto complexes have a purely combinatorial description and several conditions for the vanishing of their cohomology are already known.
We give a vanishing result of the cohomology of the Aomoto complex in terms of nonresonant condition along the hyperplane at infinity of the coning of $\mathcal{A}$. The proof is using minimality of arrangements and descriptions of Aomoto complex in terms of chambers. Our methods also provide a new proof for the well known vanishing theorem of local system cohomology groups of $M(\mathcal{A})$ which was first proved by Cohen, Dimca and Orlik.
(Received January 29, 2016)

1118-05-162 **Masahiko Yoshinaga*** (yoshinaga@math.sci.hokudai.ac.jp), Department of Mathematics, Hokkaido University, North 10, West 8, Kita-ku, Sapporo, 060-0810. *Linial arrangements and Eulerian polynomials.*

For an irreducible root system Φ, the n-th Linial arrangement $\mathcal{A}_\Phi^{[1,n]}$ is the set of hyperplanes defined by $\alpha = k$, where $\alpha \in \Phi^+$ and $k = 1, \dots, n$.

We will discuss the relation between the characteristic polynomial $\chi(\mathcal{A}_\Phi^{[1,n]}, t)$ of the Linial arrangement and the Eulerian polynomial. More precisely, the main result asserts that the characteristic polynomial can be expressed by using the Eulerian polynomial.

We also discuss applications of the above formula. We conclude that for exceptional root systems $\Phi = E_6, E_7, E_8, F_4$ and for sufficiently large $n \gg 0$, all the root of the characteristic polynomial have the same real part, which gives a partial affirmative answer to a conjecture by Postnikov and Stanley.

For type A_ℓ root system, Postnikov, Stanley and Athanasiadis have already obtained an explicit formula for the characteristic polynomial. Comparison with the new formula leads to a non trivial polynomial congruence satisfied by the Eulerian polynomial. We finally remark that the congruence played an important role in Euler's (non justified) computation of special values of Riemann zeta function. (Received January 30, 2016)

1118-05-165 **Kerry Ojakian*** (kerryojakian@gmail.com), 422 43rd Street, Brooklyn, NY 11232. *Extremal cop-win graphs.*

The game of cops and robber is a two player game, played on a graph, between a cop and a robber. First the cop chooses a vertex, then the robber chooses a vertex; then play alternates. On a turn, a player may move to an adjacent vertex or remain still. A graph is cop-win if the cop can guarantee a win. The capture time of a cop-win graph is the number of cop moves required to win. Let capt(n) be the capture time of a cop-win graph on n vertices with maximum capture time. Gavenciak showed that capt(n) = $n-4$, for $n \ge 7$, and characterized these extremal graphs. We introduce new tools that allow us to reprove this result and prove other related results. Our tools involve a particular ranking of the vertices of the graph and an examination of what kinds of rankings are possible. This is joint work with David Offner. (Received January 30, 2016)

1118-05-171 **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 $S = \{s_1, s_2, \dots, s_q\} \subseteq [\alpha]$ 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 January 30, 2016)

1118-05-174 **June Huh*** (huh@princeton.edu), Princeton, NJ 08540. *Matroids in permutohedrons in flag varieties.*

I will talk about the three objects and the two inclusions mentioned in the title; possible generalizations will be speculated. (Received January 31, 2016)

1118-05-189 **Eva-Maria Feichtner*** (emf@math.uni-bremen.de), Department of Mathematics & Computer Science, University of Bremen, 28359 Bremen, Germany. *Bergman fans - a link between arrangement theory and tropical geometry.* Preliminary report.

Tropicalizations of arrangement complements turn out to be rational polyhedral fans whose link at the origin is homeomorphic to the order complex of the respective intersection lattice. On the level of matroids, the so-called Bergman fans are discrete-geometric constructions that allow to recover the matroid. Proving the latter requires an intriguing mix of discrete-geometric and tropical techniques.

Part of this material is joint work with Michael Falk. (Received January 31, 2016)

1118-05-191 **Michael R Yatauro*** (mry3@psu.edu), Media, PA 19063, and **Monika Heinig**. *Uniform optimality results for trees in the Neighbor Component Order Edge Connectivity Network Model.*

Let G be a finite simple graph. Consider a model in which edges of G fail independently, and when an edge fails we remove it from G along with the incident vertices. We say that a set of edges F is a *failure set* of G if after all edges of F fail, the components of the induced subgraph all contain at most $k-1$ vertices, for some prescribed $k \geq 1$. If an edge fails with probability ρ, then the *unreliability* of G, denoted $\mathcal{U}_k(G, \rho)$, is the probability that a randomly selected set of edges is a failure set. Given a class of graphs $\mathcal{G}$, we say $H \in \mathcal{G}$ is *uniformly most reliable* (resp. *uniformly least reliable*) in $\mathcal{G}$ if $\mathcal{U}_k(H, \rho) \leq \mathcal{U}_k(G, \rho)$ (resp. $\mathcal{U}_k(H, \rho) \geq \mathcal{U}_k(G, \rho)$) for all $G \in \mathcal{G}$ and every value of ρ, with $0 < \rho < 1$. In this talk, we prove the existence of unique uniformly most reliable and uniformly least reliable graphs in the class of trees when $k = 1$. (Received January 31, 2016)

1118-05-212 **Jonathan Cutler** and **Nathan Kahl***, (nathan.kahl@shu.edu). *On the values of independence polynomials at -1.*

The independence polynomial $I(G; x)$ of a graph G is $I(G; x) = \sum_{k=0}^{\alpha(G)} s_k x^k$, where s_k is the number of independent sets in G of size k. The decycling number of a graph G, denoted $\phi(G)$, is the minimum size of a set $S \subseteq V(G)$ such that $G - S$ is acyclic. Engström proved that the independence polynomial satisfies $|I(G; -1)| \leq 2^{\phi(G)}$ for any graph G, and this bound is best possible. Levit and Mandrescu provided an elementary proof of the bound, and in addition conjectured that for every positive integer k and integer q with $|q| \leq 2^k$ there is a connected graph G with $\phi(G) = k$ and $I(G; -1) = q$. In this talk, we sketch our proof of this conjecture. (Received February 01, 2016)

1118-05-216 **Charles L Suffel*** (csuffel@stevens.edu), Stevens Institute of Technology, Castle Point on the Hudson(EAS Bldg), Hoboken, NJ 07030, and **Monika Heinig**, **Daniel Gross**, **John Saccoman** and **Michael Yaturo**. *On a relianility model associated with the edge domination number for trees.*

Consider a graph whose nodes do not fail but edges do, independently and all with the same probability. However, when an edge fails it's endnodes are subverted , i.e. they are removed from the graph. Given a positive threshold value k , the surviving subgraph obtained upon removal of the endnodes of the failing edges is a failure state if each of it's components has order at most k-1. When k=2 the minimum size of a failed set of edges required to obtain a failure state is the edge domination number of the graph. When k=2 ,we determine those trees that are most reliable for all values of the edge failure probility and those that least reliable for all values of the edge failure probability. (Received February 01, 2016)

1118-05-235 **John T Saccoman*** (saccomjt@shu.edu), Seton Hall University, Department of Mathematics & Computer Science, South Orange, NJ 07079. *A Survey of Laplacian Integral Graphs and Multigraphs.*

The number of spanning trees in a graph or multigraph is an important measure of vulnerability to disconnection by edge failure. The eigenvalues of the Laplacian matrix associated with the graph or multigraph are used to

compute the number of spanning trees. We say that a graph is a split graph if its node set can be partitioned into a clique and an independent set. A split graph G is a threshold graph if, for all pairs of nodes u and v in G, $N(u) - \{v\} \subseteq N(v) - \{u\}$ whenever $deg(u) \leq deg(v)$. We present some infinite families of graphs and multigraphs of these types, or nearly of these types, whose Laplacian eigenvalues are all integers. (Received February 01, 2016)

1118-05-236 **Monika M. Heinig*** (mheinig@stevens.edu), **Daniel Gross**, **John T. Saccoman** and **Charles Suffel**. *A polynomial time algorithm for computing neighbor component order edge connectivity of arbitrary unicycles.*

If a spy network is modeled as an undirected graph in which the nodes represent spies and the edges are the communication links between spies, then consider the scenario where the interception of a link compromises the identity of both endnode spies. In graph-theoretic terms, edges can fail but nodes cannot. When an edge fails, its endnodes are subverted, i.e., removed from the graph. Given a threshold value $k \geq 1$, the surviving subgraph produced by the failure of edges and the subversion of their endnodes is said to be in a failure state if all of its components have order $\leq k-1$. The minimum number of edge failures to yield a failure state is called the neighbor component order edge connectivity and is denoted $\lambda_{nc}^{(k)}$. It is the case that $\lambda_{nc}^{(1)}$ is the size of a minimum edge cover of the nodes and $\lambda_{nc}^{(2)}$ is the edge domination number. Thus, the complexity is polynomial for $k = 1$ but becomes NP hard when k is increased to 2. We present a polynomial time algorithm for determining the neighbor component order edge connectivity of arbitrary unicycles, which utilizes polynomial time algorithms for arbitrary trees, weighted paths, and weighted cycles. (Received February 01, 2016)

1118-05-252 **Christin Bibby**, Department of Mathematics, London, Ontario N6A5B7, Canada, **Graham C Denham*** (gdenham@uwo.ca), Department of Mathematics, London, Ontario N6A5B7, Canada, and **Eva Maria Feichtner**, Dept. of Mathematics and Computer Science, 28359 Bremen, Germany. *Combinatorics and rational models.* Preliminary report.

Although hyperplane arrangement complements are rationally formal, we note that they have non-minimal rational (CDGA) models which are topologically and combinatorially significant, in light of recent ideas of Bibby and Dupont, as well as foundational results of De Concini and Procesi. As an application, we revisit and extend the formulas of Manin, Yuzvinsky, Callegaro and Gaiffi for the Betti numbers of certain families of wonderful compactifications. (Received February 02, 2016)

06 ► Order, lattices, ordered algebraic structures

1118-06-160 **Yuri Movsisyan*** (yurimovsisyan@yahoo.com), Alex Manoogian 1, 0025 Yerevan, Armenia. *Free distributive bilattices.*

It is commonly known that the free Boolean algebra on n free generators is isomorphic to the Boolean algebra of Boolean functions of n variables. The free bounded distributive lattice on n free generators is isomorphic to the bounded distributive lattice of monotone Boolean functions of n variables. In this talk we characterize finitely generated free distributive bilattices via functional representation. (Received January 30, 2016)

11 ► Number theory

1118-11-110 **Dmitry Kleinbock** and **Nick Wadleigh***, wadleigh@brandeis.edu. *Inhomogeneous Dirichlet's Theorem and shrinking targets.*

Dirichlet's theorem states that for a real $m \times n$ matrix,

$$\|Aq + p\|^m < \frac{1}{t}, \|q\|^n \leq t$$

has nontrivial integer solutions for all $t \geq 1$. Davenport and Schmidt have observed that if $\frac{1}{t}$ is replaced with $\frac{c}{t}, c < 1$, almost no A has the property that there exist solutions for sufficiently large t. Replacing $\frac{c}{t}$ with an arbitrary function, it's natural to ask when precisely does the set of such A drop to a null set. We do not answer this question, but the analogous inhomogeneous question seems to be amenable to the tools of dynamics on the space of affine lattices. Namely, we give a necessary and sufficient condition on a function ψ such that for almost all pairs (A, b) where A is an $m \times n$ matrix and b an m-tuple, the system

$$\|Aq + b + p\|^m < \psi(t), \|q\|^n \leq t$$

has integer solutions for all large enough t. (Received January 26, 2016)

1118-11-114 **Byungchul Cha*** (cha@muhlenberg.edu), **Emily Nguyen** (en247768@muhlenberg.edu) and **Brandon Tauber** (bt247069@muhlenberg.edu). *A tree of Pythagorean triples and its generalization.* Preliminary report.

It is known that all primitive Pythagorean triples (x, y, z), that is, all positive integer triples (x, y, z) without common factor satisfying $x^2 + y^2 - z^2 = 0$, can be given a certain tree-like structure. More precisely, if (x, y, z) is such a triple with y even, then there exists a unique sequence $\{k_1, \ldots, k_l\}$ with $k_j \in \{1, 2, 3\}$ such that $(x, y, z)^T = M_{k_1} \cdots M_{k_l}(3, 4, 5)^T$ with

$$M_1 := \begin{pmatrix} 1 & -2 & 2 \\ 2 & -1 & 2 \\ 2 & -2 & 3 \end{pmatrix}, \quad M_2 := \begin{pmatrix} -1 & 2 & 2 \\ -2 & 1 & 2 \\ -2 & 2 & 3 \end{pmatrix}, \quad M_3 := \begin{pmatrix} 1 & 2 & 2 \\ 2 & 1 & 2 \\ 2 & 2 & 3 \end{pmatrix}.$$

We present a generalization of this theorem to different quadratic forms other than the Pythagorean one. (Received January 26, 2016)

1118-11-152 **Alex V Kontorovich*** (alex.kontorovich@rutgers.edu), 110 Frelinghuysen Rd., Piscataway, NJ 08854. *Geometry and arithmetic of circle packings.*

We will discuss many new families of circle packings exhibiting the same arithmetic features of the Apollonian packing. This is joint work with Kei Nakamura. (Received January 29, 2016)

1118-11-241 **Dmitry Kleinbock*** (kleinboc@brandeis.edu), 450 South St, Department of Mathematics, Brandeis Universit, Waltham, MA 02454-9110. *Homogeneous dynamics and intrinsic approximation.*

Dynamics on homogeneous spaces has been a useful tool in solving many previously intractable Diophantine approximation problems for almost three decades, starting from the work of Margulis on the Oppenheim conjecture. In this lecture I will describe some existing connections between homogeneous dynamics and Diophantine approximation, and then show how a similar approach can help quantify the density of rational points on quadric hypersurfaces (intrinsic approximation problems). The new work is joint with Lior Fishman, Keith Merrill and David Simmons. (Received February 02, 2016)

13 ► Commutative rings and algebras

1118-13-34 **Richard Erwin Hasenauer*** (hasenaue@nsuok.edu) and **Jim Coykendall** (jcoyken@clemson.edu). *Factorization in Prüfer domains of finite character.*

We will discuss factorization in Prüfer domains of finite character. In particular we will show that if D is a one-dimensional atomic Prüfer domain of finite character, then D is a bounded factorization domain. We will also show if D is an one-dimensional atomic Prüfer domain of finite character with exactly one idempotent maximal ideal, then D is a finite factorization domain. (Received January 11, 2016)

1118-13-44 **Thomas G. Lucas*** (tglucas@uncc.edu), Department of Mathematics and Statistics, University of North Carolina Charlotte, Charlotte, NC 28223. *Additively regular rings and Marot Rings.*

A commutative ring R with set of zero divisors $Z(R)$ is said to be additively regular if for each pair of elements $a, b \in R$ with b regular (i.e., $b \notin Z(R)$), there is an element $c \in R$ such that $a + cb$ is regular. Also R is a Marot ring if each regular ideal (one not contained in $Z(R)$) can be generated by its regular element. An example by D.D. Anderson and J. Pascual shows that a ring may have a unique regular maximal ideal M where some invertible ideals (including M) are not principal. We will consider what happens for invertible ideals in Marot rings and additively regular rings that have only finitely many regular maximal ideals. Also we consider the regular ring of quotients $R_{(S)}$ and the large ring of quotients $R_{[S]}$ for a multiplicative subset $S \subsetneq R$. For a prime P of a Marot ring R, D. Portelli and W. Spangher showed $R_{(S)} = R_{[S]}$ for $S = R \backslash P$. (Received January 14, 2016)

1118-13-65 **Marco Fontana*** (fontana@mat.uniroma3.it), Dipartimento di Matematica e Fisica, Universita' degli Studi Roma Tre, Largo San Leonardo Murialdo, 1, 00146 Rome, Italy. *Essential domains and Pruefer v-multiplication domains: recent developments.*

This talk is partially based on a joint work with S. El Baghdadi and M. Zafrullah.

It is well known that a Prüfer v-multiplication domain (for short, PvMD) is an essential domain, since each localization at its t-prime ideals is a valuation domain.

M. Griffin in 1967 gave a very simple characterization of PvMDs in case of integral domains with the t-finite character (i.e., satisfying the property that each nonzero element is contained in finitely many t-maximal ideals). In this case, they are exactly the essential domains with the t-finite character. However, in general, an essential domain is not necessarily a PvMD. A very illuminating example was given by Heinzer-Ohm in 1973.

In 2015, Finocchiaro-Tartarone have gone through this construction and one of the main results of their paper describes the class of PvMDs precisely as a subclass of essential domains verifying an additional "topological" condition, regarding ultrafilter limits of suitable families of prime ideals.

In this talk, I will discuss a different and purely algebraic approach for characterizing PvMDs in the class of essential domains. (Received January 20, 2016)

1118-13-96 **Giulio Peruginelli*** (gperugin@math.unipd.it), Dipartimento di Matematica, Via Trieste, 63, 35121 Padova, Italy, and **Jean-Luc Chabert**, Department of Mathematics, Amiens, France. *Polynomial overrings of* Int($\mathbb{Z}$).

The classical ring of integer-valued polynomials Int($\mathbb{Z}$) is defined as the set of polynomials with rational coefficients which map the integers into themselves under evaluation. In this talk we will show that each ring between Int($\mathbb{Z}$) and $\mathbb{Q}[X]$ can be represented as a ring of integer-valued polynomials over a subset of the profinite completion of $\mathbb{Z}$. We also give a classification of those polynomial overrings of Int($\mathbb{Z}$) which admit a regular basis. (Received January 26, 2016)

1118-13-100 **Hans Schoutens*** (hschoutens@citytech.cuny.edu), Department of Mathematics, Graduate Center CUNY, 365 5th Avenue, NY, NY 10016. *Big Cohen-Macaulay algebras in mixed characteristic via Witt vectors.*

The theory of Witt vectors assigns to a ring of positive characteristic a (possibly non-Noetherian) ring of mixed characteristic. This process induces an action on the ideals of a power series ring over a complete discrete valuation ring. Of particular interest are the ideals that are invariant under this action: I show that their quotient ring then admits a big (=non-Noetherian) Cohen-Macaulay algebra. I will conclude with an application to local toric rings, which is a generalization of the classical toric rings. (Received January 26, 2016)

1118-13-104 **Hannah Altmann*** (haltmann@morris.umn.edu), **Eloisa Grifo**, **Jonathan Montano**, **William Sanders** and **Thanh Vu**. *Lower bounds on the level of perfect complexes.* Preliminary report.

Let R be an associative ring. An R-complex F is *perfect* if it is quasiisomorphic to a bounded complex of finitely generated projective modules. A useful invariant associated to every perfect complex is its level. We can think of the level of F as the number of steps it takes to build F out of R. We will discuss finding bounds on the level of a perfect complex. In particular, we will show that the length of the largest gap in the homology of a complex F gives a lower bound for the level of F. (Received January 26, 2016)

1118-13-126 **Neil Epstein** and **Jay Shapiro*** (jshapiro@gmu.edu), jshapiro@gmu.edu. *Perinormal integral domains, Part I.*

We introduce a new class of integral domains, the *perinormal* domains, which fall strictly between Krull domains and weakly normal domains. We establish basic properties of the class, and in the case of universally catenary domains we give equivalent characterizations of perinormality. (Later on, we point out some subtleties that occur only in the non-Noetherian context.) We provide examples from algebra and geometry. (Received January 29, 2016)

1118-13-129 **Sean Sather-Wagstaff** and **Jonathan Totushek*** (jtotushe@uwsuper.edu). *Using semidualizing complexes to detect Gorenstein rings.*

A result of Foxby states that if there exists a complex with finite depth, finite flat dimension, and finite injective dimension over a local ring R, then R is Gorenstein. In this talk we investigate some homological dimensions involving a semidualizing complex and improve on Foxby's result by answering a question of Takahashi and White. In particular, we prove for a semidualizing complex C, if there exists a complex with finite depth, finite $\mathcal{F}_C$-projective dimension, and finite $\mathcal{I}_C$-injective dimension over a local ring R, then R is Gorenstein. (Received January 27, 2016)

1118-13-149 **Evan Houston*** (eghousto@uncc.edu), **Salah Kabbaj** and **Abdeslam Mimouni**. *$\star$-Reductions of ideals and Prüfer v-multiplication domains.*

Recall that an ideal is said to be *basic* if it has no proper reductions. J. Hays (1973, 1975) characterized Prüfer domains as domains in which every finitely generated ideal is basic and one-dimensional Prüfer domains as

domains in which every ideal is basic. We extend this to Prüfer v-multiplication domains. The extension is somewhat surprising, and we produce examples to explain why. (Received January 29, 2016)

1118-13-156 **Jim Coykendall*** (jcoyken@clemson.edu), Department of Mathematical Sciences, Martin Hall O-10, Clemson University, Clemson, SC 29634, and **Stacy Trentham**. *Spontaneous atomicity in polynomial extensions.*

We say that an integral domain is atomic if every nonzero nonunit in the domain can be factored into a (finite) product of atoms. If R is an integral domain then it is easy to see that if $R[x]$ is atomic then R must be atomic, but even in the case of integral domains, it is not completely understood under what conditions $R[x]$ is itself atomic.

For rings with zero divisors, the situation is worse. There are various definitions of atomicity that all collapse to the standard definition in the case of integral domains. The main focus of this talk (after some background and perspective) will be the presentation of a commutative ring with identity that is not atomic (in fact, it has no irreducibles whatsoever) but its polynomial ring is atomic. (Received January 29, 2016)

1118-13-166 **Bruce Olberding*** (olberdin@nmsu.edu), Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88011. *Intersections of rank one valuation rings.* Preliminary report.

The class of rings that can be represented as an intersection of rank one valuation rings is large and diverse. It includes all integrally closed Noetherian domains (more generally, Krull domains) as well as important Prüfer domains such as the ring of entire functions, the ring of integer-valued polynomials and the holomorphy ring of a formally real function field over a real closed field. While it is well understood when the intersection of rank one valuation rings is a Krull domain, the situation in which such an intersection is a Prüfer domain is more subtle. In this talk we consider topological and geometric features of intersections of rank one valuation rings, with special emphasis on the case in which the intersection is a Prüfer domain. Some applications to the theory of quadratic transforms of a regular local ring are given. (Received January 30, 2016)

1118-13-190 **Mark Batell*** (mbatell@outlook.com). *On a class of half-factorial domains.* Preliminary report.

Let R be an integral domain. For elements $a, b \in R$, let $[a, b]$ denote their greatest common divisor, if it exists. We say that R has the *Z-property* if whenever a, b, c, d and e are nonzero nonunits of R such that $abc = de$, then $[ab, d] \neq 1$ or $[ab, e] \neq 1$. The purpose of this paper is to study this property. The atomic integral domains that have this property constitute a class of half-factorial domains. Also, it is known that R must have this property in order for the polynomial ring $R[x]$ to be half-factorial. We use it to give a characterization of half-factorial polynomial rings in the case where every v-ideal of the coefficient ring R is v-generated by two elements. We also show that if R is a Krull domain with this property, then R has torsion class group. (Received January 31, 2016)

1118-13-208 **Dan McGregor*** (mcgregor.36@buckeyemail.osu.edu). *Kronecker function rings.* Preliminary report.

For any integrally closed domain D, a Kronecker function ring D^* is an overring of the polynomial ring $D[X]$ with certain properties. They have proven to be a useful tool in studying the valuation overrings of D, but comparatively little work has been done on the structure of these rings themselves. I have some preliminary results concerning these rings, both individually and when considering the collection of all Kronecker function rings of D as a set. (Received February 01, 2016)

1118-13-225 **Michael C Steward*** (steward.57@osu.edu). *Extending the Skolem Property.* Preliminary report.

If I is a finitely generated ideal of some ring of integer-valued polynomials $Int(D)$, then for each element d of D, $I(d)$ is an ideal of D called the value ideal of I at d. $Int(D)$ is said to have the Skolem property if each of its proper, finitely generated ideals must have some proper value ideal. It is said to have the strong Skolem property if its finitely generated ideals are characterized by their value ideals. We will consider analogues of the Skolem property for other polynomial rings. (Received February 01, 2016)

1118-13-233 **Jason G Boynton*** (jason.boynton@ndsu.edu), Fargo, ND 58104. *Studying rings of integer-valued polynomials via pullback constructions.*

Let D be an integral domain with field of fractions K and let $E \subseteq D$ be any subset. Recall that $\mathrm{Int}(E, D) = \{g(x) \in K[x] : g(E) \subseteq D\}$ is the ring of integer-valued polynomials determined by the subset E. We realize

Int(E, D) as a pullback construction in order to study the transference of some coherent-like conditions and factorization properties. (Received February 01, 2016)

1118-13-243 **Jesse Eliott*** (jesse.elliott@csuci.edu), 305 Channel Islands Drive, Camarillo, CA 93012. *Star operations on commutative rings and applications to Krull and factorial rings with zero divisors.*

We advance a natural generalization of the theory of star operations on integral domains to commutative rings and apply it to the study of Krull and factorial rings with or without zero divisors. (Received February 02, 2016)

1118-13-247 **Carmelo Antonio Finocchiaro*** (carmelo@mat.uniroma3.it), Via Marina 48, 95013 Fiumefreddo di Sicil, Catania, Italy. *Topology, intersections of modules and flatness.*

As it is well-known, multiplication by an ideal I does not commute with the intersection of a family of ideals. But, when the ideal I is flat and the family is finite, then multiplication commutes with intersection. We generalize this result by showing that finite families of ideals can be replaced by compact subspaces of a natural topological space. Several consequences of this fact will be presented. This talk is based on a joint paper with Dario Spirito. (Received February 02, 2016)

1118-13-248 **Neil Epstein*** (nepstei2@gmu.edu), 4400 University Drive, MS: 3F2, Fairfax, VA 22030, and **Jay Shapiro**. *Perinormal integral domains, part II.*

We explore ways that perinormal domains may be constructed, primarily via pullback diagrams, both in Noetherian and non-Noetherian contexts. In the former case, we introduce a very flexible method of construction by "gluing" the primary decomposition of any ideal of height at least two in a large class of normal Noetherian domains. In the latter, we show e.g. how perinormality arises from hypersurface contraction and the classical $D + M$ construction. We provide both an algebraic and a geometric / topological perspective on these constructions. Three notions arise from these constructions: (1) relative perinormality associated to an arbitrary ring inclusion, (2) fragile integral extensions, and (3) near-normal domains. (Received February 02, 2016)

14 ► Algebraic geometry

1118-14-54 **Andras Lorincz**, **Claudiu Raicu**, **Uli Walther*** (walther@math.purdue.edu) and **Jerzy Weyman**. *Bernstein-Sato polynomials of ideals of generic matrices.*

We discuss the Bernstein-Sato polynomial and Monodromy Conjecture in general, and give explicit computations for the ideal of the maximal minors of a generic mxn matrix. (Received January 18, 2016)

1118-14-77 **Clément Dupont*** (cdupont@mpim-bonn.mpg.de), Vivatsgasse, 7, 53111 Bonn, Germany. *Co-arrangements and bi-arrangements.*

In this talk I will advertise co-arrangements (which are dual to arrangements) and bi-arrangements (which form a self-dual class containing arrangements and co-arrangements) as a way of producing interesting Hodge-Tate structures. The computational aspect of the subject involves a bivariant generalization of the Orlik-Solomon algebra. (Received January 22, 2016)

1118-14-158 **Nero Budur**, **Yongqiang Liu**, **Luis Saumell** and **Botong Wang*** (wang@math.wisc.edu), Department of Mathematics, University of Wisconsin-Madison, 480 Lincoln Drive, Madison, WI 53706. *Cohomology support loci of local systems.*

Let X be a smooth complex algebraic variety, and let U be an open subset of X whose complement is a hypersurface. Let L be a local system on U. We will discuss the local behavior of $\mathbf{R}j_*L$, where $j : U \to X$ is the inclusion map. More specifically, we will talk about the support of Sabbah's specialization complex and its relation with cohomology support loci. (Received January 29, 2016)

1118-14-211 **Mahir Bilen Can*** (mcan@tulane.edu), 6823 St. Charles Ave, Department of Mathematics, Tulane University, New Orleans, LA 70118, and **Selman Akbulut**. *Complex G_2 and associative grassmannian.* Preliminary report.

In this talk we will report on our recent progress on the moduli of quaternion subalgebras of a complex octonion algebra. It turns out that this variety is the unique smooth spherical compactification of $G_2/SO(4)$ with Picard number 1. By using techniques from calibrated geometries, we describe its defining ideal in the projectivization of 3-forms on $\mathbb{C}^7$ and study various $SL(2)$ actions. We calculate its Poincare polynomial by using Bialynicki-Birula decomposition. Finally, we contrast our results with other compactifications of the symmetric variety $G_2/SO(4)$. (Received February 01, 2016)

1118-14-222 **Sean Timothy Paul*** (stpaul@wisc.edu), 480 Lincoln Drive, Madison, WI 53706. *The CM stable locus is Zariski Open.*

As a corollary of the proof of global generation of the line bundles defining CM-stability we show that in a flat family of smooth Fano manifolds with finite automorphisms, the locus of points in the base admitting a KE metric is open in the Zariski topology. A similar result had been established several years ago by S. Donaldson. (Received February 01, 2016)

17 ► Nonassociative rings and algebras

1118-17-38 **Chongying Dong** (dong@ucsc.edu), Math Department, UC Santa Cruz, 1156 High Street, Santa Cruz, CA 95064, **Feng Xu** (xufeng@ucr.edu), Math Department, UC Riverside, 900 University Avenue, Riverside, CA 92521, and **Nina Yu*** (ninay@ucr.edu), Math Department, 900 University Avenue, UC Riverside, Riverside, CA 92521. *Permutation orbifold of lattice vertex operator algebras.* Preliminary report.

The permutation orbifold study the permutation actions on the tensor products of vertex operator algebras. Namely, given a vertex operator algebra V , then tensor product of n-copies of V as a vector space naturally has a vertex operator algebra structure. Any element of the symmetric group S_n gives an automorphism of $V^{\otimes n}$ of finite order. The fixed points set is a vertex operator subalgebra which is called a permutation orbifold model. In this talk, I will talk about 2-cyclic permutation orbifold model of lattice vertex operator algebras. (Received January 12, 2016)

1118-17-66 **Lev Borisov*** (borisov@math.rutgers.edu), 110 Frelinghuysen Rd, Hill Center, Mathematics Department, Piscataway, NJ 08854. *Vertex algebras associated to reflexive Gorenstein cones.*

Toric mirror symmetry has led to the construction of families of N=2 vertex algebras associated to pairs of reflexive Gorenstein cones and coefficient functions. These algebras and their representations are overall poorly understood. I will highlight the motivation and the construction of these algebras and state open questions in hope that other participants of the special session will try to answer them. (Received January 20, 2016)

1118-17-68 **Yi-Zhi Huang*** (yzhuang@math.rutgers.edu), Department of Mathematics, Rutgers University, 110 Frelinghuysen Road, Piscataway, NJ 08854. *Modular invariance for rational and logarithmic conformal field theories.*

In this talk, I will first give a quick review the modular invariance theorem for rational conformal field theories, including the modular invariance conjecture of Moore and Seiberg, Zhu's proof of a partial result and my proof of this conjecture of Moore-Seiberg. Then I will discuss the modular invariance for logarithmic conformal field theories, including the partial modular invariance result obtained by Miyamoto, the thesis work of Fiordalisi and a joint paper in preparation with Fiordalisi proving the modular invariance under the condition that the vertex operator algebra is positive energy, C_2-cofinite and has no nonzero finite-dimensional modules. (Received January 20, 2016)

1118-17-91 **Thomas Creutzig** and **Andrew R Linshaw***, Department of Mathematics, University of Denver, Denver, CO 80208. *Orbifolds and cosets via invariant theory.*

The orbifold and coset constructions are standard ways to create new vertex algebras from old ones. It is believed that orbifolds and cosets will inherit nice properties such as strong finite generation, C_2-cofiniteness, and rationality, but few general results of this kind are known. I will discuss how these problems can be studied systematically using ideas from classical invariant theory. This is based on joint work with T. Creutzig. (Received January 25, 2016)

1118-17-147 **Bojko Bakalov*** (bojko_bakalov@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695. *Twisted logarithmic modules of vertex algebras.*

Motivated by logarithmic conformal field theory and Gromov–Witten theory, I will introduce a notion of a twisted module of a vertex algebra relative to any (not necessarily semisimple) automorphism, generalizing that considered previously by Y.-Z. Huang. Two features of such twisted modules are that they involve the logarithm of the formal variable and the action of the Virasoro operator L_0 on them is not semisimple. I will derive a Borcherds identity and commutator formula for twisted modules. Examples for affine vertex algebras, free bosons, and symplectic fermions will be presented. (Received January 29, 2016)

1118-17-237 **Corina Calinescu*** (ccalinescu@citytech.cuny.edu), **Antun Milas** and **Michael Penn**. *Principal subspaces of basic $A_{2n}^{(2)}$-modules.*

The principal subspaces of standard modules for untwisted affine Lie algebras were introduced by Feign and Stoyanovsky, and have been further studied by several authors from different standpoints. By using the theory of vertex algebras we study the algebraic and combinatorial properties of the principal subspace of the basic module for the twisted affine Lie algebra associated to A_{2n}. This is joint work with Antun Milas and Michael Penn. (Received February 01, 2016)

1118-17-250 **Liang Kong*** (kong.fan.liang@gmail.com), W383 Kingsbury Hall, 33 Academic Way, Durham, NH 03824. *Vertex operator algebras and conformal field theories.*

A vertex operator algebra is not yet a conformal field theory. But it is an important ingredient of conformal field theory. I will review some relations between these two concepts and results in open-closed rational conformal field theories. (Received February 02, 2016)

1118-17-272 **Nils Scheithauer*** (scheithauer@mathematik.tu-darmstadt.de), TU Darmstadt, Fachbereich Mathematik, Schlossgartenstrasse 7, 64289 Darmstadt, Germany. *Construction and classification of holomorphic vertex operator algebras.*

We develop an orbifold theory for finite cyclic groups acting on holomorphic vertex operator algebras. Then we show that Schellekens' classification of holomorphic conformal field theories is a theorem on vertex algebras. Finally we use our results to construct some new holomorphic vertex operator algebras as lattice orbifolds. In the proofs of these results we assume the rationality of the fixed point subalgebra of a finite order automorphism. (Received February 03, 2016)

19 ► K-theory

1118-19-194 **Ulysses A Andrews** (ulysses.andrews@uconn.edu), **Edith Aromando**, **Joe P Chen**, **Lee Fisher**, **Luke Rogers** and **Alexander Teplyaev***. *The effect of contrast ratio on wave propagation speed in fractal media.*

We consider a family of self-similar graph Laplacians on the unit interval with fractal measure parameterized by a parameter p. Our parameter p is a transition probability for self-similar random walks, and also p is related to the contrast ratio of the fractal medium. A known theoretical result by Yin-Tat Lee arXiv:1111.2938 shows that in our case the wave propagation speed is infinite. However, our simulations suggest that almost all of a smooth wave propagates with finite wave speed v and that $v \sim 1/(2p)$ for $0 < p < 1/2$. (Received January 31, 2016)

20 ► Group theory and generalizations

1118-20-36 **Thomas Creutzig*** (creutzig@ualberta.ca), , Canada. *Open Hopf links and logarithmic VOAs.*

If the tensor category of a VOA is modular, then Hopf links agree up to normalization with the entries of the modular S-matrix of characters.

I will introduce open Hopf links in the context of not necessarily modular but braided tensor categories; I will then explain how they give rise to representations of the tensor ring and how they relate to the original Hopf links. The advantage is that open Hopf links are useful beyond the semi-simple setting. The main goal is then to explain how open Hopf links relate to characters of logarithmic VOAs. (Received January 12, 2016)

1118-20-132 **Alexander I. Suciu** and **He Wang*** (wang.he1@husky.neu.edu), Department of Mathematics, Northeastern University, BOSTON, MA 02115. *Towards a new resonance-Chen ranks formula: the case of welded braids.*

The resonance varieties were introduced by Michael Falk in the context of hyperplane arrangements. Since then, this idea has been used to study any finitely generated group G. The Chen ranks of G are the LCS ranks of its maximal metabelian quotients. Cohen and Suciu computed the Chen ranks of the pure braid groups. Recently, Cohen and Schenck completed the proof of the resonance-Chen ranks formula conjectured by Suciu for arrangement groups. Closely related to the pure braid groups are the (upper) welded pure braid groups. We will present several results on the resonance varieties and the Chen ranks of the upper welded pure braid groups. These results provide a testbed for generalizing the resonance-Chen ranks formula. (Received January 28, 2016)

1118-20-240 **Simon Wood*** (simon.wood@anu.edu.au). *Symmetric functions and their relation to free field vertex algebras.* Preliminary report.

Free field vertex algebras, while also being mathematically interesting in their own right, are an invaluable tool for constructing many other interesting vertex algebras. In this talk I will review how one can construct such free field realisations and how they are related to symmetric functions, in particular, how they distinguish certain bases of symmetric functions called Jack symmetric functions. These free field realisations will be used to present a new proof of the rationality of the N=1 superconformal minimal models and their module classification. (Received February 02, 2016)

22 ► Topological groups, Lie groups

1118-22-184 **Ilia Smilga*** (ilia.smilga@normalesup.org). *Free affine groups acting properly discontinuously.* Preliminary report.

In 1983, Margulis found an example of a free group of affine transformations (Zariski-dense in $\mathrm{SO}(2,1) \ltimes \mathbb{R}^3$) acting properly discontinuously on the affine space $\mathbb{R}^3$. Since then, only a few other examples have been found. We are going to present a possible way to classify possible Zariski closures of such groups. Given a real semisimple group G and a representation ρ of G on a vector space V, there seems to be a simple algebraic criterion on ρ that allows one to decide whether the affine group $G \ltimes V$ has a Zariski-dense free subgroup acting properly discontinuously. (Received January 31, 2016)

26 ► Real functions

1118-26-5 **George A Anastassiou*** (ganastss2@gmail.com), George Anastassiou, Department of Mathematical Sciences, University of Memphis, Memphis, TN 38152. *New fractional Taylor's formulae.* Preliminary report.

We present five new generalized Caputo type fractional Taylor's formulae under as weak as possible assumptions, and four new generalized Canavati type fractional Taylor's formulae.They are expected to have big impact in various branches of Mathematics. (Received September 13, 2015)

1118-26-155 **Lance E. Miller** and **Benjamin Steinhurst*** (bsteinhurst@mcdaniel.edu). *Sierpinski-type fractafolds with Algebraic content: p-fractals.* Preliminary report.

A recent result of Hernandez and Teixeira has shown that the zero set of a function involving the length of an ideal in $k[x,y]$ (called a syzygy gap fractal) where k is a field of characteristic $p > 0$ when intersected with well chosen hyperplanes yield level p Sierpinski gaskets. This function is derived from two ideals $\langle x \rangle$, $\langle y \rangle$ and a collection of linear forms x, y, and $x + y$. However it is possible to choose other ideals and linear forms. We will discuss what the analogous fractals obtained from other choices of the two ideals. As well as the self-similarity properties of the function and its zero set. The goal of this investigation is to extract algebraic information from the fractal geometry of the syzygy gap fractal (which is a function) and the wider class of p-fractals that have been introduced by Teixeira. (Received January 29, 2016)

28 ► Measure and integration

1118-28-79 **Sze-Man Ngai*** (smngai@georgiasouthern.edu), Department of Mathematical Sciences, Georgia Southern University, Statesboro, GA 30460-8093, **Wei Tang** (tangwei19910525@126.com), College of Mathematics and Computer Science, Hunan Normal University, Changsha, Hunan 410081, Peoples Rep of China, and **Yuanyuan Xie** (xieyuanyuan198767@163.com), College of Mathematics and Computer Science, Hunan Normal University, Changsha, Hunan 410081, Peoples Rep of China. *Wave propagation speed on fractals.*

We study the wave propagation speed problem on fractals that are not post-critically finite. We extend Y. T. Lee's result on infinite propagation speed to include these fractals. We also obtained a sufficient condition for finite wave propagation speed that depends on the self-similar measure. Heat kernel estimates play a crucial role in these investigations. We apply our results to the classical infinite Bernoulli convolutions and other fractals. This is a joint work with Wei Tang and Yuanyuan Xie. (Received January 24, 2016)

1118-28-89 **Benjamin J Jaye*** (bjaye@kent.edu). *Reflectionless measures for singular integral operators.*

In this talk we shall be concerned with necessary and sufficient conditions on a measure so that an associated singular integral operator is bounded. Our analysis hinges on a description of certain objects called reflectionless measures. We shall reduce certain well-known problems at the interface of harmonic analysis and geometric measure theory to a description of the reflectionless measures associated to singular integral operators. Furthermore, we show that this approach yields promising new results. The results described are joint work with Fedor Nazarov, Maria Carmen Reguera, and Xavier Tolsa. (Received January 25, 2016)

1118-28-90 **David Bate** and **Sean Li***, seanli@math.uchicago.edu. *The geometry of Radon-Nikodym Lipschitz differentiability spaces II.*

Over the last two decades, the Poincaré inequality, in the sense of Heinonen and Koskela, has played a central role in the development of analysis on metric measure spaces. Cheeger and Kleiner showed that such spaces satisfy the differentiability theory of Cheeger for Lipschitz functions taking value in Banach spaces with the Radon-Nikodym property (RNP). We give a partial converse as well as a characterization of RNP Cheeger differentiability. Namely, we introduce the notion of an asymptotic nonhomogeneous Poincaré inequality for metric measure spaces and show how it is equivalent to the space satisfying RNP Cheeger differentiability. (Received January 25, 2016)

1118-28-101 **A. Dali Nimer*** (nimer@uw.edu), Department of Mathematics, University of Washington, Box 354350, Seattle, WA 98195-435. *A sharp bound on the Hausdorff dimension of the singular set of an n-uniform measure.*

An n-uniform measure in $\mathbb{R}^d$ is a measure satisfying the following property. There exists a constant $c > 0$ such that for every point x in the support of μ and every $r > 0$,

$$\mu(B(x,r)) = cr^n.$$

These measures play a crucial role in geometric measure theory. They were introduced by Preiss and played an essential role in his proof of the characterization of rectifiable Radon measures by their density. However, the geometry of their support remains largely misunderstood. Indeed, the only known non-flat n-uniform measure is (up to multiplication by a positive constant) the "surface measure" of $\mathcal{C} \times \mathbb{R}^{n-3}$ where $\mathcal{C}$ is the Kowalski-Preiss cone described by

$$\mathcal{C} = \left\{(x_1, x_2, x_3, x_4); {x_4}^2 = {x_1}^2 + {x_2}^2 + {x_3}^2\right\}.$$

In this talk, we will focus on the singular set of n-uniform measures. In particular we will discuss the following result: if μ is an n-uniform measure in $\mathbb{R}^d$, and $\mathcal{S}_\mu$ is its singular set then

$$dim_H(\mathcal{S}_\mu) \leq n - 3.$$

This essentially says that the Kowalski-Preiss cone is the worst example in terms of the Hausdorff dimension of its singular set. (Received January 26, 2016)

1118-28-107 **Sharat Chandra**, **Fiona Galzarano*** (fig@temple.edu) and **Robert Strichartz**. *Analysis on Apollonian Gaskets.* Preliminary report.

We are interested in constructing energy forms and Laplacians on Apollonian gasket fractals that are related to the geometry of the fractal. We begin by studying finite approximations obtained by packing a finite number of circles, and we are able to compute geometric information such as arc lengths and areas of "triangular" regions. This leads to energy forms and Laplacians on the approximations. Our preliminary experimental evidence suggests that there may be several different Laplacians in the limit, depending on the criterion used for refining the approximations. (Received January 26, 2016)

1118-28-133 **Martina Zähle*** (martina.zaehle@uni-jena.de), 07737 Jena, Germany. *Gaussian space-time fields and (S)PDE on fractals.*

In the first part Gaussian space-time fields on arbitrary Ahlfors regular compact metric measure spaces are considered. If the mean quadratic increments satisfy similar upper estimates like fractional Brownian sheets, optimal Hölder continuity properties are shown. For classes of fractal spaces admitting a Laplace operator (and for more general spaces) formal space-time derivatives of such random fields are introduced. In the spatial component they become rigorous by means of duality arguments in associated fractional Sobolev spaces. For integration with respect to the time argument we use fractional calculus in Banach spaces. In this way one obtains random space-time noises which are applied in the second part to parabolic PDE on such fractals in the pathwise multiplicative sense. (Received January 28, 2016)

1118-28-135 **Guy C. David*** (guydavid@math.nyu.edu) and **Raanan Schul**. *The Analyst's Traveling Salesman Theorem in limits of metric graphs.* Preliminary report.

The "Analyst's Traveling Salesman Theorem" of Peter Jones characterizes subsets of rectifiable curves in the plane. There has been much recent work extending this result to more general spaces. In this talk, we will discuss an analog of this theorem in a class of highly non-Euclidean spaces with interesting analytic properties introduced by Laakso and Cheeger-Kleiner, which can be viewed as limits of metric graphs. (Received January 28, 2016)

1118-28-136 **Kyle Kinneberg*** (kk43@rice.edu). *Lower codimension-1 mass bounds in metric spaces.*

We discuss a "quantitative topological" isoperimetric inequality in the setting of doubling and linearly locally contractible closed metric manifolds. Namely, the codimension-1 Hausdorff measure of $\partial\Omega$ is bounded below in terms of the in-radii of Ω and its complement. (Received January 28, 2016)

1118-28-138 **Vasilis Chousionis**, **Valentino Magnani** and **Jeremy T Tyson*** (tyson@illinois.edu), 1409 West Green Street, Urbana, IL 61801. *Uniform measures and the geometry of submanifolds in the Heisenberg group.* Preliminary report.

A Borel measure on a metric space is said to be s-uniform if the measure of every ball of radius r is proportional to r^s, with a fixed proportionality constant. In Euclidean space, such measures are classified in low dimension and in low codimension, however, the full classification of uniform measures remains an open problem. I will discuss ongoing work (joint with Vasilis Chousionis and Valentino Magnani) on the classification of uniform measures in the sub-Riemannian Heisenberg group equipped with the Koranyi metric. Following an approach of Kowalski and Preiss, we analyze the structure of low codimensional uniform measures via an asymptotic formula for the volume of Koranyi balls of small radius on smooth surfaces. Our formula involves several intrinsic notions of sub-Riemannian curvature associated to such surfaces. I will give a brief overview of relevant aspects of the geometry of smooth submanifolds in sub-Riemannian spaces. (Received January 28, 2016)

1118-28-150 **Jens Malmquist*** (jmalmquist@berkeley.edu), 2606 Fulton St, Berkeley, CA 94704, and **Robert S Strichartz**. *Numerical integration for fractal measures.* Preliminary report.

We find estimates for the error in replacing an integral $\int f d\mu$ with respect to a fractal measure μ with a discrete sum $\sum_{x\in E} w(x)f(x)$ over a given sample set E with weights w. Our model is the classical Koksma-Hlawka theorem for integrals over rectangles, where the error is estimated by a product of a *discrepancy* that depends only on the geometry of the sample set and weights, and *variance* that depends only on the smoothness of f. We deal with self-similar measures on p.c.f. self-similar fractals on which Kigami has constructed notions of *energy* and *Laplacian* ($\triangle$). We develop generic results where we take the variance to be either the energy of f or the L^1 norm of $\triangle f$, and we show how to find the corresponding discrepancies for each variance. We work out the details for a number of interesting examples of sample sets for the Sierpinski gasket. (Received January 29, 2016)

1118-28-154 **Christopher J Bishop** (bishop@math.stonybrook.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794-3651, **Hrant Hakobyan*** (hakobyan@math.ksu.edu), Department of Mathematics, Kansas State University, Manhattan, KS 66502, and **Marshall Williams** (mcwill@math.ksu.edu), Department of Mathematics, Kansas State University, Manhattan, KS 66502. *Quasiconformal dimension distortion of generic Ahlfors regular subsets.*

We show that if $f : X \to Y$ is a quasisymmetric mapping between Ahlfors regular spaces, then for "almost every" bounded Ahlfors regular set $E \subseteq X$ we have

$$\dim_H f(E) \leq \dim_H E.$$

If additionally, X and Y are Loewner spaces then for "almost every" Ahlfors regular set $E \subset X$ we have

$$\dim_H f(E) = \dim_H E.$$

The precise statements of these results are given in terms of Fuglede's modulus of measures.

As a corollary of these general theorems we show that if f is a quasiconformal map of $\mathbb{R}^N$, $N \geq 2$, then for Lebesgue a.e. $y \in \mathbb{R}^N$ we have

$$\dim_H f(y + E) = \dim_H E.$$

A similar result holds for Carnot groups as well.

For planar quasiconformal maps, our general estimates imply that if $E \subset \mathbb{R}$ is Ahlfors d-regular, $d < 1$, then some component of $f(E \times \mathbb{R})$ has dimension at most $2/(d + 1)$, and we construct examples to show this bound is sharp.

These results generalize work of Balogh, Monti and Tyson and answer questions posed by these authors. (Received January 29, 2016)

1118-28-157 **Bobby Wilson*** (blwilson@mit.edu), Massachusetts Institute of Technology, Building 2, Room 350B, 77 Massachusetts Avenue, Cambridge, MA 02139. *Projections in infinite-dimensional Banach spaces.*

In this talk we will discuss the classical Besicovitch-Federer projection theorem. In particular, we will focus on the validity of the Besicovitch-Federer projection theorem in the setting of infinite-dimensional Banach spaces. We will show that this is false.

This is joint work with Marianna Csörnyei and David Bate. (Received January 29, 2016)

1118-28-159 **Jonas Azzam*** (jazzam@mat.uab.cat), Carrer Benet Mercadé 21 1r1a, 08012 Barelona, Catalunya, Spain. *Tangent measures and harmonic measure.*

Tangent measures are obtained by zooming in on the support of a measure and taking weak limits. These were developed and studied by David Preiss, who used them to show that measures whose d-densities were positive and finite must be d-rectifiable. In this talk, we will discuss some old and new applications of tangent measures and blow-up techniques to study the behavior of harmonic measure. Here, given a domain Ω, the harmonic measure of a subset $A \subseteq \partial\Omega$ is just the probability that a brownian motion starting at a fixed pole in Ω first hits $\partial\Omega$ in A. This is joint work with Mihalis Mourgoglou and Xavier Tolsa. (Received January 30, 2016)

1118-28-178 **Mihalis Mourgoglou*** (mourgoglou@mat.uab.cat), Universitat Autonoma de Barcelona, Edifici C, Facultat de Ciències, Departament de Matemàtiques, 08193 Bellaterra, Barcelona, Spain, and **Xavier Tolsa** (xtolsa@mat.uab.cat), Universitat Autonoma de Barcelona, Edifici C, Facultat de Ciències, Departament de Matemàtiques, 08193 Bellaterra, Barcelona, Spain. *Harmonic measure and Riesz transform in uniform and general domains.*

Let $\Omega \subsetneq \mathbb{R}^{n+1}$ be open and let μ be some measure supported on $\partial\Omega$ such that $\mu(B(x,r)) \leq C\, r^n$ for all $x \in \mathbb{R}^{n+1}$, $r > 0$. We show that if the harmonic measure in Ω satisfies some scale invariant A_∞ type conditions with respect to μ, then the n-dimensional Riesz transform

$$\mathcal{R}_\mu f(x) = \int \frac{x-y}{|x-y|^{n+1}}\, f(y)\, d\mu(y)$$

is bounded in $L^2(\mu)$. We do not assume any doubling condition on μ. We also consider the particular case when Ω is a bounded uniform domain. To this end, we need first to obtain sharp estimates that relate the harmonic measure and the Green function in this type of domains, which generalize classical results by Jerison and Kenig for the well-known class of NTA domains. (Received January 31, 2016)

1118-28-185 **Vasilis Chousionis*** (vasileios.chousionis@uconn.edu), Department of Mathematics, 196 Auditorium Road, Storrs, CT CT 06269. *Densities and uniformly distributed measures in the Heisenberg group.*

Marstrand's density theorem, dating from 1964, is one of the fundamental results in Geometric Measure Theory. In this talk I will give a brief overview of recent developments on measure-theoretic densities related to Marstrand's theorem. In particular I will discuss Marstrand's theorem in the Heisenberg group (joint work with Jeremy Tyson), relying on an analysis of uniformly distributed measures. Examples of such measures will be discussed, illustrating both the similarities and the differences of this sub-Riemannian setting from its Euclidean counterpart. (Received January 31, 2016)

1118-28-218 **Christoph Bandt*** (bandt@uni-greifswald.de), Mathematik, Anrdt-Universität, 17487 Greifswald, Germany. *The two-dimensional density of Bernoulli convolutions.*

By a theorem of Solomyak, the family of all Bernoulli convolutions with $1 < \beta < 2$ can be considered as an L_2 function of two parameters. We analyse and visualize the case $\beta > 1.618$. For parameters outside the overlap region there is a conjugacy with the doubling map which subsumes results by Erdös, Joo, Komornik, Sidorov, de Vries, Jordan, Shmerkin and Solomyak on points with unique addresses. Landmark points inside the overlap region are determined by the coincidence of two finite orbits. Their parameters are algebraic integers. There exist Perron numbers which are neither Pisot nor Salem and for which the Bernoulli convolution has no bounded density, and even non-trivial multifractal spectrum. A series representation for the two-dimensional density is provided. (Received February 01, 2016)

1118-28-257 **Marianna Csornyei*** (csornyei@math.uchicago.edu). *Kakeya problem for rectifiable curves.*

We study which planar sets can be moved continuously covering an arbitrary small area. The talk is based on a joint work with Chang, Hera and Laczkovich. (Received February 02, 2016)

1118-28-268 **Harrison Pugh*** (hpugh@math.sunysb.edu), Stony Brook, NY 10032. *Federer-Fleming projections, Rectifiability, and the Plateau Problem.*

I will give an overview of the Federer-Fleming projection theorem, and explain how it can be modified to prove Almgren's analytic criterion for rectifiability. I will also show how it can be applied in the absence of quasi-minimality to prove some recent results on the elliptic minimization problem. (Received February 03, 2016)

30 ► Functions of a complex variable

1118-30-20 **Alexandre Eremenko*** (eremenko@math.purdue.edu), Purdue University, 150 N University street, West Lafayette, IN 47907, and **Walter Bergweiler** (bergweiler@math.uni-kiel.de), Ludewig–Meyn– Strasse, 4, 42098 Kiel, Germany. *Critical points of Green's function and anti-holomorphic dynamics.*

We give a new, simple proof of the fact recently discovered by C.-S. Lin and C.-L. Wang that the Green function of a torus has either three or five critical points, depending on the modulus of the torus. The proof uses anti-holomorphic dynamics. As a byproduct we find a one-parametric family of anti-holomorphic dynamical systems for which the parameter space consists of only two hyperbolic components and a piecewise analytic curve separating them. (Received December 13, 2015)

1118-30-26 **Clifford J. Earle*** (cliff@math.cornell.edu), 314 Elmwood Avenue, Ithaca, NY 14850. *Canonical neighborhoods of punctures a la Beardon and Halpern.*

Canonical neighborhoods for punctures on hyperbolic Riemann surfaces were defined by Noemi Halpern (in her 1981 paper "A proof of the collar lemma") and Alan F. Beardon (in his 1983 book "The Geometry of Discrete Groups"). They are larger than the neighborhoods yielded by the well-known and more general Jorgensen inequalities, and they deserve to be better known. That is the reason for this talk.

I will describe Halpern and Beardon's constructions and some of their interesting consequences. The proofs are surprisingly easy. They rely on the obvious fact that if $f\colon U \to R$ is a universal covering of the Riemann surface R by the upper half plane U, then the group of covering transformations contains no elliptic transformations. (Received January 05, 2016)

1118-30-42 **Tao Chen***, 3110 Thomson Avenue, Long Island City, NY 11101, and **Yunping Jiang** and **Linda Keen**. *Bounded geometry and characterization of some transcendental entire maps.*

In this talk, we will follow Thurston's scheme to characterize some transcendental entire maps by a new geometric condition–bounded geometry. This is a joint work of Professor Linda Keen and Yunping Jiang. (Received January 14, 2016)

1118-30-63 **Dylan P Thurston*** (dpthurst@indiana.edu), 831 E. Third St, Bloomington, IN 47405. *Elastic graphs and degenerations of complex structures.* Preliminary report.

We describe a notion of a "p-conformal graph" (essentially a metric graph, but with a particular interpretation of the metric) and energies E^p_q for maps from a p-conformal graph to a q-conformal graph. Special cases include the length of a curve, Dirichlet (rubber-band) energy, Lipschitz stretching factor, and a versino of extremal length. The energies are sub-multiplicative, in the sense that

$$E^p_r(g \circ f) \leq E^p_q(f) E^q_r(g).$$

The same inequality is true if we minimize over homotopy classes. Furthermore, these inqualities are all tight in a fairly strong sense. In particular, we can use this to characterize when one rubber-band network is "looser" than another, which can in turn be used to give a necessary condition and a sufficient condition for one degenerating family of Riemann surfaces embeds inside another in a given homotopy class. (Received January 20, 2016)

1118-30-82 **Malik Younsi***, malik.younsi@gmail.com. *Removability, rigidity of circle domains and Koebe's Conjecture.*

As observed by He and Schramm in the '90s, conformally removable sets appear naturally in the study of the famous Koebe Uniformization Conjecture on the conformal representation of planar domains by circle domains. More precisely, He and Schramm conjectured that the conformal rigidity of a circle domain is equivalent to the

conformal removability of its boundary. In this talk, I will present some new results on this conjecture. The proofs involve deformation of Schottky groups by David homeomorphisms. (Received January 23, 2016)

1118-30-142 **Hrant Hakobyan*** (hakobyan@math.ksu.edu), 138 Cardwell Hall, Department of Mathematics, Manhattan, KS 66502. *Limits of Teichmüller geodesics in the Universal Teichmüller space.*

Thurston's boundary to the universal Teichmüller space $T(\mathbb{D})$ is the set of asymptotic rays to the embedding of $T(\mathbb{D})$ in the space of geodesic currents; the boundary is identified with the projective bounded measured laminations PML_{bdd}. We prove that each Teichmüller geodesic ray in $T(\mathbb{H})$ has a unique limit point in Thurston's boundary to $T(\mathbb{H})$ unlike in the case of closed surfaces. This is joint work with Dragomir Šarić. (Received January 29, 2016)

1118-30-145 **Hiroshige Shiga*** (shiga@math.titech.ac.jp). *Tame qc-motions and the monodromy.*

We have introduced the notion of tame qc-motions in a joint paper with Y. Jiang, S. Mitra and Z. Wang. It is a generalization of holomorphic motions. In this talk, we consider the monodromy of a tame qc-motion which is a homomorphism from the fundamental group of the parameter space to the mapping class group in some sense. We discuss properties of the monodromy and consider applications to the deformation theory of Kleinian groups. (Received January 29, 2016)

1118-30-164 **Yunping Jiang**, **Sudeb Mitra**, **Hiroshige Shiga** and **Zje Wang***, Department of Mathematics & Computer Science, Bronx Community College, 2155 University Avenue, Bronx, NY 10453. *Tame quasiconformal motions.*

In this talk, I will discuss a recent work jointly with Yunping Jiang, Sudeb Mitra, and Hiroshige Shiga on the extension problem and the universal property in quasiconformal motions and tame quasiconformal motions. In this work, we give an example of a quasiconformal motion of an infinite set in the Riemann sphere, over an interval, that cannot be extended to a quasiconformal motion of the sphere. Following this example, we introduce a new concept called tame quasiconformal motion. With this new definition, we show that any tame quasiconformal motion of a subset of the sphere, over a simply connected Hausdorff space, can be extended to a quasiconformal motion of the whole sphere, over the same parameter space. Furthermore, we show that this can be done in a conformally natural way. We relate these questions to the universal property of the Teichmuller space of a closed set in the sphere. Finally, we prove that a differentiable quasiconformal motion is a tame quasiconformal motion. (Received January 30, 2016)

31 ► Potential theory

1118-31-173 **Simon Bortz*** (sabh8f@mail.missouri.edu), University of Missouri, Columbia, MO 65211, and **Murat Akman**, **Steve Hofmann** and **Jose Maria Martell**. *Rectifiability, interior approximation and harmonic measure.*

We show that surface measure is absolutely continuous with respect to harmonic measure for domains which satisfy an infinitesimal interior thickness condition and whose boundaries are rectifiable, have locally finite surface measure and satisfy a "weak lower ADR condition". (Received January 31, 2016)

32 ► Several complex variables and analytic spaces

1118-32-45 **Henri Guenancia*** (henri.guenancia@stonybrook.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11790. *Kähler-Einstein metrics with cone singularities along self-intersecting divisors.*

After reviewing the relatively recent results about existence of Kähler-Einstein metrics with conic singularities along a smooth (or simple normal crossings) divisor, we will explain how to generalize these results in the case where the boundary divisor intersects itself. (Received January 14, 2016)

1118-32-72 **Hideki Miyachi*** (miyachi@math.sci.osaka-u.ac.jp), Department of Mathematics, Graduate School of Science, Osaka University, Machikaneyama 1-1, Toyonaka, Osaka 560-0043, Japan. *Complex analysis on Teichmüller space with extremal length.*

In this talk, I will talk about complex analytic properties of Teichmüller space by using extremal length functions. Indeed, we will discuss the plurisubharmonicity of extremal length functions. If time permits, I would like to

give my motivation for the results and a (conjectural) perspective of future research. (Received January 20, 2016)

1118-32-73 **Leon A Takhtajan*** (leontak@math.stonybrook.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794-3651. *"Kähler metrics and Chern forms on the moduli space of punctured Riemann surfaces".*

I will review known properties of the WP and TZ metrics on the moduli space of punctured Riemann surfaces, discuss Chern forms of the associated line bundles and some open problems. This is a joint work with J. Park and L.P. Teo. (Received January 20, 2016)

1118-32-88 **Takuro Abe*** (abe.takuro.4c@kyoto-u.ac.jp), Yoshida Hon-Machi, Kyoto, Kyoto 6068501, Japan. *Flags and freeness of hyperplane arrangements.*

Flags of arrangements are the flags consisting of flats in their intersection lattice. We discuss the relation between freeness and flags of arrangements including supersolvable and divisionally free arrangements. Further applications and problems related to topology and combinatorics will be also given. (Received January 25, 2016)

1118-32-127 **Nishan Chatterjee*** (nchatterjee@gradcenter.cuny.edu), 365 Fifth Avenue, New York, NY 10016, and **Yunping Jiang** and **Sudeb Mitra**. *Some metric properties of Teichmüller space of a closed set in the sphere.*

Let E be a closed set in the Riemann sphere. We discuss several metric properties of the Teichmüller space of E, denoted by $T(E)$. In particular, we extend Earle's form of Teichmüller contraction to $T(E)$, and discuss the properties of holomorphic maps from the open unit disk to $T(E)$. Finally, we discuss a generalization of Earle's form of Schwarz's lemma to $T(E)$. If time permits, we will talk about complex geodesics on $T(E)$. (Received January 28, 2016)

1118-32-205 **Michael J Falk*** (michael.falk@nau.edu), Flagstaff, AZ 86011-5717. *Milnor fibers of arrangements.*

Let Q be a reduced defining polynomial of an arrangement $\mathcal{A}$ of linear hyperplanes in $\mathbb{C}^\ell$. We prove that the first homology of the fiber $\{Q = 1\}$ of the Milnor fibration $Q\colon \mathbb{C}^\ell \setminus \{Q = 0\} \to \mathbb{C}^*$ is determined by the lattice of intersections of $\mathcal{A}$, resolving a long-standing conjecture. (Received January 31, 2016)

1118-32-209 **David Radnell*** (david.radnell@aalto.fi), Aalto University, Dept of Mathematics and Systems Analysis, Espoo, Finland. *What is a higher-genus correlation function?*

A rigged Riemann surface is a punctured Riemann surface with the data of a local holomorphic coordinate specified at each puncture. Correlation functions in chiral conformal field theory are a certain class of meromorphic functions on the moduli space of rigged Riemann surfaces. In genus-zero this is expressed by the correlation functions being meromorphic functions of the puncture locations on the sphere. In genus-one, dependence on the moduli space parameter is expressed by modular invariance which has been extensively studied in the vertex operator algebra literature.

In higher-genus, precisely defining the class of meromorphic functions on the rigged moduli space requires a particular holomorphic coordinate system and fiber structure on this infinite-dimensional complex manifold. We will discuss how this can be done within the framework of Teichmüller theory and also comment on a conjectural property of these functions. (Received February 01, 2016)

1118-32-242 **Hiroaki Terao*** (hterao00@za3.so-net.ne.jp), Office of International Affairs, North 15, West 8, Kita-ku, Sapporo, Hokkaido 060-0815, Japan. *Subarrangements and restrictions of Weyl arrangements.* Preliminary report.

Let $\mathcal{A}$ be a Weyl arrangements arising from a root system. In a recent paper by Abe-Barakat-Cuntz-Hoge-Terao [ABCHT, to appear in J. Euro. Math. Soc.], we proved that every ideal in the root poset gives a free subarrangement with the exponents which are expressed as the dual partition of the height distribution. In my talk, this fact concerning subarrangements is shown to be related to the freeness and the exponents of restrictions of Weyl arrangements. We are especially interested in the restrictions $\mathcal{A}^X$ to subspaces X of the type $A_1 \times \cdots \times A_1$. The result here can be considered as a generalization of an old result by Orlik-Solomon-Terao in "On the Coxeter arrangement and the Coxeter number" (1988) where the restriction is to a hyperplane (or to the type A_1). (The contents of this talk were obtained through the collaborations with Takuro Abe and Tran Nhat Tan.) (Received February 02, 2016)

35 ► Partial differential equations

1118-35-21 **Marcelo M Disconzi*** (marcelo.disconzi@vanderbilt.edu), 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240, and **David G Ebin**, Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *The free boundary Euler equations in 3D.*

We study the incompressible free boundary Euler equations with surface tension in three spatial dimensions. After establishing local well-posedness of the equations, we show that, under natural hypotheses, solutions are near those of the Euler equations in a fixed domain if the surface tension is sufficiently large. (Received December 18, 2015)

1118-35-22 **Marcelo M Disconzi*** (marcelo.disconzi@vanderbilt.edu), 1326 Stevenson Center, Vanderbilt University, Nashville, TN 37240. *The Einstein-Navier-Stokes system.*

We study the evolution problem for Einstein's equations coupled to a relativistic version of the Navier-Stokes equations introduced by Lichnerowicz. Assuming that the fluid is irrotational, we establish local well-posedness of the Cauchy problem and causality of solutions. (Received December 18, 2015)

1118-35-30 **Benjamin Dodson**, 3400 N Charles Street, Baltimore, MD 21218, and **Nishanth Abu Gudapati*** (nishanth.gudapati@yale.edu), 10 Hillhouse Avenue, New Haven, CT 06511. *Scattering for 2+1 Dimensional Einstein-Wave Map System.*

Wave maps are nonlinear wave structures which are natural geometric generalizations of harmonic maps on the one hand and linear wave equations on the other. Such structures occur in several situations in gauge field theories. In particular, wave maps type structures have applications in Einstein's equations of general relativity, most notably in the initial value formulation of Einstein's equations and in the Kaluza-Klein reduction.

In this talk, after motivating the study of asymptotic behaviour of Einstein's equations, we shall discuss some recent results concerning the scattering of a 2+1 dimensional Einstein-wave map system. (Received January 10, 2016)

1118-35-33 **Max D. Engelstein*** (maxe@math.uchicago.edu). *The structure of the singular set of a two-phase free boundary problem for harmonic measure.*

We study the stratification, structure and dimension of the singular set of a two-phase free boundary problem for harmonic measure. With weak regularity assumptions on the free boundary condition, the traditional tools used to study singular sets (e.g. monotonicity formulas, uniqueness of blowups) are unavailable. Instead, we must study the (pseudo)-tangent sets using techniques from geometric measure theory. When more regularity is assumed on the free boundary condition, a mix of the aforementioned GMT and traditional techniques allows us to establish even greater structure.

This is joint work with Matthew Badger and Tatiana Toro. (Received January 11, 2016)

1118-35-40 **Dipendra Regmi*** (regmid@farmingdale.edu), 2350 Broadhollow Road, Farmingdale, NY 11735. *The global regularity of Magnetohydrodynamic equations.*

Whether the classical solutions of two-dimensional incompressible ideal Magnetohydrodynamic equations can develop a finite time singularity from smooth initial data with finite energy is an outstanding open problem in fluid dynamics. In this presentation, we discuss some recent results related to two-dimensional and two-and-half dimensional Magnetohydrodynamic equations. (Received January 26, 2016)

1118-35-41 **Yongjin Lu*** (ylu@vsu.edu). *Strong 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 control. The results depend on the strength of the feedback control and the geometry of the interface. (Received January 13, 2016)

1118-35-48 **Stefanos Aretakis*** (aretakis@princeton.edu), Fine Hall, PRINCETON, NJ 08540. *Stability and scattering problems for black hole backgrounds.*

I will present results on stability and scattering problems for black holes backgrounds. These results concern both sub-extremal and extremal black holes. I will also review various applications of our methods in related topics. (Received January 17, 2016)

1118-35-50 **Xinliang An*** (xan@math.rutgers.edu), Hill Center for the Mathematical Sciences, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. *On gravitational collapse in general relativity.*

In this talk, we will address and seek the answers to three questions: 1) Can "black holes" form dynamically in vacuum? 2) To form a "black hole", what is the least size of initial data? 3) For Einstein vacuum equation, could singularities other than black hole type emerge in gravitational collapse?

This talk is based on two joint works. One is with Jonathan Luk, and the other one is with Xuefeng Zhang. (Received January 17, 2016)

1118-35-74 **Steven Derochers*** (sjderoch@ncsu.edu), Department of Mathematics, Box 8205, NC State University, Raleigh, NC 27695-8205. *On the semigroup generator for the total linearization of a hydro-elasticity model.* Preliminary report.

The finite element method is an effective tool in obtaining numerical approximations to solutions of linear boundary value problems. In this talk, we will apply a finite element method to investigate a fluid structure system involving coupled flow. Due to the coupling, a nonstandard means to eliminate the pressure term is required and will use specific extensions into the solid domain. (Received January 21, 2016)

1118-35-94 **George Avalos**, **Irena M Lasiecka** and **Roberto Triggiani*** (r.triggiani@memphis.edu), Department of Mathematical Sciences, University of Memphis, Memphis, TN. *Heat-Structure interaction in 2-3 dimension: optimal rational decay rate by micro-local analysis.*

In this paper we consider a heat-structure interaction model (first step toward a fluid-structure interaction model) in 2 or 3 dimensions. It consists of a heat equation defined on an external domain coupled at the interface with a wave equation defined on an internal domain. Boundary coupling involves matching of the velocity of the wave and of the fluid and matching the normal stresses at the interface between the two domains. We take Initial Conditions in the domain of the generator of the strongly continuous contraction semi-group that models the entire coupled system. We then shows that the solutions decay as 1/t, asymptotically, thereby establishing the conjectured optimal decay rate. This improvement of past results is established via two main technical approaches: (i) a recent frequency domain characterization of the rational decay in terms of the resolvent operator evaluated on the imaginary axis; (ii) a microlocal analysis treatment to estimate a critical term involving two problematic boundary traces. (Received January 25, 2016)

1118-35-105 **Milena Stanislavova***, Department of Mathematics, 405, Snow Hall, University of Kansas, Lawrence, KS 66045, and **Atanas Stefanov** and **Sevdzhan Hakkaev**. *Periodic traveling waves of the short pulse equation:existence and stability.*

We construct various periodic traveling wave solutions of the Ostrovsky/Hunter- Saxton/short pulse equation and its KdV regularized version.For the regularized short pulse model with small Coriolis parameter, we describe a family of periodic traveling waves which are a perturbation of appropriate KdV solitary waves. We show that these waves are spectrally stable. For the short pulse model, we construct a family of traveling peakons with corner crests. We show that the peakons are spectrally stable as well. (Received January 26, 2016)

1118-35-106 **Shitao Liu*** (liul@clemson.edu), O-228 Martin Hall, Department of Mathematical Sciences, Clemson University, Clemson, SC 29634, and **Yang Yang**. *Determine a magnetic Schrödinger operator from partial data in an infinite slab.*

We consider an inverse boundary value problem with partial data in an infinite slab for the magnetic Schrdinger operator with bounded magnetic potential and electric potential. We show that the magnetic field and the electric potential can be uniquely determined, when the Dirichlet and Neumann data are given on either different boundary hyperplanes or on the same boundary hyperplanes of the slab. (Received January 26, 2016)

1118-35-113 **Bing-Yu Zhang*** (zhangb@ucmail.uc.edu), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221-0025, and **Shuming Sun**, **Emmanuel Trelat** and **Ning Zhong**. *On sharpness of the local Kato Smoothing property of dispersive wave equations.* Preliminary report.

Solutions of the Cauchy problem for general dispersive wave equation

$$w_t + iP(D)w = 0, \quad w(x,0) = q(x), \quad x \in \mathbb{R}^n,\ t \in \mathbb{R} \tag{1}$$

have been shown by Constatin and Saut to possess a local smoothing property:

$$q \in H^s(\mathbb{R}^n) \implies w \in L^2(-T,T; H^{s+\frac{m-1}{2}}_{loc}(\mathbb{R}^n))$$

where m is the order of the pseudo differential operator $P(D)$. This local smoothing property is now called the local Kato smoothing property which was first discovered by Kato for the KdV equation and implicitly shown by Sjölin for the linear Schrödinger equation. In this paper, taking the linear KdV and Schrödinger equations as examples, we show that the local Kato smoothing property possessed by the solutions of of (0.1) is sharp in the sense:

The solution w does not belong to the space $L^2(-T,T; H^{s+\frac{m-1}{2}+\epsilon}_{loc}(\mathbb{R}^n))$ for any $\epsilon > 0$, in general, if its initial value $q \in H^s(\mathbb{R}^n)$. (Received January 26, 2016)

1118-35-115 **Duong H. Phong**, **Sebastien Picard** and **Xiangwen Zhang*** (xiangwen@math.uci.edu), Department of Mathematics, University of California, Irvine, 510D Rowland Hall, Irvine, CA 92697. *Some estimates for complex Hessian equations.* Preliminary report.

The complex Hessian equation is a class of important fully nonlinear geometric elliptic equations which can be viewed as an intermediate equation between the Laplacian equations and the complex Monge-Ampère equations. In this talk, we will talk about some *a priori* estimates for a complex Hessian equation motivated from Fu-Yau's generalization of the Strominger system. This is a joint work with D. Phong and S. Picard. (Received January 27, 2016)

1118-35-116 **Atanas Stefanov*** (stefanov@ku.edu), 1460, Jayhawk Blvd., 415, Snow Hall, Lawrence, KS 66045, and **Vladimir Georgiev**, Largo Bruno Pontecorvo 5, 56127 Pisa, Italy. *Scattering of small solutions of the cubic NLSwith short range potential.* Preliminary report.

We consider the cubic nonlinear Schroedinger equation subjected to an even external potential V. We show scattering of odd small solutions, if the corresponding static Schroedinger operator $-\partial_{xx} + V$ does not support any eigenvalues nor resonance at zero. The proof follows a factorization method devised recently by Cuccagna-Georgiev-Visciglia for the same problem, where the power non-linearity is $|u|^{p-1}u, p > 3$. This is joint work, with V. Georgiev and A.R. Giammetta, both at University of Pisa. (Received January 27, 2016)

1118-35-122 **Meir Shillor*** (shillor@oakland.edu). *Variational-hemivariational quasistatic viscoelastic problem with normal compliance, friction and material damage.*

The talk describes a model for quasistatic frictional contact between a viscoelastic body and a reactive foundation. The constitutive law is assumed to be nonlinear as it contains material damage effects described by a parabolic differential inclusion. The process of contact is described by the normal compliance condition and a subdifferential frictional condition. A variational-hemivariational formulation of the problem is shown and the existence and uniqueness of its solution is shortly discussed. The proof is based on a surjectivity result for pseudomonotone coercive operators and a fixed point argument. (Received January 27, 2016)

1118-35-125 **Tristan C. Collins*** (tcollins@math.harvard.edu), **Gabor Szekelyhidi** and **Valentino Tosatti**. *Induction on dimension.*

I will discuss how, in some geometric problems in Kahler geometry, induction on dimension can be used to produce (possibly singular) barrier functions for elliptic and parabolic equations. The main focus will be on the Kahler-Ricci flow, or Monge-Ampere equation, and the J-flow. (Received January 27, 2016)

1118-35-134 **Baris Evren Ugurcan*** (beu4@cornell.edu), University of Western Ontario, Department of Mathematics, London, Ontario N6A 5B7, Canada. *Boundary value and trace problems on the Sierpinski Gasket.*

We talk about boundary value problems and trace theorems on the Sierpinski Gasket (SG). In the first part, after introducing a trace space on the line halving the SG (following several previous work by Strichartz et al.), we give L^p-estimates for $p > 1$ for the restriction and extension operators. In the second part, by using

a wavelet-type basis, we give a solution to a biharmonic boundary value problem and study the associated regularity theory. At the end, we talk about extension of these methods to the n-polyharmonic case, possibly by also bringing in tools from stochastic processes. (Received January 28, 2016)

1118-35-146 **Gieri Simonett*** (gieri.simonett@vanderbilt.edu). *On fluid flows and phase transitions.*

Moving surfaces are ubiquitous in many areas of mathematics and the applied sciences. In this talk I will introduce a thermodynamically consistent model for the motion of heat-conducting, viscous, incompressible two-phase fluids that may undergo phase transitions. The resulting model combines the Navier-Stokes equations with the Stefan problem. Existence of solutions and stability properties of equilibria will be investigated. (Received January 29, 2016)

1118-35-163 **Yuan Pei*** (ypei4@unl.edu), 1129 S 16TH ST, Lincoln, NE 68502. *Global well-posedness for the two-dimensional anisotropic MHD-Bénard system.* Preliminary report.

MHD-Bénard system has gained significant interests in recent years. We herein study the equations in two-dimensional space, with horizontal dissipation and vertical magnetic diffusion, and without thermal diffusivity. We improve the results by Du, etc, in terms of less dissipation and larger function space for the initial data, by using the techniques of Yudovich for Euler equations, as well as the space $\sqrt{L}$ introduced by Danchin, etc. (Received January 30, 2016)

1118-35-168 **Irena Lasiecka*** (lasiecka@memphis.edu), University of Memphis, Memphis, Tennesee 38152. *Mathematical theory of PDE-dynamics arising in fluid/flow-structure interactions.*

Fluid-structure interactions and flow-structure interactions are ubiquitous in nature. Problems such as attenuation of turbulence or flutter in an oscillating structure are prime examples of relevant applications. Mathematically, the models are represented by nonlinear Partial Differential Equations (Navier Stokes and nonlinear elasticity) defined in contiguous domains and displaying strong boundary-type coupling at the interface between the two media. Moreover, in most models, the dynamical character of the two PDEs evolving on their corresponding domains is different and the overall system displays a parabolic/hyperbolic coupling, separated by the interface. This provides for a rich mathematical structure opening the door to several unresolved problems in the area of nonlinear PDE's, dynamical systems and related harmonic analysis and geometry. This talk aims at providing a brief overview of recent developments in the area along with a presentation of the most recent advances addressing the issues of well-posedness and long time behavior of the corresponding evolutionary systems. (Received January 30, 2016)

1118-35-169 **Animikh Biswas**, **Ciprian Foias** and **Adam Larios*** (alarios@unl.edu), University of Nebraska-Lincoln, Department of Mathematics, 203 Avery Hall PO Box 880130, Lincoln, NE 68588. *Attractor for a coupled parabolic-hyperbolic system from ocean dynamics.*

The Boussinesq equations arise in the study of ocean flows. Recently, there has been much work on of the equations in the partial absence of dissipative terms, but certain restrictions on the assumptions resisted very sophisticated mathematics. I will discuss an approach which does not require these restrictions, and furthermore is done with more elementary techniques. Furthermore, the large-time behavior of a dissipative system can often be understood by studying its global attractor, which can contain deep information about its underlying structure. I will show that the notion of attractor can be extended to the Boussinesq system with only partial dissipation. We will see that this generalized attractor not only has a rich structure, but also encodes a wealth of turbulent phenomena in a single object. (Received January 30, 2016)

1118-35-201 **Beat Raphael Schaad*** (schaadbeat@gmail.com), 946 mississippi street, Lawrence, KS 66044. *Smoothing results for the Korteweg—de Vries equation(KdV).*

Consider the Schrödinger operator $L_q = -\partial_x^2 + q$, where $q(x)$ is a decaying potential. There is a scattering map S which assigns to q some spectral data of L_q. The remarkable point is that this map is invertible. This inverse scattering theory goes back to Faddeev. Furthermore there is the famous connection of inverse scattering to the Korteweg-de Vries equation (KdV) which goes back to Gardner, Green, Kruskal and Miura. In a work with A. Maspero we showed with the help of this approach that the KdV flow map is one smoothing. More precisely, we showed that solutions of the KdV equation can be approximated by solutions of the linearized KdV equation up to an error which has one square integrable derivative more.

In the periodic setting we showed using different methods that the KdV flow is one smoothing as well. This was a joint work with P. Topalov and T. Kappeler. (Received January 31, 2016)

1118-35-234 **Niels Martin Møller*** (moller@ictp.it), MSRI, and ICTP, Math Section, Room 121, Strada Costiera 11, I-34151 Trieste, Italy. *Title: Estimates on mean curvature flow solitons, with applications to nonexistence theorems.*

This talk will be concerned with techniques for getting a quantitative understanding of some important known translating solitons in the n-dimensional mean curvature flow (a quasilinear parabolic geometric PDE), in $\mathbb{R}^{n+1}$. The global estimates in question follow by iteration of simple monotonicity formulae, which allows one to cook up good test functions to use in a more direct maximum principle argument - an idea and technique which, while quite elementary in nature, has been useful in several of such situations. The potential applications of better estimates are probably many. I will focus mostly on some new nonexistence theorems which follow, again from a maximum principle. (Received February 01, 2016)

37 ► Dynamical systems and ergodic theory

1118-37-28 **Linda Keen*** (lkeen@gc.cuny.edu), Mathematics Program CUNY Graduate Center, 365 Fifth Avenue, New York, NY 10016. *Shell components of transcendental meromorphic maps.*

In this talk, based on joint work with Nuria Fagella, we will be concerned with some one (complex) dimensional slices of parameter spaces of transcendental meromorphic maps. Properties of components of these slices are controlled by the singularities of the functions. Hyperbolic components those that attract an asymptotic value are quite different from what one sees in parameter spaces of rational maps: they have a shell-like appearance and are called *Shell components*. In this talk we will define these components and discuss their properties. We will give examples of families where they occur. (Received January 06, 2016)

1118-37-37 **Michelle Chu***, University of Texas at Austin, Department of Mathematics, RLM 8.100, 2515 Speedway Stop C1200, Austin, TX 78712, and **Han Li**. *Small generators of cocompact arithmetic Fuchsian groups.*

In the study of Fuchsian groups, it is a nontrivial problem to determine a set of generators. Using a dynamical approach we construct for any cocompact arithmetic Fuchsian group a fundamental region in $\mathbf{SL}_2(\mathbb{R})$ from which we determine a set of small generators. (Received January 12, 2016)

1118-37-43 **Palle E. T. Jorgensen*** (palle-jorgensen@uiowa.edu), Dept Math MLH, University of Iowa, Iowa City, IA 52242. *Probability theory of infinite iterated function systems.*

The study of spectral duality for singular measures started with a joint paper, Jorgensen-Pedersen. In the case of affine IFS measures mu, when an associated complex Hadamard matrix is further assumed to satisfy an additional symmetry condition; then the $L^2(mu)$ Hilbert space will have an orthogonal Fourier basis; in other words we get an associated fractal Fourier transform. In order to appreciate the nature of the spectral duality, note that spectral duality holds for the middle-1/4 Cantor measure, but not for its middle-1/3 cousin. Typically the distribution of the associated Fourier frequencies satisfies very definite lacunary properties, in the form of geometric almost-gap distributions; the size of the gaps grows exponentially, with sparsity between partitions. The probabilistic significance will be explored. Use will be made of reproducing kernel Hilbert spaces of analytic functions. (Received January 14, 2016)

1118-37-53 **Han Peters*** (h.peters@uva.nl), P.O. Box 94248, 1090 GE Amsterdam, Netherlands. *Fatou components of Hénon maps with a dominating splitting.* Preliminary report.

A classical result states that every Fatou component of a rational function without critical points on its Julia set is eventually mapped onto a periodic parabolic or attracting basin. In joint work with Misha Lyubich we prove a corresponding statement for complex Hénon maps. (Received January 18, 2016)

1118-37-56 **Artem Dudko***, artem.dudko@stonybrook.edu. *On measure of the Feigenbaum fixed point Julia set.*

Based on A. Avila and M. Lyubich results we will present a new explicit probabilistic criteria to verify that the Julia set of the Feigenbaum fixed point of period-doubling renormalization has zero Lebesgue measure. The talk is based on an ongoing joint work with S. Sutherland. (Received January 18, 2016)

1118-37-69 **Zhiren Wang*** (zhirenw@psu.edu), McAllister Building,Department of Mathematics, Pennsylvania State University, University Park, PA 16801. *Mobius disjointness for analytic skew products.*

Sarnak's Mobius disjointness conjecture states that the Mobius function is disjoint to every topological dynamical system of zero entropy. In this talk, we will explain why this is true for every analytic skew product map on the two torus over a rotation of the circle of arbitrary rotation number. (Received January 20, 2016)

1118-37-86 **Michael Yampolsky*** (yampol@math.toronto.edu), Mathematics Department, University of Toronto, 40 St George Street, Toronto, ON M5S2E4, Canada. *On renormalization of critical circle maps and rotation domains.*

I will review some new results on renomalization of critical circle maps and rotation domains, and will discuss open questions and applications. (Received January 24, 2016)

1118-37-93 **Eric Bedford*** (ebedford@math.stonybrook.edu), Department of Mathematics, Stony Brook University, Stony Brook, NY 11794. *No smooth Julia sets for Henon maps.*

We will discuss the polynomial automorphisms of $\mathbb{C}^2$ of positive entropy. These are the finite compositions of complex Hénon maps. We will present a result, obtained jointly with Kyounghee Kim, that the forward and backward Julia sets for these maps are never smooth. Thus this family of automorphisms contains no mappings which are analogous to the 1-dimensional case, where there are the special maps $z \mapsto z^d$ and the Tchebyshev maps. (Received January 25, 2016)

1118-37-111 **Matthieu Astorg*** (mastorg@umich.edu), University of Michigan, Department of Mathematics, 530 Church Street, Ann Arbor, MI 48109. *Summability condition and rigidity for finite type maps.*

Finite type maps are a class of analytic maps on complex 1-manifolds introduced by Epstein, that notably include rational maps and entire functions with a finite singular set. Each of those maps possess a natural finite-dimensional moduli space, and one can define a Teichmüller space parametrizing their quasiconformal conjugacy class. Using the fact that the Teichmüller space immerses into moduli space, we will generalize rigidity results of Dominguez, Makienko and Sienra under assumption of expansion along the critical orbits. (Received January 26, 2016)

1118-37-124 **Asli Deniz** and **Carsten Lunde Petersen*** (lunde@ruc.dk), Roskilde University, Universitetsvej 1, DK-4000 Roskilde, Denmark. *Holomorphic Explosions.* Preliminary report.

We introduce a new notion holomorphic explosions and discuss some examples of its usage in holomorphic dynamics. The notion of holomorphic explosion is a relative of the notion of holomorphic motions. The concept of holomorphic explosions is motivated by a study of extension properties of holomorphic motions of subsets of $\mathbb{C}$ over punctured domains in $\mathbb{C}$. (Received January 27, 2016)

1118-37-148 **Shahriar Mirzadeh*** (shahmir@brandeis.edu), Brandeis Math Dept. MS:050, 415 South St., Waltham, MA 02453. *Dimension estimates for the set of points with non-dense orbit in homogeneous spaces.*

In this talk we study the set of points in a homogeneous space whose orbit escapes the complement of a fixed compact subset. We find an upper bound for the Hausdorff dimension of this set. This extends the work of Kadyrov, where he found an upper bound for the Hausdorff dimension of the set of points whose orbit misses a fixed ball of sufficiently small radius in a compact homogeneous space. We can also use our main result to produce new applications to Diophantine approximation. This is a joint work with Dmitry Kleinbock. (Received January 29, 2016)

1118-37-175 **E. Lindenstrauss**, **G. Margulis**, **A. Mohammadi*** (amir@math.utexas.edu) and **N. Shah**. *Effective density of unipotent orbits in homogeneous spaces.*

Let X be a homogeneous space, i.e. quotient of a Lie group G by a lattice in G. In this talk we will present a work in progress with Lindenstrauss, Margulis and Shah which provides an estimate on how large a piece of a unipotent orbit is needed so it comes within epsilon distance of any point in a given compact subset of X. This estimate depends on a certain diophantine property of the base point and the acting unipotent group. (Received January 31, 2016)

1118-37-176 **Dzmitry Dudko*** (dzmitry.dudko@gmail.com), Mathematisches Institut, Georg-August Universitaet Goettingen, Bunsenstrasse 3-5, 37073 Goettingen, Germany, and **Laurent Bartholdi**. *Algorithmic aspects of branched coverings.*

We give a report on a series of articles on the algorithmic study of Thurston maps. We describe branched coverings of the sphere in terms of group-theoretical objects called bisets, and develop a theory of decompositions of bisets. We introduce a canonical "Levy" decomposition of an arbitrary Thurston map into homeomorphisms, metrically-expanding maps and maps doubly covered by torus endomorphisms. The homeomorphisms decompose themselves into finite-order and pseudo-Anosov maps, and the expanding maps decompose themselves into rational maps.

As an outcome, we prove that it is decidable when two Thurston maps are equivalent. We also show that the decompositions above are computable, both in theory and in practice. (Received January 31, 2016)

1118-37-187 **Wenyu Pan*** (wenyu.pan@yale.edu), Yale University, Mathematics Dept., 10 Hillhouse Ave, New Haven, CT 06511. *Effective equidistribution of circles in the limit sets of Kleinian groups.*

Consider a general circle packing $\mathcal{P}$ in the complex plane $\mathbb{C}$ invariant under a Kleinian group Γ. When Γ is convex-cocompact or its critical exponent is greater than 1, we obtain an effective equidistribution for small circles in $\mathcal{P}$ intersecting any bounded connected regular set in $\mathbb{C}$; this provides an effective version of an earlier work of Oh-Shah. In view of the recent result of McMullen-Mohammadi-Oh, our effective circle counting theorem applies to the circles contained in the limit set of a convex-cocompact but non-cocompact Kleinian group whose limit set contains at least one circle. Moreover consider the circle packing $\mathcal{P}(\mathcal{T})$ of the ideal triangle in $\mathbb{H}^2$ attained by filling in largest inner circles. We give an effective estimate to the number of disks whose hyperbolic areas are greater than t, as $t \to 0$, effectivising the work of Oh. (Received January 31, 2016)

1118-37-196 **Saeed Zakeri*** (saeed.zakeri@qc.cuny.edu), 65-30 Kissena Blvd., Queens, NY 11367. *Angle-tripling rotation sets and cubic polynomials.*

Rotation sets under the angle-doubling map $t \mapsto 2t \pmod{\mathbb{Z}}$ of the circle play a key role in Douady-Hubbard's study of the quadratic family and the Mandelbrot set. This talk will consider a basic higher degree analog of this idea by investigating the link between rotation sets under the angle-tripling map $t \mapsto 3t \pmod{\mathbb{Z}}$ and one-dimensional families of cubic polynomials with a persistent indifferent fixed point. We discuss the structure of angle-tripling rotation sets and show how the parameter planes of cubic polynomials provide a concrete catalog of all these rotation sets. The emphasis will be on the less explored case of irrational rotation numbers. (Received January 31, 2016)

1118-37-197 **Antoni Brzoska***, Department of Mathematics, 196 Auditorium Road, Storrs, CT 06269-3009. *Spectral properties of the Hata Tree.*

The Hata tree is the unique self-similar set in the complex plane determined by the contractions $f_1(z) = c\bar{z}$ and $f_2(z) = (1-|c|^2)\bar{z} + |c|^2$, where c is a complex number such that $|c|, |1-c| \in (0,1)$. There are three main results. First, by applying linear algebra and spectral theory, it is possible to construct a six dimensional dynamical system that can compute the eigenvalues of the probablistic Laplacian on certain graph approximations to the Hata tree called blow-ups. It is also possible to compute the spectrum of the probabilistic Neumann Laplacian on the limiting infinite lattice. Second, the Sabot theory can be applied to construct a two dimensional dynamical system to compute the eigenvalues of a class of normalized graph Laplacians (including the probabilistic Laplacian) on these blow-ups. Third, it is possible to reconstruct the Hata tree as the union of two copies of a mixed affine nested fractal indentified at a point. It is possible to state results on the spectral asymptotics of the eigenvalue counting function of a certain class of Laplacians (not including the probabilistic Laplacian) on this mixed affine nested fractal. (Received January 31, 2016)

1118-37-200 **Luke Rogers**, Department of Mathematics, 196 Auditorium Road, Storrs, CT 06269-3009, **Antoni Brzoska**, Department of Mathematics, 196 Auditorium Road, Storrs, CT 06269-3009, **Stephen Loew***, Coe College, 1220 First Avenue NE, Cedar Rapids, IA 52402, **Madeline Hansalik**, Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843-3368, and **Aubrey Coffey**, Agnes Scott College, 141 E. College Ave., Decatur, GA 30030. *Magnetic spectral decimation on two-point model graphs.*

In a paper of Malozemov and Teplyaev, the authors show it is possible to use the technique of spectral decimation to compute the spectrum of probabilistic Laplacians on a sequence of symmetric self-similar graphs known as M-point model graphs. In this paper, these results are extended to magnetic Laplacians in the case where

$M = 2$. An example is worked out in the case of graph approximations to the diamond fractal. (Received January 31, 2016)

1118-37-202 **Araceli Bonifant*** (bonifant@uri.edu), Department of Mathematics, University of Rhode Island, 5 Lippitt Road, Lippitt Hall Room 202G, Kingston, RI 02881, and **Marius Dabija** and **John Milnor** (jack@math.stonybrook.edu), Institute for Mathematical Sciences, Stony Brook, NY 11794-3660. *Computing the transverse Lyapunov exponent along an invariant elliptic curve.*

We will describe the methods for computing the transverse Lyapunov exponent of a rational map along an invariant elliptic curve. (Received January 31, 2016)

1118-37-206 **Trevor Clark*** (trevorcclark@gmail.com), Department of Mathematics, Imperial College London, London, SW7 2AZ, United Kingdom, and **Sebastian van Strien**, Imperial College London. *Quasisymmetric rigidity.*

Rigidity plays a central role in the study of the dynamics of mappings in dimension one. It is the phenomenon that occurs when fairly weak information about a mapping, for example, its combinatorial or topological data, determines metric information about the mapping. In joint work with Sebastian van Strien, building on earlier work of Sebastian van Strien, Oleg Kozlovski and Weixiao Shen, we have proved quasisymmetric for a broad class of smooth mappings. I will survey some of the tools used to prove quasisymmetric rigidity and discuss some of its implications. (Received February 01, 2016)

1118-37-217 **R Cheung***, 10 Hillhouse Avenue, New Haven, CT 06511. *Quadratic diophantine inequalities.* Preliminary report.

We consider Diophantine inequalities for suitable classes of quadratic forms over number fields and estimate the growth of their number of solutions using recurrence theorems on the moduli space of lattices. (Received February 01, 2016)

1118-37-219 **Laura G DeMarco*** (demarco@northwestern.edu), Department of Mathematics, Northwestern University, 2033 Sheridan Road, Evanston, IL 60208, and **Sarah Koch**. *Postcritical configurations.*

We study the set of elements in the moduli space $\mathcal{M}_{0,n}$ that arise as the postcritical set for a postcritically finite rational map. For a given configuration $X \in \mathcal{M}_{0,n}$, we also address the question of which combinatorics can be realized as the restriction $f : X \to X$ for a postcritically finite f with $P(f) = X$. (Received February 01, 2016)

1118-37-224 **Dale Winter*** (dale.alan.winter@gmail.com). *Spectral gap in homogeneous dynamics via smooth dynamical tools.* Preliminary report.

We'll be interested in hyperbolic manifolds $X = \Gamma\backslash \mathrm{SO}(n,1)/\mathrm{SO}(n)$ for Γ a discrete subgroup, usually of infinite covolume. These objects are very often studied using the tools of homogeneous dynamics, and in particular using the representation theory of $\mathrm{SO}(n,1)$. Unfortunately this approach has serious difficulties when Γ is very sparse (more precisely when the critical exponent $\delta(\Gamma) < (n-1)/2$). I'll describe some of the efforts to fill this void, and some of the ideas from smooth dynamical systems that have gained traction. This is part of an intricate story that has been developed by many people and touches on areas as diverse as expander graphs, prime number theorems, sieve, and equidistribution of holonomies. (Received February 01, 2016)

1118-37-227 **Kathryn Dabbs*** (kdabbs@math.utexas.edu), **Michael Kelly** and **Han Li**. *Effective equidistrubution of translates of maximal horospherical measures in the space of lattices.*

Recently Mohammadi and Salehi-Golsefidy gave necessary and sufficient conditions under which certain translates of homogeneous measures converge, and they determined the limiting measures in the cases of convergence. The class of measures they considered includes the maximal horospherical measures. In this paper we prove the corresponding effective equidistribution results in the space of unimodular lattices, $\mathrm{SL}_n(\mathbb{R})/\mathrm{SL}_n(\mathbb{Z})$. We also prove the corresponding results for probability measures with absolutely continuous densities in rank two and three. Then we address the problem of determining the error terms in two counting problems also considered by Mohammadi and Salehi-Golsefidy. (Received February 01, 2016)

1118-37-261 **Tanya Firsova***, 138 Cardwell Hall 1228 N. 17th Street, Manhattan, KS, and **Jeremy Kahn** and **Nikita Selinger**. *Deformation spaces.*

I'll talk about deformation spaces of rational maps. (Received February 02, 2016)

1118-37-263 **John H. Hubbard*** (jhh8@cornell.edu), Cornell University, Department of Mathematics, 431 Malott Hall, Ithaca, NY 14853. *A new proof of Jakobson's theorem.*

Jakobson's theorem asserts that there is a set of c's of positive measure such that the real polynomial $x^2 + c$ admits an invariant measure absolutely continuous with respect to Lebesgue measure. The proof I will present is based on puzzles and tableaux, and eventually a probabilistic argument.

The text of this abstract is slightly different from that published in the program of the meeting.

(Revised version received March 14, 2016)

1118-37-264 **Remus Radu*** (rradu@math.stonybrook.edu), Institute for Mathematical Sciences, Stony Brook University, Stony Brook, NY 11794-3660. *Hedgehogs in higher dimensions and their applications.*

Hedgehogs in dimension one were introduced by Pérez-Marco in the '90s and proved to be an important tool for studying the dynamics of non-linearizable analytic germs. In this talk we discuss hedgehogs in dimension two for neutral dissipative holomorphic germs of $(\mathbb{C}^2, 0)$. This is based on joint work with T. Firsova, M. Lyubich, and R. Tanase. (Received February 02, 2016)

1118-37-265 **Michael Kelly*** (michaesk@umich.edu). *BD equivalence and return times for certain Heisenberg Nilflows.*

Laczkovic (1992) determined necessary and sufficient conditions under which a separated net in Euclidean space can be realized as a uniformly bounded perturbation of a lattice. In this talk we will report a generalization of Laczkovic's result in the Heisenberg group. Our main application of this result is a study of the regularity properties of the return times of certain Heisenberg nilflows. This is joint work with Tullia Dymarz, Sean Li, and Anton Lukyanenko. (Received February 02, 2016)

40 ► Sequences, series, summability

1118-40-249 **Sang Woo Kim** (williamkim0505@gmail.com), Shanghai American School, 258 Jinfeng Road Huacao Town, Minhang Dist., Shanghai 201107, Peoples Rep of China, and **Jay-Young Cho*** (cho.jay.young7@gmail.com), Demarest HS, 150 Knickerbocker Rd, Demarest, NJ 07627. *Optimization of the relations in social network nodes using numerical simulations.*

In many disciplines including computational science and sociology, the study of networks and analyzing their patterns and structures of the data is pervasive. Using geometrical models and their patterns, this research focuses on sequence data and network analysis. The branches of some of the complex social networks may support for a given proposal while others may be against it. The key to the analysis of the behaviors of complex social networks, is to obtain more efficient procedures or structures. This paper investigates the relationships among the nodes and vectors representing communications with other branches, for complex 3D social networks as well as 2D networks using numerical analysis. This problem is formulated as an optimization problem since when a complex social network achieves a pattern, the optimal calculation of the complex social network can be derived at the same time. To increase the efficiency, the total number of branches can be maximized or minimized. The approximated optimization problem is then solved via a conventional method, or through a computer numerical simulation, a comparison can be done of the behaviors of 2D social networks to the complex linear 3D social networks that are presented. (Received February 02, 2016)

41 ► Approximations and expansions

1118-41-84 **Robert Ravier*** (robert.ravier@duke.edu) and **Robert Strichartz** (str@math.cornell.edu). *Sampling with average values on the Sierpinski Gasket.*

In the case of some fractals, sampling with average values on cells is more natural than sampling on points. We investigate this method of sampling on SG and SG_3. In the former, we show that the cell graph approximations have the spectral decimation property and prove an analog of the Shannon sampling theorem. We also investigate the numerical properties of these sampling functions and make conjectures which allow us to look at sampling on infinite blowups of SG. In the case of SG_3, we show that the cell graphs have the spectral decimation property, but show that it is not useful for proving an analogous sampling theorem. (Received January 24, 2016)

1118-41-221 **Felipe A. Ramirez*** (framirez@wesleyan.edu), Wesleyan University, Middletown, CT.
Rational approximation of points lying on submanifolds of Euclidean space.

When a property holds for almost every point in Euclidean space, it is natural to ask whether it continues to hold generically on some submanifold of Euclidean space. So, for example, Khintchine's theorem gives a condition under which almost all points in Euclidean space are rationally approximable at some given rate. Does this condition still guarantee the same for almost all points on an embedded surface? I will discuss this, and other similar questions arising in Diophantine approximation. (Received February 01, 2016)

42 ► Fourier analysis

1118-42-256 **Han Jun Jeon** (hanjunjeon@gmail.com), Lehigh University, 27 Memorial Dr West, Bethlehem, PA 18015, and **Hayoung Kyung*** (hyk281@nyu.edu), NYU, 50 West Fourth St, New York, NY 10003. *Image processing using computational and numerical simulations.*

The different ways of selecting frequency, area of focus and low pass filters to produce a better MRI image are shown in this paper. A less ringing artifact was generated in the MRI image produced from the filter, which is narrow in frequency domain. However, the resolution was decreased as well. On the contrary, the image resolution can be improved by using a wider filter function; but doing so will cause inefficiencies such as an increase in execution time and ringing artifact to a degree. In this paper, to improve the resolution of the MRI images, several exponential functions using non-conventional algorithms were presented. An ideal low pass filter (LPF) frequency would be able to increase the resolution of the MRI image as well as decrease the Ringing Artifact. A huge amount of time and computational operation in the simulation is required for the process of transformation, from a physical spatial frequency to image domain. Time-efficiency is therefore resulted from manipulating the data to exclude certain amounts of high or low frequencies in k-space. This research strives to develop a better physical and computational algorithm that would not only enhance the quality of the final image, but also decrease the amount of time taken to produce the image. (Received February 02, 2016)

43 ► Abstract harmonic analysis

1118-43-75 **krystal taylor***, The Ohio State University. *Fractional maximal operators and intersections of sets.*

We establish L^p bounds for the Bourgain-Stein spherical maximal operator in the setting of compactly supported Borel measures μ, ν satisfying natural local size assumptions $\mu(B(x,r)) \leq Cr^{s_\mu}, \nu(B(x,r)) \leq Cr^{s_\nu}$. Taking the supremum over all $t > 0$ is not in general possible for reasons that are fundamental to the fractal setting, but we are able to obtain single scale ($t \in [1,2]$) results. As an application, we consider to what extent it is possible to obtain a lower bound on the dimension of a set from a lower bound on the dimension of the intersection of this set with a suitably large collection of manifolds. (Received January 21, 2016)

46 ► Functional analysis

1118-46-18 **Buthinah Bin Dehaish*** (bbendehaish@kau.edu.sa), Department of Mathematics, Science College, Jeddah, 21593, Saudi Arabia. *An approximation of monotone Lipchitzian mappings on Banch Spaces.*

Let $(X, \|.\|)$ be a Banach space. Let C be a nonempty, bounded, closed, and convex subset of X and $T : C \to C$ be a monotone Lipchitzian mapping. In this talk we will study the convergent of the fixed point of Lipchitzian by using a successive iteration process. (Received December 02, 2015)

1118-46-29 **Gareth Speight*** (gareth.speight@uc.edu), Department of Mathematical Sciences, 4199 French Hall West, University of Cincinnati, Cincinnati, OH 45221. *A measure zero universal differentiability set in the Heisenberg Group.*

The Heisenberg group $\mathbb{H}^n$ is a metric measure space equipped with translations and dilations. Lipschitz functions on $\mathbb{H}^n$ are Pansu differentiable almost everywhere, but $\mathbb{H}^n$ admits no bilipschitz embedding into a Euclidean space. We show there exists a measure zero 'universal differentiability set' in $\mathbb{H}^n$ containing a point of Pansu differentiability for every real-valued Lipschitz function. The proof adapts techniques from Banach space theory, showing that existence of an 'almost maximal' directional derivative implies Pansu differentiability. Joint work with Andrea Pinamonti. (Received January 07, 2016)

1118-46-99 **Zead Mustafa*** (zead@qu.edu.qa), Math, Stat & Physics Dept., Qatar University, Doha, Doha 2713, Qatar, and **Vahid Parvaneh**, **Jamal Rezaei Roshan** and **Zoran Kadelburg**. *b2-Metric spaces and some fixed point theorems.*

The aim of this paper is to establish the structure of b2-metric spaces, as a generalization of 2-metric spaces.Some fixed point results for various contractive-type mappings in the context of ordered b2-metric spaces are presented. We also provide examples to illustrate the results presented herein, as well as an application to integral equations. (Received January 26, 2016)

1118-46-181 **Luke G Rogers*** (luke.rogers@uconn.edu). *Magnetic operators on resistance spaces.*

We may model a quantum particle on a fractal substrate in a magnetic field by a magnetic operator based on a fractal Laplacian. Sufficient conditions for the existence of a self-adjoint magnetic operator in the case that the substrate admits a resistance form were found by Michael Hinz and the author. Spectral properties in the special case of the Sierpinski Gasket with a locally exact magnetic field will also be discussed. The latter results are from a collaboration with Jessica Hyde, Jesse Muller, Daniel Kelleher and Luis Seda. (Received January 31, 2016)

1118-46-195 **Ulysses A Andrews*** (ulysses.andrews@uconn.edu). *The existence and uniqueness of diffusions on infinitely ramified $4N$ gaskets.*

Following the methods used by Barlow and Bass to prove the existence of a diffusion on the Sierpinski Carpet we establish the existence of a diffusion for a class of planar fractals which are not post critically finite. As a corollary, we establish the existence of a diffusion on the Octagasket, thus answering a question posed by Strichartz. By following the Barlow-Bass proof of a uniform elliptic Harnack inequality we can give heat kernel asymptotics and resistance estimates for the above class of fractals. This allows us to use the techniques of Barlow, Bass, Kumagai, and Teplyaev to establish the uniqueness of the diffusion. (Received January 31, 2016)

1118-46-198 **Michael Hinz**, **Maria Rosaria Lancia**, **Alexander Teplyaev*** (teplyaev@uconn.edu) and **Paola Vernole**. *Fractal snowflake domain diffusion with boundary and interior drifts.*

We study a (elliptic measurable coefficients) diffusion in the classical snowflake domain in the situation when there are diffusion and drift terms not only in the interior but also on the fractal boundary, which is a union of three copies of the classical Koch curve. In this example we can combine the fractal membrane analysis, the vector analysis for local Dirichlet forms and quasilinear PDE and SPDE on fractals, non-symmetric Dirichlet forms, and analysis of Lipschitz functions. We show that intrinsic derivatives on the fractal can be defined in a certain point-wise sense, and that an weakly self-similar family globally Lipschitz functions are dense in the Domain of the Dirichlet form. (Received February 01, 2016)

1118-46-251 **Marius V Ionescu*** (ionescu@usna.edu), United States Naval Academy, Department of Mathematics, 572C Holloway Road, Chauvenet Hall, Annapolis, MD 21402, and **Kasso Okoudjou** and **Luke G Rogers**. *Some properties of Schrödinger Operators on the Sierpinski Gasket.* Preliminary report.

A generalized Schrödinger operator with potential χ on the Sierpinksi gasket K is an operator of the form $H = p(-\Delta) + [\chi]$, where $p : (0, \infty) \to \mathbb{R}$ is a measurable function. We consider Δ to be the Laplacian on the Sierpinski gasket defined by the self-similar measure on K. We show that Schrödinger operators on K with continuous symbol p and continuous potential χ satisfy a weak and a strong maximum principle. As an ingredient in the proof of the strong maximum principle, we prove a version of the Hopf lemma for Schrödinger operators on K. We describe next the asymptotics of clusters of eigenvalues of a generalized Schrödinger operator in terms of the symbol p. Our latter results generalize earlier work of Okoudjou and Strichartz. This talk is based on joint work with Kasso Okoudjou and Luke G. Rogers. (Received February 02, 2016)

49 ► Calculus of variations and optimal control; optimization

1118-49-103 **Jessica Merhej*** (jem05@uw.edu), Department of Mathematics, University of Washington, Box: 354350, Seattle, WA 98195. *On the geometry of rectifiable sets with Carleson and Poincaré-type conditions.*

A central question in Geometric Measure Theory is the study of whether geometric properties of a set translate into analytical ones. For example, a plane can be written as the graph of a linear function. In 1960, E. R. Reifenberg proved that if a set is well approximated by planes at every point and at every scale, then the set is

a bi-Hölder image of a plane. In this talk, we discuss conditions that ensure that a subset of $\mathbb{R}^{n+1}$ is in fact a subset of a bi-Lipschitz image of an n-plane. Our conditions are motivated by ideas arising in harmonic analysis and metric geometry. (Received January 26, 2016)

1118-49-119 **Frank Morgan*** (fmorgan@williams.edu). *Isoperimetric problems with density.*
Since their appearance in Perelman's proof of the Poincaré Conjecture, there has been a huge surge of interest in spaces with density and the isoperimetric problem. We describe some recent results and open problems. (Received January 27, 2016)

51 ► Geometry

1118-51-23 **Jane Piore Gilman*** (gilman@rutgers.edu). *Primitive curve lengths on pairs of pants, intersection numbers and seam lengths.*
We review the non-Euclidean Euclidean Algorithm and use it to find new inequalities for primitive curve length, essential self-intersection numbers and seam lengths on pairs of pants. (Received January 07, 2016)

1118-51-27 **Kasra Rafi***, Department of Mathematics, 40 St. George Street, Toronto, ON M5S 2E4, Canada, and **Maxime Fortier Bourque**. *Balls in Teichmüller space are not convex.* Preliminary report.
We prove that when 3g - 3 + p > 3, the Teichmüller space of the closed surface of genus g with p punctures contains balls which are not convex in the Teichmüller metric. We analyze the quadratic differential associated to a Teichmüller geodesic and, as a key step, show that the extremal length of a curve (as a function of time) can have a local maximum. (Received January 06, 2016)

1118-51-78 **Bram Petri*** (brampetri@gmail.com), Bonn, Germany. *Typical and atypical hyperbolic surfaces.*
In this talk I will speak about a combinatorial construction of compact hyperbolic surfaces. This construction gives rise to a countable yet dense subset of every moduli space of compact hyperbolic surfaces.

I will speak about two ways to use this construction. First of all, it can be randomized, which makes it possible to say something about the geometry of a typical hyperbolic surface. On the other hand, it can also be used to construct surfaces with unusual geometric properties. In particular, I will speak about joint work with Alex Walker, in which we used them to construct surfaces with large systoles. (Received January 22, 2016)

1118-51-120 **Viveka Erlandsson*** (viveca.erlandsson@aalto.fi). *Counting curves on hyperbolic surfaces.*
In this talk I will discuss the growth of the number of closed geodesics of bounded length, as the length grows. More precisely, let γ be a closed curve on a hyperbolic surface $\Sigma = \Sigma(g, n)$ and let $S_\gamma(L)$ denote the number of curves in the mapping class orbit of γ with length bounded by L. Due to Mirzikhani it is known that in the case that γ is simple this number is asymptotic to $L^{6g-6+2n}$. Here we consider the case when γ is an arbitrary closed curve, i.e. not necessarily simple. This is joint work with Juan Souto. (Received January 27, 2016)

1118-51-210 **Federica Fanoni*** (federica.fanoni@gmail.com). *Filling sets of curves and systoles.*
A set of curves on a surface is filling if there is no simple closed curve disjoint from the set, or equivalently if it cuts the surface into a union of disks with at most one puncture.

I will talk about bounding the size of filling sets of curves with restrictions on the number of intersections and discuss what happens if we endow the surface with a hyperbolic metric and we require the curves to be systoles. Joint work with Hugo Parlier. (Received February 01, 2016)

1118-51-239 **John Duncan***, 400 Dowman Drive, W401, Atlanta, GA 30322. *Sigma Models and VOAs.*
It has been understood for some time that (suitably restricted) vertex operator algebras should serve as "chiral halves" of two-dimensional conformal field theories. We will describe a recent result that suggests a different role for vertex operator algebra in physics. (Received February 01, 2016)

1118-51-245 **Or Hershkovits*** (or.hershkovits@cims.nyu.edu), 251 Mercer Street, New York, NY 10012. *Mean curvature flow of Reifenberg Sets.*
In this talk, we will discuss the short time existence and uniqueness of smooth mean curvature flow in arbitrary dimension starting from a class of sets which is general enough to include some fractal sets (for which even the area is not defined).Those so-called (ε, R) Reifenberg sets have a weak metric notion of a tangent hyper-plane

at every point and scale $r < R$ (with accuracy determined by ε), but those tangents are allowed to tilt as the scales vary.

We show that if X is an (ε, R) Reifenberg set with ε sufficiently small, there exists a unique smooth mean curvature flow emanating from X. When $n > 1$, this provides the first known example of instant smoothing, by mean curvature flow, of sets with Hausdorff dimension larger than n.

A corresponding result in high co-dimensions generalizes (qualitatively) all short time existence and uniqueness results for high co-dimensional mean curvature flow. (Received February 02, 2016)

1118-51-246 **Chris Arettines*** (chris.arettines@gmail.com), NY. *Algorithmic solutions to topological questions about closed geodesics on surfaces.*

Given a closed curve presented as a word in the fundamental group of a surface, we will present an algorithm which determines a configuration for the curve which self-intersects minimally, and an algorithm which determines whether the complement of the curve is a disjoint union of topological disks. We will then show how these algorithms can be used to investigate various questions related to closed geodesics. (Received February 02, 2016)

1118-51-260 **Robert Suzzi Valli*** (robert.suzzivalli@manhattan.edu). *Non-simple closed geodesics on orbifolds.*

If $\mathbb{H}$ is the hyperbolic plane and Γ is a Fuchsian group, then the quotient $X = \mathbb{H}/\Gamma$ is an orbifold surface. In the case that Γ contains elliptic elements, their fixed points in $\mathbb{H}$ project to cone points on X. The presence of cone points requires a finer notion of paths and homotopy on X with the goal of defining the orbifold fundamental group, $\pi_1(X, b)$, and obtaining an isomorphism between $\pi_1(X, b)$ and Γ. With this at our disposal we will study once self-intersecting closed geodesics on X which are disjoint from the cone points, called *figure eight geodesics*. Among other things, we identify the shortest figure eight geodesic on a triangle group orbifold, and then use this to find the shortest figure eight geodesic among all orbifold surfaces without cone points of order two. (Received February 02, 2016)

52 ► Convex and discrete geometry

1118-52-85 **Sergey Yuzvinsky*** (yuz@uoregon.edu), Dept. of Mathematics, University of Oregon, Eugene, OR 97405. *On free line arrangements.* Preliminary report.

An arrangement of hyperplanes is free if its module of derivations is free. The most intriguing question about free arrangements is the question by H. Terao whether the property of being free is determined by the intersection poset. The answer to this question is not known even for (affine) line arrangements.

A result by the speaker of 1993 reduced this question to studying dimensions of a finite number of homogeneous components of a certain graded linear space - the global sections of a sheaf on the intersection poset. For zero-dimensional sections the question was answered. In the talk we will discussed the sections of dimension one. (Received January 24, 2016)

1118-52-121 **Christopher Bishop***, Dept of Mathematics, Stony Brook University, Stony Brook, NY 11794-3651, and **Dennis Sullivan** and **Michael Wigler**. *Planar maps with at most six sides on average.*

Given a decomposition of the plane into infinitely many cells or countries, how many neighbors can a country have, on average? Suppose that the diameters of the countries are bounded above, that the areas are bounded away from zero, and that we compute averages over the sub-maps defined by containment in an expanding region $tR + x$ (R is a fixed region, $t > 0$ is a dilation factor, and $x \in \mathbb{R}^2$ is a translation factor). Then for any $\epsilon > 0$, we prove the limsup of the average number of sides is bounded by 6 as $t \to \infty$. The area and diameter conditions are both sharp in the sense that dropping either one allows counterexamples. A weaker conclusion still holds if we don't bound the cell sizes, but control their shapes instead (e.g., convex with bounded aspect ratio). In this case, there is some sequence of expanding sub-maps along which the average number of sides tends to a limit ≤ 6. (Received January 27, 2016)

1118-52-170 **Christin Bibby*** (cbibby2@uwo.ca). *Representation stability for the cohomology of arrangements.* Preliminary report.

We consider a sequence of linear, toric, or elliptic arrangements arising from one of the families of root systems of type A, B, C, or D. The complement to one of these arrangements has an action of the corresponding Weyl

group, giving an action on its cohomology. We study the stability of the rational cohomology as a sequence of Weyl group representations. (Received January 30, 2016)

1118-52-192 **Max Douglas Wakefield*** (wakefiel@usna.edu), 572-C Holloway Rd, Depatment of Mathematics, US Naval Academy, Annapolis, MD 21402. *Flag incidence algebras.* Preliminary report.

For any locally finite poset $(P, \leq)$ the classical incidence algebra is the set of functions from $P \times P$ to some ring R that are zero on incomparable elements. We consider instead functions from P^n for $n > 2$ to some ring R that are zero on non-flag (or non-chain) sequences of elements. Using these flag incidence algebras one can define generalized Möbius functions, Whitney numbers, characteristic polynomials, and so on. Then we develop some formulas with these generalized Whitney numbers. This leads to some formulas for certain coefficients of the so called matroid Kazhdan-Lusztig polynomials. (Received January 31, 2016)

53 ► Differential geometry

1118-53-19 **Pei-Ken Hung***, Rm 408, MC 4424, 2990 Broadway, New York, NY 10027. *The Gibbons-Penrose inequality.*

The Gibbons-Penrose inequality, like the Penrose inequality, is a conjecture proposed by Penrose as a test of the weak consmic censorship. It's also a spacetime generalization of the Minkowski inequality. I will discuss the heuristic argument of Penrose and some known results in this direction. (Received December 08, 2015)

1118-53-32 **Valentino Tosatti*** (tosatti@math.northwestern.edu), 2033 Sheridan Road, Evanston, IL 60208, and **Xiaokui Yang**. *Compact Kähler manifolds with nonpositive holomorphic sectional curvature.*

I will discuss our proof of the following result: if a compact Kähler manifold has nonpositive holomorphic sectional curvature then its canonical bundle is nef, and if the holomorphic sectional curvature is strictly negative then the canonical bundle is ample. The second statement confirms a conjecture of Yau, and was proved by Wu-Yau when the manifold is projective. (Received January 11, 2016)

1118-53-35 **Valentino Tosatti*** (tosatti@math.northwestern.edu), 2033 Sheridan Road, Evanston, IL 60208. *Collapsing of the Kähler-Ricci flow.*

I will discuss the collapsing behavior of the (suitably normalized) Ricci flow on a compact Kähler manifold, as time goes to infinity (assuming that a long-time solution exists). Assuming that the manifold fibers over a lower-dimensional base (which as I will explain is a very natural assumption), the flow shrinks the smooth fibers and collapses to a twisted Kähler-Einstein metric on the base. Most of these results come from joint works with Gross, Hein, Weinkove, Yang and Zhang. (Received January 11, 2016)

1118-53-47 **Po-Ning Chen*** (pnchen@math.columbia.edu), Room 505, MC 4404 2990 Broadway, New York, NY 10027. *Quasi-local energy for spacetimes with a cosmological constant.*

In this talk, we discuss the question of defining quasi-local energy and for surfaces in spacetimes with a cosmology constant. We follows the ideas and techniques developed in studying the Wang-Yau quasi-local energy. For spacetimes with a cosmologcial constant, we use the de Sitter or Anti de Sitter space with the corresponding cosmology constant as the reference space to define the quasi-local energy. We will discuss the properties of the newly defined quasi-local energy and show that many of the results about the Wang-Yau quasi-local energy can be generalized to the new setting. The talk is based on joint work with Mu-Tao Wang and Shing-Tung Yau. (Received January 17, 2016)

1118-53-49 **Yakov M Shlapentokh-Rothman*** (yshlapen@math.princeton.edu), Fine Hall, Washington Road, Princeton, NJ 08544. *Time-periodic Einstein-Klein-Gordon bifurcations Of Kerr.*

For a positive measure set of Klein-Gordon masses $\mu^2 > 0$, we construct one-parameter families of solutions to the Einstein-Klein-Gordon equations bifurcating off the Kerr solution such that the underlying family of spacetimes are each an asymptotically flat, stationary, axisymmetric, black hole spacetime, and such that the corresponding scalar fields are non-zero and time-periodic. An immediate corollary is that for these Klein-Gordon masses, the Kerr family is not asymptotically stable as a solution to the Einstein-Klein-Gordon equations. This is joint work with Otis Chodosh. (Received January 17, 2016)

1118-53-52 **C. Sormani** (sormanic@member.ams.org) and **Iva Stavrov*** (istavrov@lclark.edu). *On intrinsic flat stability of the Positive Mass Theorem.* Preliminary report.

The rigidity part of the Positive Mass Theorem states that the only asymptotically flat 3-manifold with nonnegative scalar curvature, vanishing ADM mass, and empty or compact outermost minimal boundary is the Euclidean space. It has furthermore been conjectured that a sequence of pointed asymptotically flat 3-manifolds whose ADM mass converges to zero must converge in the pointed intrinsic flat sense to Euclidean space; here we assume that the manifolds have nonnegative scalar curvature, that their boundaries are outmost minimal, and that they are centered on well chosen points which do not disappear down increasingly deep wells. The conjecture has been proven in the rotationally symmetric (by work of Lee-Sormani) and graph settings (by work of Huang-Lee-Sormani). It is also known (by work of Lee-Sormani) that the conjecture is false if intrinsic flat convergence is replaced by a stronger form of convergence. This talk will address some recent results regarding the conjecture in the context of geometrostatic (Brill-Lindquist) manifolds. (Received January 18, 2016)

1118-53-55 **Jeffrey Jauregui*** (jaureguj@union.edu) and **Dan Lee**. *Lower semicontinuity of the ADM mass for C^0 convergence.*

In joint work with Dan Lee, we study the behavior of the ADM mass for a convergent sequence of asymptotically flat manifolds. The main result is that the mass cannot increase when passing to the limit, for pointed C^0 Cheeger-Gromov convergence (under natural and necessary hypotheses of nonnegative scalar curvature and the absence of interior horizons). Because of the lower regularity convergence, we rely heavily on Huisken's isoperimetric mass concept. (Received January 18, 2016)

1118-53-67 **Song Sun***, Department of mathematics, Stony Brook University, Stony Brook, NY 11794, and **Xiuxiong Chen** and **Bing Wang**. *Kahler-Ricci flow, Kahler-Einstein metric, and K-stability.*

We study the asymptotic behavior of certain canonical geometric flows on projective manifolds, and relate it to algebraic stability and "optimal degenerations". For Kahler-Ricci flow on Fano manifolds this leads to a new proof of the Kahler-Einstein result. This also has applications to Calabi flow, and possibly in the future to other geometric problems. Some interesting questions will be discussed. (Received January 20, 2016)

1118-53-76 **Ovidiu Munteanu*** (ovidiu.munteanu@uconn.edu), University of Connecticut, 196 Auditorium Rd, Unit 3009, Storrs, CT 06268. *Interior estimate for the Ricci flow.*

We show that the norm of the Riemann curvature tensor of any smooth solution of the Ricci flow can be explicitly estimated in terms of its initial values on a given ball, a local uniform bound of the Ricci tensor and the elapsed time. (Received January 22, 2016)

1118-53-108 **Gang Liu***, 970 Evans Hall. *On the volume growth of Kahler manifolds with nonnegative bisectional curvature.*

Let M be a complete Kahler manifold with nonnegative bisectional curvature. Suppose there exists a nonconstant polynomial growth holomorphic function, we prove M is of maximal volume growth, provided the universal cover is not splitting. (Received January 26, 2016)

1118-53-117 **Karsten Gimre*** (gimre@math.columbia.edu), Room 509, MC 4406, 2990 Broadway, New York, NY 10027. *Local solvability of the optimal isometric embedding equation.*

The Wang-Yau prescription for quasilocal gravitational energy is defined by the infimization of an integral quantity which involves the isometric embedding problem. We will discuss a local solvability result for the corresponding Euler-Lagrange equation. (Received January 27, 2016)

1118-53-123 **Tristan C. Collins*** (tcollins@math.harvard.edu), **Adam Jacob** and **Shing-Tung Yau**. *The deformed Hermitian-Yang-Mills equation.*

The deformed Hermitian-Yang-Mills equation is a complexification of the Monge-Ampere equation which arises from Mirror Symmetry. I will discuss the existence of solutions to this equation, and state some conjectures relating existence to stability. (Received January 27, 2016)

1118-53-137 **Spiro Karigiannis*** (karigiannis@uwaterloo.ca), Department of Pure Mathematics, University of Waterloo, 200 University Avenue West, Waterloo, ON N2L 3G1, Canada. *Octonionic-algebraic structure and curvature of the moduli space of G_2 manifolds.* Preliminary report.

Let M be a compact irreducible G_2 manifold. The moduli space $\mathcal{M}$ of torsion-free G_2 structures on M is a smooth manifolds with an affine Hessian structure. Moreover, it carries a symmetric cubic form and a symmetric quartic form. These tensors are closely related to the curvature of the moduli space, and are built using a particular

algebraic structure on 2-tensors on M that is closely related to the octonions. I will explain all of these ideas, and hopefully end with a theorem about estimates on the curvature. This is work in progress with Christopher Lin and John Loftin. (Received January 28, 2016)

1118-53-139 **Jason D Lotay*** (j.lotay@ucl.ac.uk). *Laplacian flow in G_2 geometry.*
A key challenge in Riemannian geometry is to find Ricci-flat metrics on compact manifolds, which has led to fundamental breakthroughs, particularly using geometric analysis methods. All non-trivial examples of such metrics have special holonomy, and the only special holonomy metrics which can occur in odd dimensions must be in dimension 7 and have holonomy G_2. I will describe recent progress on a proposed geometric flow method for finding metrics with holonomy G_2, called the Laplacian flow. This is joint work with Yong Wei (University College London). (Received January 28, 2016)

1118-53-141 **Yu Li*** (yli427@wisc.edu), 480 Lincoln Drive, Madison, WI 53706. *Ricci Flow on asymptotically Euclidean Manifold.*
In this talk, we will discuss some properties of asymptotically Euclidean manifold under Ricci flow and how those results are related to the positive mass theorem. (Received January 28, 2016)

1118-53-144 **Sirin Aktay*** (sirins@anadolu.edu.tr) and **Nulifer Ozdemir**. *G_2 Structures and almost contact metric structures deformed by vector fields.*
In this study, we give some recent results on deformations of manifolds with G_2 structures by vector fields together with examples. We also study the deformation of almost contact metric structures induced by G_2 structures and investigate the class of the new almost contact metric structure obtained by the deformation. (Received January 29, 2016)

1118-53-161 **Justin Corvino*** (corvinoj@lafayette.edu). *Deformation of the Einstein constraints with the dominant energy condition.*
We discuss the extension of localized deformation results for the Einstein constraints map in the setting of the dominant energy condition, with applications to gluing and density theorems. Particular care must be taken to achieve controlled localized perturbation where the dominant energy condition may not be strict. This work is joint with Lan-Hsuan Huang. (Received January 30, 2016)

1118-53-180 **Tristan C Collins** and **Gabor Szekelyhidi*** (gszekely@nd.edu). *Sasaki-Einstein metrics and K-stability.*
We show that a polarized affine variety admits a Ricci flat Kähler cone metric, if it is K-stable. This generalizes Chen-Donaldson-Sun's solution of the Yau-Tian-Donaldson conjecture to Kähler cones, or equivalently, Sasakian manifolds. As an application we show that the five-sphere admits infinitely many families of Sasaki-Einstein metrics. (Received January 31, 2016)

1118-53-203 **Hung Tran*** (hungtt1@uci.edu). *The Bochner-Weitzenböck formula and applications.*
We discuss various Bochner-Weitzenböck formulas and their applications to study special metrics, including gradient Ricci solitons and harmonic Weyl. Rigidity results are obtained. (Received January 31, 2016)

1118-53-204 **Sema Salur*** (sema.salur@rochester.edu), UR Mathematics 915 Hylan Building, University of Rochester RC Box 270138, Rochester, NY 14627. *Manifolds with special holonomy and applications.* Preliminary report.
Examples of n-dimensional Ricci flat manifolds are Riemannian manifolds whose holonomy groups Hol(g) are subgroups of SU(n), for n=2m, and subgroups of the exceptional Lie group G_2, for n=7. We call them Calabi-Yau and G_2 manifolds, respectively. They are also examples of manifolds with special holonomy. Calibrated submanifolds of Calabi-Yau and G_2 manifolds are volume minimizing in their homology classes and their moduli spaces have many important applications in geometry, topology and physics. In this talk we give a report of recent research on the calibrations inside the manifolds with special holonomy. (Received January 31, 2016)

1118-53-207 **Mustafa Kalafat*** (mkalafat@tunceli.edu.tr), Tunceli Üniversitesi, Mekatronik Mühendisliği Bölümü, Aktuluk, Tunceli 62000. *Algebraic topology of and coassociative-free immersions into G_2 holonomy Riemannian 7-manifolds.*
In this talk, we give a survey of various results about the topology of oriented Grassmannian bundles related to the exceptional Lie group G_2. Some of these results are new. One often encounters these spaces when studying submanifolds of manifolds with calibrated geometries. As an application we deduce existence of certain special 3 and 4 dimensional submanifolds of G_2 holonomy Riemannian manifolds with special properties. These are called Harvey-Lawson(HL) pairs. They appeared first in the work of Akbulut & Salur about G_2 dualities. Another

application is to the coassociative-free embeddings. We show that if there is a coassociative-free embedding of a 4-manifold into the Euclidean 7-space then the signature vanishes along with the Euler characteristic. The converse of this theorem is proved in the more general sense by İ.Ünal using h-principle techniques. We will talk about this direction if time permits. Joint work with S.Akbulut and İ.Ünal. (Received February 01, 2016)

1118-53-213 **Ibrahim Unal*** (iunal@metu.edu.tr), Middle East Technical University, Department of Mathematics, 06800 Ankara, Turkey. *An application of h-Principle to calibrated manifolds.*

Plurisubharmonic functions and pseudo-convexity in complex geometry are canonically generalized to any calibrated manifold (X, ϕ) by Harvey and Lawson. Quite a few results proved in complex geometry via plurisubharmonic functions are also extended to calibrated manifolds. One important example of these results is the notion of ϕ-free submanifolds, the analogues of the totally real submanifolds, which are used to construct families of strictly ϕ-convex domains with different topological types.

Similar to totally real embeddings in complex manifolds we prove that the h-principle holds for ϕ-free embeddings for coassociative calibration in G_2-manifolds, for Cayley calibration in $Spin(7)$-manifolds and for quaternionic calibration in Quaternion/Hyper-Kähler manifolds. Hence, we get important results about the topology of ϕ-free submanifolds, especially in G_2-geometry.

In this talk, after a quick introduction to calibrated manifolds, I will try to explain similarities between complex and calibrated geometries via these new concepts and results. For the rest, I will talk about the geometry of ϕ-free submanifolds and discuss the h-principle for ϕ-free embeddings of closed manifolds into G_2 and $Spin(7)$-manifolds. (Received February 01, 2016)

1118-53-215 **Hans-Joachim Hein*** (hein@umd.edu) and **Claude LeBrun**. *Mass in Kahler geometry.*

In General Relativity, isolated gravitating systems are modeled by complete Riemannian 3-manifolds asymptotic to flat $\mathbb{R}^3$ at infinity. The "mass" of such a manifold is a real number defined in terms of the higher order asymptotics of the metric. As its name suggests, in the examples coming from physics, it represents the total mass of the gravitating system. From a mathematical point of view, it makes sense as an invariant of asymptotically (locally) Euclidean manifolds in all dimensions, and has been widely studied as such. We prove an explicit formula for the mass in the Kahler case, which implies the Positive Mass Theorem for Kahler manifolds. (Received February 01, 2016)

1118-53-220 **Mihai Bailesteanu*** (mihaib@ccsu.edu), 1615 Stanley Street, 120 Marcus White Hall, New Britain, CT 06050. *Applications of Harnack inequalities to nonlinear parabolic equations.*

Inspired by the work of Li-Yau, Hamilton and Perelman, we use the method of gradient estimates to determine Harnack inequalities for nonlinear parabolic equations. We discuss the method to come up with the Harnack quantity and prove that it's non-negative. We also present some old and new estimates obtained from the Harnack inequality. (Received February 01, 2016)

1118-53-226 **Haotian Wu*** (hwu@uoregon.edu), Department of Mathematics, University of Oregon, Eugene, OR 97403. *Asymptotic shapes of neckpinch singularities in geometric flows.*

Geometric flows such as Ricci flow and mean curvature flow are natural and important tools to understand the geometry and topology of Riemannian manifolds. Geometric flows are nonlinear parabolic (heat) partial differential equations (PDEs) that tend to develop singularities in finite time. A useful approach to analyzing the singularities is the technique of matched asymptotics, which can provide detailed and precise information including the rates of curvature blow-up, the set of points where a singularity forms, and the behavior of the solution in a space-time neighborhood of that singularity. In this talk, we will survey the results concerning the asymptotic shapes of neckpinch singularities in Ricci flow and mean curvature flow. (Received February 01, 2016)

1118-53-228 **Albert J. Todd*** (ajtodd@southalabama.edu). *On the standard G_2 almost contact metric structure.*

An almost contact metric structure on an odd-dimensional smooth manifold is a quadruple (ϕ, ξ, η, g) consisting of a $(1,1)$-tensor, a non-vanishing vector field ξ, a 1-form η and a compatible metric g satisfying a number of relations; a G_2-structure on a smooth 7-manifold induces, in particular, a 3-form φ, a two-fold vector cross product and G_2 metric g_φ. Work of Arkian, Cho and Salur shows that one can construct a particular almost contact metric structure that encodes the two-fold vector cross product and the G_2 metric; we call this the standard G_2 almost contact metric structure. It is known from work of Fernández and Gray that there are 2^4 classes of G_2 structures and from work of Chinea and Gonzalez that there are 2^{12} classes of almost contact metric

structures. Recent articles by several authors, including myself, have focused on understanding the relationships between the classes of G_2 structures and the classes of the resulting standard G_2 almost contact metric structure. In this talk, I will report on my work on the classification problem for the standard G_2 almost contact metric structure as well as recent research on related problems. (Received February 01, 2016)

1118-53-230 **Alexei Kovalev*** (a.g.kovalev@dpmms.cam.ac.uk), DPMMS, Centre for Mathematical Sciences, Wilberforce Road, Cambridge, CB3 0WB, United Kingdom. *Metrics with holonomy* Spin(7) *on generalized connected sums.* Preliminary report.

Berger's classification of the Riemannian holonomy contains two, closely related, exceptional groups G_2 and Spin(7) which occur on, respectively, 7- and 8-dimensional manifolds. Previously, the author gave examples of asymptotically cylindrical Riemannian 8-manifolds with holonomy Spin(7). Their cross-sections 'at infinity' are G_2-manifolds. Generalized connected sums of pairs of 8-manifolds with 'compatible' cross-sections are compact manifolds admitting Spin(7)-metrics, via a gluing argument; this includes topologically new examples. After briefly reviewing the above results, we shall show that the gluing of asymptotically cylindrical Spin(7)-manifolds also produces some examples which are diffeomorphic to compact, holonomy Spin(7) manifolds previously obtained by Joyce by a different method. We also show examples where the families of Spin(7)-metrics obtained by the two methods are deformations of each other. (Received February 01, 2016)

1118-53-231 **Longzhi Lin*** (lzlin@ucsc.edu). *Star-shaped mean curvature flow.*

A one-parameter family of hypersurfaces in Euclidean space evolves by mean curvature flow if the velocity at each point is given by the mean curvature vector. It can be viewed as a geometric heat equation, i.e., it is locally moving in the direction of steepest descent for the volume element, deforming surfaces towards optimal ones (minimal surfaces). In this talk we will discuss some recent work on the local curvature estimate and convexity estimate for the star-shaped mean curvature flow and the consequences. These estimates hold for any singularities via elliptic regularization. In particular, star-shaped MCF is generic in the sense of Colding-Minicozzi. (Received February 01, 2016)

1118-53-232 **Stephen James Kleene*** (skleene@gmail.com), University of Rochester, Department of mathematics, Hylan Building, Rochester, NY 14627. *Minimal laminations on curves.*

We describe how to construct sequences of embedded minimal surfaces in a tube along a smooth curve in $\mathbb{R}^3$ with curvature blowup on a prescribed compact subset, using PDE methods. The method is very general and has applications to numerous gluing problems (Received February 01, 2016)

1118-53-254 **Simon K Donaldson***, sdonaldson@scgp.stonybrook.edu. *Survey of progress and problems on G_2-manifolds.*

There are two "exceptional" cases in Berger's classification of Riemannian holonomy groups. These occur in dimensions 7 and 8 and are related to the Cayley numbers. In this talk we will discuss the 7-dimensional case of G_{2}-manifolds, with holonomy the exceptional Lie group G_{2}. The subject began in 1987 when Bryant found local examples. Nine years later, Joyce constructed compact examples by resolving the singularities of quotients of tori. Another construction of compact examples, with input from complex algebraic geometry, was found by Kovalev and later substantially extended by Corti, Haskins, Nordstrom and Pacini. This body of examples opens up many intriguing but difficult questions on existence and moduli of solutions. The main aim of the talk will be to give an overview of this area. We will also discuss adiabatic limits of fibred G_{2}-manifolds, and compare with related work on other geometric structures, such as Calabi-Yau manifolds. (Received February 02, 2016)

1118-53-266 **Andrew Cooper***, Box 8205, Raleigh, NC 27695. *A maximum principle for circle-valued temperatures.*

We will establish a 'maximum principle' for circle-valued solutions of the heat equation on a Riemannian manifold. Of particular interest is the time-dependent version of this result, which allows the Riemannian metric to degenerate over time. (Received February 02, 2016)

54 ► General topology

1118-54-87 **Benoît Guerville-Ballé*** (benoit.guerville-balle@math.cnrs.fr), Department of Mathematics, Tokyo Gakugei University, Koganei-shi, Tokyo, 184-8501, Japan. *Linking invariant of line arrangements.*

We construct a topological invariant of line arrangements, which is in some sense an adaptation of the linking number of knot theory. As an application, we show that this invariant distinguishes a new Zariski pair of line arrangements (ie a pair of arrangements having same combinatorics, yet different topology). Futhermore, this example provides the first example of arithmetic Zariski pair with non-isomorphic fundamental group. (Received January 25, 2016)

55 ► Algebraic topology

1118-55-39 **Filippo Gianluca Callegaro*** (callegaro@dm.unipi.it), Dipartimento di Matematica, Università di Pisa, Largo Bruno Pontecorvo 5, 56127 Pisa, PI, Italy, and **Emanuele Delucchi** (emanuele.delucchi@unifr.ch), Department of Mathematics, University of Fribourg, Chemin du Musée 23, 1700 Fribourg, Fribourg, Switzerland. *The integer cohomology algebra of toric arrangements.*

We compute the integer cohomology ring of the complement of a toric arrangement, giving a description of the toric analogous of the Orlik-Solomon algebra. We begin recalling some basic combinatorial invariants and we investigate the dependency of the cohomology ring from the arrangement's combinatorial data. To this end, we first consider the real complexified case and we study a morphism of spectral sequences associated to certain combinatorially defined subcomplexes of the toric Salvetti category. Then we use a technical argument in order to extend the results to full generality. In the case of a non-unimodular arrangement, it is still an open problem to find a purely combinatorial description of the integer cohomology ring. (Received January 13, 2016)

1118-55-46 **Noureen Khan*** (noureen.khan@unt.edu). *Algebraic structure of virtual rational tangles.*

Recall that a virtual knot is composed of both classical and virtual crossings and ideally it can arise as the numerator closure of a virtual 2-tangle. The class of virtual rational tangles resides as a special class of virtual 2-tangles and particularly interesting because of their presentation as generalized rational 2-tangles. A virtual rational 2-tangle should be considered as diagrammatic picture of two strands of a tangle which are far from each other. In this paper we present characteristics of virtual rational tangles to define algebra of virtual rational tangles. (Received January 15, 2016)

1118-55-95 **Weiyan Chen***, 5734 S. University Ave., Chicago, IL 60637. *Topology of braid arrangement via counting polynomials.* Preliminary report.

Many problems about the braid arrangement (topology) are equivalent to counting polynomials over finite fields (combinatorics). In this talk, I will present several results about the representation of the symmetric groups on the cohomology of the braid arrangement complement, and explain how they are proved by counting polynomials. For example, I will show that the i-th cohomology of the braid arrangement complement in C^n not only stabilize in n as representations of S_n (recovering a theorem of Church-Ellenberg-Farb), but also are recurrent in i in certain sense. Part of the work is joint with Joel Specter. (Received January 25, 2016)

1118-55-98 **Matthew M Wroten*** (mmw23@psu.edu), **Jayadev Athreya**, **Steven Lalley** and **Jenya Sapir**. *Statistical regularities of long geodesics on hyperbolic surfaces: local geometric properties.* Preliminary report.

Any finite geodesic segment γ on a closed hyperbolic surface S partitions S into a finite number of non-overlapping geodesic polygons of various shapes and sizes, whose vertices are the self-intersection points of γ. If a geodesic segment γ of length T is chosen by selecting its initial tangent vector X at random, according to (normalized) Liouville measure on T^1S, then with probability 1, as $T \to \infty$ the maximal diameter of a polygon in the induced partition will converge to 0, and hence the number of polygons in the partition will become large. The goal of this talk is to elucidate some of the statistical properties of this random polygonal partition for large T. Our main result will be a *local* geometric description of the partition: roughly, this will assert that in a neighborhood of any point $x \in S$ the partition will, in the large$-T$ limit, look as if it were induced by a Poisson line process. (Received January 26, 2016)

1118-55-140 **Rita Jimenez Rolland*** (rita@matmor.unam.mx). *Representation stability and point counting.*

In this talk we will consider some families of varieties with actions of certain finite reflection groups – varieties such as the hyperplane complements associated to these groups. Using results of Grothendieck–Lefschetz and Lehrer we can relate the topology of those varieties with point counts over finite fields. Our main objective is to explain how the theory of representation stability developed by Church–Ellenberg–Farb and Wilson corresponds to asymptotic stability of these point counts. (Received January 28, 2016)

1118-55-229 **Mario Salvetti*** (salvetti@dm.unipi.it), Largo B. Pontecorvo, 5, 56127 Pisa, Italy. *On local system cohomology of arrangements and of Artin groups.*

We are interested in calculating topological invariants for the complement of an arrangement of hyperplanes, with special attention to the case of the configuration spaces of Artin groups (including the case of infinite type Artin groups).

We consider some combinatorial cojectures and some methods, in particular we show how some combinatorial methods are useful for doing calculations. (Received February 01, 2016)

57 ► Manifolds and cell complexes

1118-57-80 **Boya Wen*** (u3502798@connect.hku.hk). *k-Forms on Products of Weighted Graphs and Fractals.* Preliminary report.

The theory of k-forms on differentiable manifolds is rich and profound. Recent research also defined and studied differential equations on fractals. It is then natural to ask if it is possible to develop a theory of k-forms on Cartesian products of fractals. Our approach is to first study the graph approximations of fractals. We defined analogous notions of k-cells, k-chains, k-vectors, k-covectors, k-vector fields, k-covector fields, integration of a k-covector field along a k-chain, exterior differentiation of a k-covector field etc on products of weighted graphs, and found that the theory is in parallel with the classical theory on manifolds. Then we attempt to pass to the fractal limit via a self-similar transform of weights, which is not yet complete and could be studied in future research. (Received January 23, 2016)

1118-57-128 **Yair N Minsky*** (yair.minsky@yale.edu), 10 Hillhouse Ave, PO Box 208283, New Haven, CT 06520, and **Samuel Taylor**. *Fibrations, subsurface projections and veering triangulations.*

Agol's veering triangulation for 3-manifolds that fiber over the circle can be obtained very explicitly, via a construction of Gueritaud, from the stable and unstable laminations of the monodromy. We study the way in which these triangulations interact with the arc complexes of the surface and its subsurfaces. This allows us to examine the "profile" of subsurface projections associated to each fiber in a fibred face of the Thurston norm ball, obtaining some bounds that do not depend on the complexity of the fibers. (Received January 27, 2016)

1118-57-172 **Chandrika Sadanand*** (chandrika@math.stonybrook.edu). *Taut maps associated to minimal Heegaard Splittings.* Preliminary report.

Consider the following two tools for studying 3-manifolds: decomposition into primes, and Heegaard splittings. From each Heegaard splitting of a 3-manifolds, a class of maps arises between 2-complexes - something that can often be visualized. I will define these classes of maps, discuss their geometry and the effect of this geometry for minimal genus Heegaard splittings of prime 3-manifolds. (Received January 30, 2016)

1118-57-269 **Feng Luo***, 110 Frelinghuysen Road, Piscataway, NJ 08854, and **David Gu**, **Ren Guo**, **Jian Sun** and **Tianqi Wu**. *Discrete conformal geometry on polyhedral surfaces and its convergence.*

Our recent work on discrete conformal geometry on compact polyhedral surfaces shows that a discrete version of the uniformization theorem holds. The relationship between the discrete uniformization theorem and convex isometric embeddings of polyhedral surfaces and the convergence of discrete conformal geometry to the smooth conformal geometry will be addressed. (Received February 03, 2016)

58 ► Global analysis, analysis on manifolds

1118-58-12 **Paul Feehan** and **Manousos Maridakis*** (mmanos@math.rutgers.edu), Hill Center for the Mathematical Sciences, 110 Frelinghuysen Rd, Piscataway, NJ 08854-8019.
Lojasiewicz-Simon gradient inequalities with applications to Harmonic map energy functional.

Lojasiewicz-Simon gradient inequalities have become increasingly interesting by their wealth of potential applications. In this article we are concerned with an abstract version of a Lojasiewicz-Simon gradient inequality established under very weak assumptions and its applications for Harmonic map energy functional. (Received October 15, 2015)

1118-58-92 **David Bate***, bate@math.uchicago.edu, and **Sean Li**. *The geometry of Radon-Nikodym Lipschitz differentiability spaces I.*

We give a purely geometric characterisation of those metric measure spaces that satisfy the differentiability theory of Cheeger for Lipschitz functions taking value in Banach spaces with the Radon-Nikodym property. This characterisation is centred on a notion of connecting points in the metric space by certain Lipschitz curves that form partial derivatives of any Lipschitz function at almost every point. This allows us to form the total Cheeger derivative from partial derivatives analogously to the Euclidean case. (Received January 25, 2016)

1118-58-118 **Michael Hinz*** (mhinz@math.uni-bielefeld.de), Department of Mathematics, Bielefeld University, Postfach 100131, 33615 Bielefeld, Germany, and **Alexander Teplyaev**.
Densely defined non-closable curl on topologically one-dimensional Dirichlet metric measure spaces.

We consider the exterior derivative operator defined on 1-forms on topologically one dimensional spaces with a strongly local regular Dirichlet form. One can show that the exterior derivative operator taking 1-forms into 2-forms is not closable if the martingale dimension is larger than one. Perhaps some of the most interesting examples include the non self-similar Sierpinski carpets introduced by Mackay, Tyson and Wildrick, and in the talk we will concentrate on them. For some of these carpets we prove that not only the curl operator is not closable, but that its adjoint operator has a trivial domain. (Received January 27, 2016)

1118-58-151 **Timothy P Carson*** (tcarson@math.utexas.edu). *Warped Product Ricci Flow and a Pohozaev Identity.*

There are many examples of Ricci solitons which are warped products. The Ricci soliton equation on a warped product formally resembles an elliptic equation which has been studied since the 1980s in connection with blowups of a nonlinear parabolic equation.

In this talk, we expose parallels between this parabolic equation and Ricci flow on warped products. One fact which carries over is the existence of a Pohozaev identity, which forces warped product gradient shrinking solitons over complete one- or two- dimensional bases to be products. This contrasts with the expanding and steady cases, where examples over non-compact bases are known in almost every dimension, but maximum principle arguments show that (non-product) examples do not exist over compact bases. The result extends one by Doo-Song Kim, who showed that warped products that are Einstein over two dimensional compact bases must be products. The comparison to the parabolic PDE explains why a void exists in our understanding of Kim's result in higher dimensions and shrinking Ricci solitons on warped products; even for the PDE in Euclidean space results are quite technical. (Received January 29, 2016)

1118-58-179 **Daniel J Kelleher*** (dkellehe@purdue.edu), Department of Mathematics, West Lafayette, IN 47907, and **Fabrice Baudoin**. *Bakry-Emery gradient estimates for metric measure spaces and Poincare Duality on fractals.*

There has been much work in establishing the relationship between Bakry-Emery gradient inequalities and other functional inequalities, similar to that of curvature dimension inequalities. This work establishes that on doubling metric measure Dirichlet spaces with suitable conditions, that the Bakry-Emery inequality implies bounds on Reisz Transforms, an isoperimetric inequality, Wasserstein Control and a Log-Sobolev inequality. The gradient estimate is proven on the Sierpinski Gasket with harmonic energy measures as well for some metric graphs. These are spaces on which other notions of curvature have been elusive. To obtain these results, the space of differential forms on these spaces is classified using a measurable analogue of Poincare duality for classical differential forms. (Received January 31, 2016)

1118-58-271 **Paul M. N. Feehan*** (paul.feehan@rutgers.edu). *The Lojasiewicz-Simon gradient inequality and its applications to differential geometry, topology, and mathematical physics.*

The Lojasiewicz-Simon gradient inequality is a generalization, due to Leon Simon (1983), to analytic or Morse-Bott functionals on Banach manifolds of the finite-dimensional gradient inequality, due to Stanislaw Lojasiewicz (1963), for analytic functions on Euclidean space. In this talk, we shall discuss several generalizations of the Lojasiewicz-Simon gradient inequality and a selection of their applications, including global existence and convergence of Yang-Mills gradient flow over 4-manifolds, discreteness of energies of Yang-Mills connections over 4-manifolds, and discreteness of energies of harmonic maps from Riemann surfaces into analytic Riemannian manifolds. (Received February 03, 2016)

60 ► Probability theory and stochastic processes

1118-60-64 **Dong Hyun Cho*** (j94385@kyonggi.ac.kr), Department of Mathematics, Kyonggi University, Suwon, Kyonggido 16227, South Korea. *Change of scale formulas using a multivariate normal distribution on a function space.*

Let $a \in C[0,T]$, h is of bounded variation with $h \neq 0$ a.e. on $[0,T]$ and define a stochastic process $Z : C[0,T] \to \mathbb{R}$ by

$$Z(x,t) = \int_0^t h(s)dx(s) + x(0) + a(t)$$

for $x \in C[0,T]$ and for $t \in C[0,T]$, where the integral denotes a generalized Paley-Wiener-Zygmund integral. For a partition $t_0 = 0 < t_1 < \cdots < t_n < t_{n+1} = T$ of $[0,T]$ define random vectors $Z_n : C[0,T] \to \mathbb{R}^{n+1}$ and $Z_{n+1} : C[0,T] \to \mathbb{R}^{n+2}$ by

$$Z_n(x) = (Z(x,t_0), \cdots, Z(x,t_n))$$

and

$$Z_{n+1}(x) = (Z(x,t_0), \cdots, Z(x,t_n), Z(x,t_{n+1})).$$

Using simple formulas for generalized conditional Wiener integrals on $C[0,T]$ with the conditioning function Z_n and Z_{n+1} we evaluate generalized analytic conditional Wiener integrals of the cylinder function

$$F(x) = f\bigg(\int_0^t v_1(s)dZ(x,s), \cdots, \int_0^t v_r(s)dZ(x,s)\bigg),$$

where $f \in L_p(\mathbb{R}^r)$ with $1 \leq p \leq \infty$ and $\{v_1, \cdots, v_r\}$ is an orthonormal subset of $L_2[0,T]$. We then establish various change of scale transformations for the generalized analytic conditional Wiener integrals of F with Z_n and Z_{n+1} using a multivariate normal distribution. (Received January 20, 2016)

1118-60-177 **Joe P Chen*** (joe.p.chen@uconn.edu), University of Connecticut, Storrs, CT 06269, and **Alexander Teplyaev** (teplyaev@member.ams.org), University of Connecticut, Storrs, CT 06269. *Hydrodynamic limit of the boundary-driven exclusion process on the Sierpinski gasket.*

We study the symmetric simple exclusion process on the Sierpinski gasket (SG) driven by the action of particle reservoirs attached to boundary vertices of SG. In the diffusive scaling limit, we obtain the law of large number (in the form of a nonlinear heat equation) and large deviation functionals for the empirical density and current.

There are two important ingredients to our proofs.

1) An optimal estimate of transport energy in the exclusion process, based on the "octopus inequality" of Caputo, Liggett, and Richthammer.

2) The technology of differential forms (grad, div) on fractals developed by the second author and collaborators. (Received January 31, 2016)

62 ► Statistics

1118-62-13 **Ammar M Sarhan*** (asarhan@mathstat.dal.ca), , Canada. *Two parameter discrete distribution with a bathtub hazard shape.*

This paper presents a two-parameter discrete distribution based on a continuous two-parameter bathtub distribution. As far as I know, it is the only two-parameter discrete distribution which shows a bathtub shaped hazard function. Some statistical properties of the distribution are discussed. Three different methods are used to estimate its two unknown parameters. The point estimators of the parameters have no closed form solutions. The bootstrap method is used to estimate the distributions of these point estimators. Different approximations

of the interval estimations for the two parameters are discussed. Real data sets are analyzed to show how this distribution works in practice. A large simulation study is performed to investigate the properties of the estimations obtained and compare their performances. (Received October 17, 2015)

68 ► Computer science

1118-68-270 **Alan Jaehyun Kim*** (alankim117@gmail.com), Choice Research Group, 32 Piermont Rd., Cresskill, NJ 07626, and **Richard Kyung** (nycrick@gmail.com), Choice Research Group, 32 Piermont Rd., Cresskill, NJ 07626. *Study of the new LPFs to enhance the process of the biomedical imaging.*

By using coils to give stimuli to the hydrogen atoms in the human body, the MRI scanner collects data in a matrix called the K-Space. However, because the K-space is composed of digital numbers that cannot be visualized by the human brain, a computer must use a transform to convert the data into a final image. However, LPFs inevitably create trade-offs. Because the amount of matrix data varies directly with image resolution and with computational speed, image resolution varies inversely with computational speed. It is thus evident that we need to use LPFs to match the purpose. For relatively simple scans, for instance, those of the bone exterior, MRI scanners would use LPFs that have lower resolutions but faster computation. In contrast for extremely detailed scans, like scans of the brain structure, MRI scanners would need LPFs that have higher resolutions but slower computation. The objective of this lab is to determine the optimal low-pass filters for different levels of required accuracies. In particular, this paper suggests sinusoidal functions as LPFs for scans to improve accuracy and quality of the resolution, since impulse functions for scans show that relatively lower accuracy in image resolution. (Received February 03, 2016)

76 ► Fluid mechanics

1118-76-182 **Radu Dascaliuc***, Department of Matheamtics, Oregon State University, Corvallis, OR 97331-4605, and **Zoran Grujic** and **Michael S. Jolly**. *On the attractor of the 3D Navier-Stokes equations under the vorticity coherence assumption.*

We will discuss energy-enstrophy bounds on the (weak) global attractor assuming coherence of vorticity direction in regions of intense vorticity. This setting, relevant to both empirical and numerical picture of turbulence featuring formation of coherent vortex structures, is known to imply regularity of the solutions. We relate our results to the question of turbulnce and compare them to similar bounds in general case as well as under typical scaling-invariant Navier-Stokes regularity criteria. (Received January 31, 2016)

1118-76-255 **Richard Wu** (richardwu1213@gmail.com), Horace Mann School, 231 W 246th St., Bronx, NY 10471, and **Minsu Kim*** (mk4226@nyu.edu), NYU, 50 West Fourth St., New York, NY 10003. *Study of the velocity and pressure gradients across the aortic valve.*

Aortic valve disease has induced a growing need for information on bio-fluid flow analysis over the last few decades. The bioengineering approaches have been empirically derived with biophysical and numerical justification for their application. In this paper, researches based on the biomechanical determinants of blood flow in the stenosed aortic valve have been carried out using physical and computational analysis. According to cardiovascular physiology, stenosis of the aortic valve leads to a pressure gradient across the valve during the time in which blood flows through the valve opening. This aortic valve gradient is expressed as an increase and decrease on each side of the defective valve. In this paper, Aortic Valve Areas(AVA) are calculated based on the different pressure gradients across the aortic valve. The continuity equation and Gorlin equation are used and computational simulations are carried out. The results show that severe AS causing LV systolic dysfunction depends on the transaortic velocity. The data show that there are patients who can be classified in AS category with mild AVV and pressure gradient, which makes therapeutic management complicated. (Received February 02, 2016)

1118-76-262 **Bogdan Nita*** (nitab@mail.montclair.edu), 1 Normal Avenue, Montclair, NJ 07043. *The interaction between fibers and fluids through experimental and numerical models.*

Fluid structure interaction plays a major role in everyday life and in applications from engineering, military and medical fields. In this study we model the interaction between flexible fibers clamped to a sphere and a fluid flowing with speeds 0 and 50 cm/s. We look at initial fiber position with respect to the flow, and different fiber lengths in a 3D environment. Both experimental and numerical methods are used for the study. (Received February 02, 2016)

81 ► Quantum theory

1118-81-193 **Ling Chen*** (chenling2013@ucas.ac.cn). *On axiomatic approaches to intertwining operator algebras.*

We study intertwining operator algebras which are direct sums of modules (not necessarily irreducible) for vertex operator algebras equipped with intertwining operators among these modules satisfying some basic properties for intertwining operators. In the case that the intertwining operator algebras involve only irreducible modules for the vertex operator algebras, a number of results were given by Huang. We formulate and prove the generalizations of these results in the general case. In particular, we construct fusing and braiding isomorphisms for intertwining operator algebras in the general case and prove that they satisfy the genus-zero Moore-Seiberg equations. Moreover, we study the duality properties of intertwining operator algebras and prove various equivalence results between axioms and properties. Furthermore, using the skew-symmetry property and the genus-zero Moore-Seiberg equations, we prove an S_3-symmetry of the Jacobi identity for intertwining operator algebras. (Received January 31, 2016)

83 ► Relativity and gravitational theory

1118-83-8 **Vladimir Chernov*** (vladimir.chernov@dartmouth.edu), 6188 Kemeny, Darmouth College, Hanover, NH 03755, and **Stefan Nemirovski** (stefan@mi.ras.ru), Gubkina, d 8, Moscow, 119991, Russia. *Cosmic censorship of smooth structures.*

It is observed that on many 4-manifolds there is a unique smooth structure underlying a globally hyperbolic Lorentz metric. For instance, every contractible smooth 4-manifold admitting a globally hyperbolic Lorentz metric is diffeomorphic to the standard $\mathbb{R}^4$. Similarly, a smooth 4-manifold homeomorphic to the product of a closed oriented 3-manifold N and $\mathbb{R}$ and admitting a globally hyperbolic Lorentz metric is in fact diffeomorphic to $N \times \mathbb{R}$. Thus one may speak of a censorship imposed by the global hyperbolicty assumption on the possible smooth structures on (3+1)-dimensional spacetimes (Received October 02, 2015)

1118-83-24 **Andrew S. Goetz** and **Alan R. Parry*** (alan.parry@uconn.edu). *Parametrizations of the Poisson-Schrödinger Equations in Spherical Symmetry.*

We consider solutions to the Poisson-Schrödinger system of equations of the form $f(t,r) = \mathrm{e}^{i(m-\omega)t}F(r)$. There exist well-known standing wave solutions of this type called static states. We recall that these solutions can be parametrized by several different choices of a set of three parameters, any two of which can be chosen to be continuous while the third becomes discrete. Each value of the discrete variable corresponds to a static state with a different number of nodes (i.e. zeros) of F. For convenience we parametrize the solutions by the total mass M_{tot}, the radius R_{99} containing 99% of the total mass, and the particle mass term m of the system. We show that other reasonable choices of parameters are tightly correlated to M_{tot}, R_{99}, and m and hence are tightly related to each other as well. We also show that for a given choice of any two of M_{tot}, R_{99}, and m, there is a minimum value of the remaining discrete variable which is always obtained by the 0-node ground state. We explicitly write down how this value depends on the choice of the other two parameters. We use these explicit relationships to verify two known related results and describe a possible application of this work. (Received December 23, 2015)

1118-83-31 **Aghil Alaee*** (khangha@ualberta.ca). *Mass-angular momentum inequality for bi-axisymmetric black holes.*

One of the interesting problem in mathematical relativity is the geometric inequalities for black holes with symmetries, such as Dain inequality and extension of Penrose inequality for four dimensional axisymmetric black holes. Recently, the investigation of general relativity in higher dimensions has attracted a great deal of interest for a number of physical reasons, such as the gauge theory-gravity correspondence and string theory. In addition, known examples of Myers-Perry black hole, black ring, and black lens solutions in higher dimensions assure the existence of a rich variety of such objects whose mathematical properties are only just beginning to be uncovered. In this talk we show recent progress of the extension of Dain's inequality to higher dimensions. In particular, we show that extreme Myers-Perry initial data realize the unique absolute minimum of the total mass in a physically relevant (Brill) class of maximal, asymptotically flat, bi-axisymmetric initial data for the Einstein equations with fixed angular momenta and spherical topology. As a consequence, we prove the relevant mass-angular momentum inequality in this setting for 5-dimensional black holes with spherical horizon topology. (Received January 10, 2016)

1118-83-51 **Christina Sormani** and **Carlos Vega*** (vegaca@slu.edu). *Null distance on a spacetime.*
In this talk, we will discuss a new distance function on spacetime. More specifically, fixing any spacetime M with time function τ, we define a 'null distance function' $\hat{d}_\tau$, built from and closely related to the causal structure of M. Indeed, in basic model cases, $\hat{d}_\tau$ encodes the causal structure completely. In general, $\hat{d}_\tau$ is a conformally invariant pseudometric, which is definite if and only if τ satisfies a natural 'anti-Lipschitz' condition. While there is typically no canonical choice for τ, one is offered in the finite-past setting by the 'cosmological time function' defined by Andersson, Galloway, and Howard. We show that, under their basic niceness condition, this induces a definite null distance function, and hence provides a uniform way of metrizing spacetimes which emanate from a common initial singularity, e.g., a 'big bang'. (Received January 18, 2016)

1118-83-57 **Hari K Kunduri*** (hkkunduri@mun.ca), Department of Mathematics and Statistics, Memorial University of Newfoundland, St John's, NL , Canada, and **James Lucietti**. *Black Holes with Lens-space horizon topology.*
Galloway and Schoen have proved that spatial cross-sections H of the event horizon of a five-dimensional, asymptotically flat, stationary black hole satisfying the dominant energy condition must have a positive Yamabe invariant. It is unclear whether every topology allowed by this constraint are realized by solutions to the Einstein equations. Under the additional assumption that the geometry admits a $U(1) \times U(1)$ isometry subgroup, the allowed topologies of H are further restricted to be $S^3, S^1 \times S^2$, or $L(p,q) = S^3/Z_p$. Explicitly known solutions realizing the former two topologies have been found.

In this talk I will describe the first example of asymptotically flat black holes with lens space horizon topology. The geometry is regular on and outside an event horizon with $H = S^3/Z_2$. These form a 3-parameter family of solutions of supergravity, which is an extension of Einstein-Maxwell theory in five dimensions. The geometry admits Killing spinor fields (i.e. they are supersymmetric) which greatly simplifies the construction. (Received January 18, 2016)

1118-83-58 **C-Y. Lin*** (cylin@math.toronto.edu), Toronto, and **C. Sormani**. *Braintree's mass and Hamilton's modified Ricci flow.*
Two of the most important quasilocal masses studied in Riemannian General Relativity are the Hawking mass and Bartnik mass of a surface. Via a quantity which we call the "asphericity mass", we relate these two quasilocal masses. In this talk, I will discuss that the Bartnik mass is bounded from above by the Hawking mass and the asphericity mass, defined by applying Hamilton's modified Ricci flow and depends only upon the restricted metric of the surface and not on its mean curvature. The theorem is proven by studying a class of asymptotically flat Riemannian manifolds foliated by surfaces satisfying Hamilton's modified Ricci flow with prescribed scalar curvature. Furthermore, I will discuss the rigid case when the Hawking mass of the inner surface of the manifold agrees with its ADM mass. (Received January 18, 2016)

1118-83-59 **Steven L Liebling***, 720 northern blvd., Brookville, NY 11738. *Recurrences and islands of stability in spherically symmetric AdS.*
We consider the dynamics of a spherically symmetric massless scalar field coupled to general relativity in anti-de Sitter spacetime using both fully nonlinear, numerical evolutions and a two-timescale analysis. (Received January 18, 2016)

1118-83-60 **Alan Parry*** (alan.parry@uconn.edu). *Geometric flows in General Relativity.*
In this talk, we will survey several results from the last 25 years that have used geometric flows to solve important problems in general relativity. These will include the proofs of the Penrose inequality using inverse mean curvature flow by Huisken and Ilmanen and a conformal flow of metrics by Bray. We will also discuss more recent work by authors including Bray, Hayward, Mars, Simon, and Jauregui, generalizing the inverse mean curvature flow. This will include discussing the behavior of these flows with respect to the Hawking mass, and how they might be applied to further generalize the Penrose inequality. (Received January 19, 2016)

1118-83-223 **Lan-Hsuan Huang** and **Dan A Lee*** (dlee2@qc.cuny.edu), New York, NY 10011, and **Christina Sormani**. *Stability of the positive mass theorem for graphs.*
The rigidity of the positive mass theorem is the fact that Euclidean space is the only complete asymptotically flat manifold with nonnegative scalar curvature and zero mass. We will explore the stability of this statement in the case of graphical hypersurfaces of Euclidean space. (Received February 01, 2016)

85 ► Astronomy and astrophysics

1118-85-15 **Babatunde J Falaye*** (fbjames11@physicist.net), Ave Santa Barbara 145, Col Planetario Lindavi, 22054 Mexico City, Mexico. *Triangular libration points in the R3BP under combined effects of oblateness, radiation and power-law pro le.* Preliminary report.

We study the effects of oblateness up to J_4 of the primaries and power-law density profile (PDP) on the linear stability of libration location of an infinitesimal mass within the framework of restricted three body problem (R3BP), by using a more realistic model in which a disc with PDP is rotating around the common center of the system mass with perturbed mean motion. The existence and stability of triangular equilibrium points have been explored. It has been shown that triangular equilibrium points are stable for $0 < \mu < \mu_c$ and unstable for $\mu_c \leq \mu \leq 1/2$, where μ_c denotes the critical mass parameter. We find that the comprehensive effects of the perturbations have a stabilizing proclivity. Libration points play a very important role in space mission and as a consequence, our results have a practical application in space dynamics and related areas. The model may be applied to study the navigation and stationkeeping operations of spacecraft (infinitesimal mass) around the Jupiter (more massive) -Callisto (less massive) system, where PDP accounts for the circumsolar ring of asteroidal dust, which has a cloud of dust permanently in its wake. (Received October 28, 2015)

1118-85-62 **Shabnam Beheshti*** (s.beheshti@qmul.ac.uk), School of Mathematical Sciences, Queen Mary University of London, London, E1 4NS, United Kingdom, and **Edgar Gasperin Garcia**. *Marginally stable circular orbits in stationary axisymmetric spacetimes.*

Marginally stable circular orbits (MSCOs) play an important role in our understanding of astrophysical phenomena, ranging from matter configurations in accretion to motion of test particles/photon orbits around massive neutron stars. We derive a necessary condition for the existence of MSCOs for stationary axisymmetric spacetimes using, unexpectedly, a tool from algebraic geometry; this gives rise to a natural geometric characterization of circular orbits, as well as a concrete algorithm for calculating MSCO conditions. Our discussion will be guided by several concrete examples of physical interest. (Received January 19, 2016)

92 ► Biology and other natural sciences

1118-92-267 **Jihye Yoon** (jihyeyoon@hafs.hs.kr), Choice Research Group, 32 Piermont Rd., Cresskill, NJ 07626, and **Richard Kyung*** (richardkyung@yahoo.com), Choice Research Group, 32 Piermont Rd., Cresskill, NJ 07626. *Estimating biological growth curves using statistical and computational simulations.*

Modeling bacteria or cell growth in oncology and microbiology, carrying out the curve fitting from the large data can be a difficult task when the pattern is complicated. It is not easy for researchers to extract the coefficients from the curve fitting process in order to characterize cell growth in oncology. A general form of the exponential function is employed, and error minimization steps to identify its coefficients is used when the curve fitting with higher-order polynomial does not describe the data well. In this paper, several functions were compared to describe a statistical bacterial growth curve. The curves were compared statistically by using a few models to figure out the characteristics of the model and their outcomes. Quantifying error in a curve fit, the fitting curve that provides a minimum error is considered as the best curve. Thus, the following assumptions were made: 1) positive or negative errors have the same value 2) weight greater errors more heavily. In the cases tested, the modified equation was checked using the Matlab programming, to see if it is statistically sufficient to describe the growth of a sample data. This technology can be further used in designing new biological experiments. (Received February 02, 2016)

93 ► Systems theory; control

1118-93-131 **Scott Hansen*** (shansen@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011. *Stabilization of multilayer Rao-Nakra beam and plate systems.*

The classical 3-layer Rao-Nakra sandwich beam model consists of two outer "face plate" layers that obey the Kirchhoff hypothesis and a shear-deformable inner core layer. I'll describe some exact controllability and stabilization results for a multilayer version of the Rao-Nakra beam model and recent results for boundary and locally distributed stabilization of the analogous plate system. (Received January 28, 2016)

94 ► Information and communication, circuits

1118-94-183 **Loren Anderson*** (loren.james.anderson@ndsu.edu) and **Hannah Davis** (davi2495@umn.edu). *Fractal AC Circuits.*

We consider fractal AC circuits that generalize Feynman's infinite ladder in the sense that the characteristic impedance can have positive real part despite all circuit components having purely imaginary impedances. Convergence of finite approximations and computation of harmonic functions will be discussed. (Received January 31, 2016)

97 ► Mathematics education

1118-97-10 **Amy Cohen*** (acc@math.rutgers.edu), Dept. of Mathematics Hill Center Rutgers, 118 Frelinghuysen Road, Piscataway, NJ 08854-8019. *Research mathematicians working in the mathematical education of teachers.*

At large public universities, research-active mathematicians can be involved in the mathematical education of teachers in several ways including importantly (1) the design and delivery of mathematics courses for prospective teachers,(2) participation in summer institutes for early- and mid-career teachers, and (3) participation in math circles for teachers. This talk describes "what worked and why" at Rutgers University in NSF-funded summer institutes for middle school teachers, in summer institutes for upper primary grade teachers, and the interaction of those institutes with the design and delivery of academic year courses for prospective teachers at all K-12 levels and of a required semester-long seminar for prospective teaching assistants. Interaction with mid-career teachers has proved intellectually engaging, challenging, and re-invigorating – sometimes in happy contrast to work with less engaged undergraduates. (Received October 05, 2015)

1118-97-81 **Alan Sultan*** (asultan956@aol.com), Department of Mathematics, Queens College, Flushing, NY 11367. *Description of a special, intense teacher education program.* Preliminary report.

We describe in this talk the TIME 2000 program at Queens college. This is a very intense program which has been in existence for over seventeen years and where students are taken directly from high school and fully immersed in the teaching of mathematics from the day they enter college. The unusual success of this program is documented, and the issues of administering such a program are discussed. (Received January 23, 2016)

1118-97-102 **Daniel L Goroff*** (goroff@sloan.org). *Probability, behavioral economics, and mathematics education.* Preliminary report.

Nature made our brains good at many things, but experiments show that probability is not one of them. Why do the simplest concepts of probability sometimes seem so challenging? Just thinking carefully about conditional probabilities can help unravel puzzles about everyday life, mathematics education, classroom decisions, and teacher education. (Received January 26, 2016)

1118-97-130 **Melkana A Brakalova*** (brakalova@fordham.edu) and **Lisa Berger**. *Mathematics teacher education programs in the NYC area.* Preliminary report.

Undergraduate and graduate degree programs for math teachers can be run by one or more schools within the same university. We will discuss some successes and challenges of such programs at two different universities in the NYC area, Fordham University and Stony Brook University, where the mathematics education programs are run by the Mathematics Department and by the Graduate School of Education, in collaboration with the Mathematics Department, respectively. (Received February 02, 2016)

1118-97-153 **Ryota Matsuura*** (matsuura@stolaf.edu), 1520 St. Olaf Avenue, Northfield, MN 55057. *Budapest Semesters in Mathematics Education: a study abroad program for pre-service secondary teachers.*

Budapest Semesters in Mathematics Education (BSME) is a semester-long program in Budapest, Hungary, designed for undergraduates (and recent graduates) interested in teaching middle school or high school mathematics. BSME was conceived by the founders of Budapest Semesters in Mathematics (BSM), and the two programs share a common goal—to provide their participants with an opportunity to experience the mathematical and general culture of Hungary. BSME is specifically intended for students who are not only passionate about mathematics, but also the *teaching* of mathematics.

BSME participants study the *Hungarian approach* to learning and teaching, in which a strong and explicit emphasis is placed on problem solving, mathematical creativity, and communication. At BSME, participants

take on a dual role: as students, they engage with challenging mathematical tasks from the secondary curriculum, learning mathematics by *doing* mathematics; then as teachers, they reflect the learning experience and explore how to bring the Hungarian approach to their own future classrooms.

In this presentation, I will give an overview of BSME and describe how the program prepares future teachers to address important national needs in mathematics education. (Received January 29, 2016)

1118-97-167 **Japheth Wood*** (jwood@bard.edu), PO Box 5000, Annandale-on-Hudson, NY 12504-5000. *Mathematicians' roles in Math Circles.*

Mathematicians are invested in helping improve math education in the US, but a well-understood role for individual mathematicians in the K-12 context has been lacking. This talk proposes that Math Circles (and other pre-college math enrichment opportunities) provide a context in which mathematicians assume a prominent role in improving math education. The roles that mathematicians play in several math circles around the region are described. (Received January 30, 2016)

1118-97-188 **Megan Brunner*** (meb30@geneseo.edu). *Mathematics and intercultural competence in the middle school.* Preliminary report.

As today's world becomes increasingly more globalized, there is a greater need to develop intercultural competence (ICC) in children through education. In this study we focused on addressing this need through mathematics by drawing on a model of ICC for education developed by Michael Byram. We created lesson plans to be used in mathematics classrooms that incorporate core ideas of different disciplines to help students get a better understanding of the mathematics while also attending to the development of their intercultural competence. In addition, we created two assessment tools - a survey to assess attitudes towards and knowledge of cultures and learning across content areas, and a rubric to assess interactions and reflections. In this presentation we will share the lesson plans and the assessment tools, as well as describe the theories that guided our work. We will also discuss how these ideas can be expanded or modified to incorporate other interdisciplinary topics in mathematics. (Received January 31, 2016)

1118-97-199 **Juliana V. Belding*** (juliana.belding@bc.edu), MA. *Math immersion for teachers in a math-science partnership: increasing connections to classroom practice.* Preliminary report.

In this talk, I will discuss my work with other mathematicians and math educators in the DeBT-M Math-Science Partnership, the goal of which is increasing high-quality mathematics learning experiences for all secondary students in Pittsburgh Public Schools.

After giving a brief overview of the MSP, I will talk about the three-week math immersion experience and the tension between a focus on doing mathematics and making connections to curriculum and classroom practice.

In particular, I will address how and why we've evolved toward more explicit modeling of instructional practices by mathematician facilitators while maintaining the mathematical content outside the curriculum (e.g.: in number theory and combinatorics). I'll end with possible take-aways for similar collaborations. (Received January 31, 2016)

1118-97-214 **Cassie Williams*** (willi5cl@jmu.edu), Harrisonburg, VA , and **John (Zig) Siegfried**. *What happens when you stop lecturing to your students?* Preliminary report.

"Active learning" has garnered attention in post-secondary STEM education in the past few years, and with good reason. Alternative course structures like flipped classrooms and inquiry-based learning (IBL) can not only improve content learning but also change student perceptions of what mathematics is and their own ability to do mathematics. In this talk, I will present my own experiences from six semesters of flipping calculus courses and one semester using IBL in an upper-division course with a significant population of pre-service teachers. In particular I will share data collected in these courses and try to put that data in a broader perspective. (Received February 01, 2016)

1118-97-238 **Glenn Stevens*** (ghs@math.bu.edu). *PROMYS: The Program in Mathematics for Young Scientists.*

Since 1989, the Program in Mathematics for Young Scientists (PROMYS) has provided an environment in which young people can practice mathematics in ways that are characteristic of research mathematics. PROMYS is a six week residential program for secondary students and their teachers from across the country, and internationally as well. The program has been sustained and enriched by two guiding principles: (1) An emphasis on mathematical habits of mind that support independence and creativity in facing unfamiliar mathematical challenges; and (2) a belief that mathematics is a deeply human activity best experienced within a richly interacting and

mutually supportive community of learners including high school students, undergraduate and graduate students, secondary school teachers, and experienced mathematical researchers.

In this talk we will describe the history of PROMYS as well as some of the nuts and bolts methods of the program, with special attention to what we call the "Experience First" principles. (Received February 01, 2016)

1118-97-244 **Myong-Hi Kim*** (kimm@oldwestbury.edu), SUNY Old Westbury, Old Westbury, NY 11568. *Contributions that mathematicians can make for math education.* Preliminary report.

I will discuss aspects of how mathematicians can contribute to mathematics education, focusing on contributions when teaching future teachers and when they have good math problems and tasks for K-12 students. I will also give examples of how mathematicians are involved in K-12 curriculum development in Korea. (Received February 02, 2016)

1118-97-253 **Patrick X. Rault*** (rault@geneseo.edu), SUNY Geneseo, 326C South Hall, Geneseo, NY 14607. *The Greater Upstate New York Inquiry-Based Learning Consortium.* Preliminary report.

The Greater Upstate New York Inquiry-Based Learning Consortium (UNY IBL) began as a group of professors meeting for biweekly dinners to discuss the successes and challenges in their classrooms. In recent years there has been a significant increase in the number of faculty pursuing active learning activities, so under the support of a generous grant we expanded into a regional network in 2014 by offering workshops, mentoring, and MAA special sessions. Recent research has documented the barriers which instructors face in adopting the IBL teaching style, and we aim to offer support to overcome these barriers. Our membership has thus grown exponentially. In this presentation, we'll describe how the UNY IBL consortium operates and we will provide some suggestions for creating your own regional network for supporting the adoption and enhancement of IBL techniques. (Received February 02, 2016)

03 ► Mathematical logic and foundations

1119-03-34 **Cheng Chang*** (chengchang@my.unt.edu), 1155 Union Circle #311430, Denton, TX 76203, and **Su Gao**. *The complexity of the classification problem of continua.*

We prove that the homeomorphism problem for connected compact metric spaces is Borel bireducible with a universal orbit equivalence relation induced by a Borel action of a Polish group. (Received January 25, 2016)

1119-03-66 **Martino Lupini*** (lupini@caltech.edu), 1200 E. California Blvd, MC 253-37, Pasadena, CA 91125. *The Lusky simplex.*

It is a classical result of Lindenstrauss, Olsen, and Sternfeld that the Poulsen simplex is the unique metrizable Choquet simplex with dense extreme boundary, it contains any metrizable Choquet simplex as a closed face, and any affine homeomorphism between its closed faces extends to an automorphism. I will explain how the Lusky simplex—i.e. the unit ball of the dual of the Gurarij Banach space—satisfies analogous uniqueness, universality, and homogeneity properties within the class of unit balls of duals of separable Lindenstrauss spaces. I will also present a new characterization and canonical construction of the Gurarij space using the theory of ternary rings of operators. Analogous results hold in the noncommutative setting for the Gurarij operator space introduced by Oikhberg. (Received February 05, 2016)

1119-03-83 **Longyun Ding**, School of Mathematical Sciences and LPMC, Nankai University, Tianjin, 300071, Peoples Rep of China, and **Su Gao***, Department of Mathematics, 1155 Union Circle #311430, University of North Texas, Denton, TX 76203. *Non-archimedean abelian Polish groups and their actions.*

We investigate the structure of non-archimedean abelian Polish groups whose orbit equivalence relations are all Borel. Such groups are called tame. We show that a non-archimedean abelian Polish group is tame if and only if it does not involve $\mathbb{Z}^\omega$ or $(\mathbb{Z}(p)^{<\omega})^\omega$ for any prime p. In addition to determining the structure of tame groups, we also consider the actions of such groups and study the complexity of their orbit equivalence relations in the Borel reducibility hierarchy. It is shown that if such an orbit equivalence relation is essentially countable, then it must be essentially hyperfinite. We also find an upper bound in the Borel reducibility hierarchy for the orbit equivalence relations of all tame non-archimedean abelian Polish groups.. (Received February 08, 2016)

1119-03-99 **Douglas Ulrich** (ds_ulrich@hotmail.com), **Richard Rast*** (richard.rast@gmail.com) and **Michael C Laskowski** (mcl@math.umd.edu). *Potential cardinality for countable first order theories.*

Understanding the countable model theory of a theory T has long been a topic of research. The number of countable models is a classical but very coarse invariant of T, and this was refined significantly by Friedman and Stanley with the notion of Borel reductions.

Given theories T_1 and T_2, it is often straightforward to show that T_1 is Borel reducible to T_2. However, there are few tools to show that no such Borel reduction exists. Most of the existing tools only work when the isomorphism relation of one or both is particularly simple, or at least Borel.

We define the notion of "potential cardinality" of T, denoted $\|T\|$, as the number of formally consistent, possibly uncountable Scott sentences which imply T. It turns out that if T_1 Borel reduces to T_2, then $\|T_1\| \leq \|T_2\|$. Additionally, it turns out that very frequently, $\|T\|$ can be computed and is not a proper class.

We use this idea to give a new class of examples of first-order theories whose isomorphism relations are neither Borel nor Borel complete. Along the way we answer an old question of Koerwien and a new question of Laskowski and Shelah. (Received February 10, 2016)

1119-03-112 **William Chan*** (wcchan@caltech.edu). *The countable admissible ordinal equivalence relation.*

F_{ω_1} denotes the equivalence relation on ${}^\omega 2$ defined by $x\ F_{\omega_1}\ y$ if and only if $\omega_1^x = \omega_1^y$. Marker showed it is not an orbit equivalence relation of a continuous action of a Polish group on ${}^\omega 2$. Becker showed it is not even the orbit equivalence relation of a Borel action of a Polish group. On the other hand, Montalban has shown that it is Borel reducible to an isomorphism relation of countable structures.

This talk will discuss some additional invariant descriptive set theoretic properties of F_{ω_1}: First, we show that F_{ω_1} can only be classified by countable structures of high Scott rank. An almost Borel reduction between E and F is a Borel function that may possibly fail to be a reduction on countably many E-classes. Zapletal has shown that there is an almost Borel reduction between E_{ω_1} and F_{ω_1} if there is a measurable cardinal. We show this fails in L and set-generic extensions of L. Sy-David Friedman asked whether F_{ω_1} is Borel bireducible to an isomorphism relation of a counterexample to Vaught's conjecture. We show that there is no Borel reduction of such an isomorphism relation to F_{ω_1} in L and set-generic extensions of L. (Received February 11, 2016)

1119-03-117 **Valentina Harizanov*** (harizanv@gwu.edu), Department of Mathematics, Washington, DC 20052. *Transforming structures into structures.*

We investigate computability-theoretic properties of countable structures. Frequently, interesting phenomena are first obtained on structures of special kind, which result from specific complicated constructions and may not come from natural classes. It is often desirable to find such phenomena on structures in other, well-known classes. We will present algorithmic ways of transforming certain countable structures and their isomorphisms into other types of algebraic structures and their isomorphisms in such a way that relevant computability-theoretic properties are transferred. (Received February 11, 2016)

1119-03-119 **Jared K Holshouser*** (jaredholshouser@my.unt.edu). *Jónsson Properties for non-ordinal sets under the axiom of determinacy.*

It was recently shown that, in $L(\mathbb{R})$, all cardinals below Θ have the Jónsson property. Slightly generalizing this notion, we can ask whether or not sets which cannot be well-ordered in $L(\mathbb{R})$ also have the Jónsson property. In this talk, we will discuss versions of this property for $\mathbb{R}$, $\mathbb{R}/E_0$, and finally arbitrary sets in $L_\Theta(\mathbb{R})$. (Received February 12, 2016)

1119-03-122 **Samuel Coskey*** (scoskey@nylogic.org), 1910 University Dr, Boise, ID 83725-1555. *López-Escobar's theorem and metric structures.*

This is joint work with Martino Lupini. López-Escobar's theorem states that any Borel class of countable structures can be axiomatized using a sentence of infinitary logic (with countable conjunctions and disjunctions). In this talk we present a variant of López-Escobar's theorem for metric structures. This theorem will imply that any Borel class of separable metric structures can be axiomatized using a sentence of an appropriate infinitary continuous logic. As a corollary we obtain a connection between the topological Vaught conjecture and a model-theoretic version. (Received February 12, 2016)

1119-03-124 **Konstantin Slutsky*** (kslutsky@gmail.com). *Time change equivalence of multidimensional flows.*

A time change equivalence (TCE, for short) between free $\mathbb{R}^d$-flows is an orbit equivalence which is also a homeomorphism between orbits. This notion has been studied for a long time in ergodic theory, especially in the case d=1, where it is known that there are uncountably many pairwise time change inequivalent flows. In higher dimensions, results of Rudolph and Feldman show that up to TCE there is only one ergodic (quasi) measure preserving flow.

The Borel setting was addressed by Miller and Rosendal. Based on their results on Kakutani equivalence of Borel automorphisms, they were able to show that any two non-smooth free $\mathbb{R}$-flows are TCE. Higher dimensional situation remains unclear.

In the talk we will show that up to a compressible set any orbit equivalence between co-compact cross sections can always be extended to a TCE between the $\mathbb{R}^d$-flows. In particular, any two non-smooth flows are TCE up to a compressible set. (Received February 12, 2016)

1119-03-136 **Aristotelis Panagiotopoulos*** (panagio2@illinois.edu). *Menger compacta and projective Fraïssé limits.*

In every dimension n, there exists a canonical compact, metrizable space called the n-dimensional Menger space. For $n = 0$ it is the Cantor space and for $n = \infty$ it is the Hilbert cube. On the first part of the talk I will illustrate how basic notions of classical descriptive set theory naturally generalize into higher homotopical dimensions. In the second part of the talk I show how projective Fraïssé machinery can be employed in the study of the Menger compacta.

This is a joint work with Slawomir Solecki. (Received February 13, 2016)

1119-03-137 **Hakim J. Walker*** (hjwalker@gwu.edu), 801 22nd Street NW, Room 724A, Washington, DC 20052. *Complexity of isomorphisms for certain classes of infinite graphs.* Preliminary report.

Two computable structures $\mathcal{A}$ and $\mathcal{B}$ are *computably isomorphic* if there exists a computable bijection from $\mathcal{A}$ to $\mathcal{B}$ that preserves all of the functions and relations in the structure. Furthermore, we say that $\mathcal{A}$ is *computably categorical* if every two computable copies of $\mathcal{A}$ are computably isomorphic. Significant work on computable categoricity has been done for a variety of mathematical structures, including linear orders, abelian groups, Boolean algebras, and many others.

We introduce the notion of a (2,1):1 structure, which consists of a countable set A together with a function $f : A \to A$ such that for every element x in A, f maps either exactly one or exactly two elements of A to x. These structures extend the notions of injection structures, 2:1 structures, and (2,0):1 structures studied by Cenzer, Harizanov, and Remmel in 2014, all of which can be thought of as infinite directed graphs. In this talk, we will investigate various computability-theoretic properties of (2,1):1 structures, provide conditions under which such structures are (and are not) computably categorical, and present some interesting examples. (Received February 13, 2016)

1119-03-147 **Simon Thomas*** (sthomas@math.rutgers.edu), Mathematics Department, 110 Frelinghuysen Road, Piscataway, NJ 08854. *The quasi-isometry relation for finitely generated groups.* Preliminary report.

I will discuss some possible approaches to showing that the quasi-isometry relations for finitely generated groups is not hyperfinite. (Received February 14, 2016)

1119-03-174 **Konstantinos A. Beros*** (beros@unt.edu), 1155 Union Circle, #311430, Denton, TX 76203-5017. *A completeness result in the difference hierarchy.*

While Wadge-completeness results in the usual Borel classes are relatively common, such results in the difference hiearchy are comparatively rare. In this talk, I shall present an example of a set which is easy to define in the context of ergodic theory and which is Wadge-complete for the class of differences of $F_{\sigma\delta}$ sets. (Received February 15, 2016)

1119-03-180 **Stephen C Jackson*** (jackson@unt.edu), Department of Mathematics, University of North Texas, Denton, TX 76203, and **Ed Krohne**, **Su Gao** and **Brandon Seward**. *Recent results in the combinatorics of Abelian group actions.* Preliminary report.

We discuss some recent results in the theory of actions by the groups Z^n using 2-colorings and specialized marker constructions. (Received February 15, 2016)

1119-03-182 **Cody Robert Dance*** (cody.dance@unt.edu). *The External Ultrapower of HOD via W_1^1.*

Assuming $AD + V = L(\mathbb{R})$, the study of the structure of HOD is one of the main themes in modern set theory. In particular, little is known about the large cardinal structure of HOD and how it interacts with the structural theory of $L(\mathbb{R})$. In studying the large cardinal structure of HOD, it is natural to consider the external ultrapower of HOD (which uses all functions in $L(\mathbb{R})$) via a measure μ, where μ is some measure in $L(\mathbb{R})$. Besides Woodin's proof that δ_1^2 is strong to Θ in HOD, external ultrapowers are not well understood. Let W_1^1 be the unique normal measure on ω_1. In this talk we compute the external ultrapower of HOD via W_1^1 and we analyze the associated embedding. In particular, we answer a question of Woodin and show that the canonical embedding is an iteration of HOD (at least for some large initial segment). Time allowing, we will use our analysis to answer the following question of Jackson Ketchersid "For which $\alpha < \omega_\omega$ is there an $f : \omega_1^n \to \omega_1$ such that $f \in HOD$ and $[f]_{W_n^1} = \alpha$?" (Received February 15, 2016)

1119-03-184 **Joseph Zielinski*** (jzieli2@uic.edu). *Locally Roelcke precompact Polish groups.*

We consider the property of local Roelcke precompactness. The groups with this property form a proper subclass of the locally (OB) groups, while still generalizing both the Roelcke precompact and the locally compact Polish groups. We consider examples and properties of such groups, and of a related object, the ideal of relatively Roelcke precompact subsets, for an arbitrary Polish group. (Received February 15, 2016)

1119-03-205 **Marcin Sabok***, McGill University, Department of Mathematics and Statistics, 805 Sherbrooke St W, Montreal, QC H3A 0B9, Canada. *Topological conjugacy of Toeplitz subshifts.*

I will discuss the the descriptive set theoretic complexity of the equivalence relation of conjugacy of Toeplitz subshifts of a residually finite group G. On the one hand, we will see that if G is the group of integers, then topological conjugacy on Toeplitz subshifts with separated holes is amenable. In contrast, if G is non-amenable,

then conjugacy of Toeplitz G-subshifts is a non-amenable equivalence relation. The results are motivated by a general question, asked by Gao, Jackson and Seward, about the complexity of conjugacy for minimal, free subshifts of countable groups. This is joint work with Todor Tsankov. (Received February 15, 2016)

1119-03-206 **Andrew Marks*** (marks@math.ucla.edu). *Jump operations for Borel graphs.*
We introduce a jump operation on bipartite Borel graphs, defined by analogy with Louveau's jump operation on Borel equivalence relations. We show that if G is a bipartite Borel graph, then the jump of G is a bipartite Borel graph which has no Borel homomorphism to G (though G has a Borel homomorphism to its jump). We also consider a jump analogous to the Friedman-Stanley jump, where there are interesting open questions. We use this jump operation to answer a question of Kechris and the speak. This is joint work with Adam Day. (Received February 15, 2016)

1119-03-246 **Clinton T Conley*** (clintonc@andrew.cmu.edu). *One-ended subforests and treeability.*
We discuss some classes of locally compact Polish groups for which (measure-theoretic) treeability of their orbit equivalence relations can be established by finding appropriate one-ended subforests. This talk includes joint work with Damien Gaboriau, Andrew Marks, and Robin Tucker-Drob. (Received February 16, 2016)

1119-03-252 **Bing Xu*** (xbing@mail.fresnostate.edu). *The Relationship between the Topological Properties and Common Modal Logics.* Preliminary report.
It is well-known (proved by McKinsey and Tarski in Ann. of Math. (2) 45 (1944) 141) that **S4** is sound and complete with respect to all interpretations in all topological spaces. We show that given any set X and any interpretation of $\Box$ in X that satisfies **S4**, the image of this interpretation is a topology on X. We also study the influence of the modal axioms of **S4** on topological properties of the image. (Received February 16, 2016)

1119-03-257 **Slawomir Solecki*** (ssolecki@math.uiuc.edu), Department of Mathematics, 1409 West Green Street, Urbana, IL 61801, and **Todor Tsankov**. *Logic and high homogeneity of the pseudo-arc.*
The pseudo-arc is the generic compact connected metric space. By results of Irwin and myself, the pseudo-arc is represented as a quotient of a canonical combinatorially constructed object—a projective Fraisse limit. I will introduce the notion of a generic tuple of points in the projective Fraisse limit associated with the pseudo-arc and give a characterization of such generic tuples. I will state a transfer theorem, which allows one to recover high homogeneity of the pseudo-arc from our characterization of generic tuples. (Received February 16, 2016)

1119-03-259 **Aaron Hill***, aaron.hill@louisville.edu. *Characterizing properties of and relations between rank-1 transformations.*
The rank-1 transformations form a generic subset of the (Polish) group of all measure-preserving transformations. Certain properties (e.g. having trivial centralizer) and relations (e.g. the isomorphism relation) are complete analytic on the group of all measure-preserving transformations, but become Borel when restricted to the class of rank-1 transformations. We give some examples of this phenomenon. (Received February 17, 2016)

05 ► Combinatorics

1119-05-12 **Stephanie van Willigenburg*** (steph@math.ubc.ca). *An introduction to quasisymmetric Schur functions.*
In algebraic combinatorics a central area of study is Schur functions. These functions were introduced early in the last century with respect to representation theory, and since then have become important in other areas such as quantum physics and algebraic geometry.

These functions also form a basis for the algebra of symmetric functions, which in turn forms a subalgebra of the algebra of quasisymmetric functions that itself impacts areas from category theory to card shuffling. Despite this strong connection, the existence of a natural quasisymmetric refinement of Schur functions was considered unlikely for many years.

In this talk we will meet such a natural refinement of Schur functions, called quasisymmetric Schur functions. Furthermore, we will see how these quasisymmetric Schur functions refine many well-known Schur function properties, with combinatorics that strongly reflects the classical case including diagrams, walks in the plane, and pattern avoidance in permutations.

This talk will require no prior knowledge of any of the above terms. (Received November 16, 2015)

1119-05-30 **Jacques A Verstraete*** (jacques@ucsd.edu), Department of Mathematics, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093, **Kostochka Alexandr** (kostochk@math.uiuc.edu), Department of Mathematics, University of Illinois Urbana-Champaign, 1409 W. Green Street (MC-382), Urbana, IL 61801, and **Benny Sudakov** (benjamin.sudakov@math.ethz.ch), Department of Mathematics, ETH HG G 65.1, Ramistrasse 101, Zurich, 8092. *Cycles in k-chromatic graphs.*

Erdős conjectured that every k-chromatic triangle-free graph contains cycles of at least $k^{2-o(1)}$ distinct lengths. In this talk, we prove this conjecture in a strong form, showing that there exists a constant $c > 0$ such that every k-chromatic triangle-free graph contains cycles of at least $ck^2 \log k$ distinct lengths. This result is best possible up to the value of the constant c, and part of a more general result which connects Ramsey Theory to k-chromatic graphs which do not contain certain prescribed subgraphs. (Received January 24, 2016)

1119-05-36 **Kevin Rao*** (m_xing@hotmail.com), 38 DuPont Circle, Sugar Land, TX 77479, and **Hans Li** and **William Liu**. *A combinatorial proof for the rank-unimodality of poset order ideals.* Preliminary report.

Posets are sets with ordering relations between some of its elements. Our research deals with order ideals of the product of linear posets called *chains* (denoted $n_1 \times n_2 \times n_3 \dots$). We aim to show that these levels, or the structure of $L(n_1 \times n_2 \times n_3 \dots)$, are rank unimodal.

We improved a standard poset algorithm and demonstrating rank unimodality in novel infinite families of posets. We thus gained insight on the structure of higher dimensional posets. Then we found an ingenious bijection between $L(n_1 \times n_2 \times n_3 \dots)$ and $W_1(n_1 \times n_2 \times n_3 \dots)$, which is the first proof that holds for all possible products of chains. Applying our bijection, we proved our second result that the product of any three chains is rank-unimodal, making the biggest breakthrough since O'Hara's 1990 proof of two-chain posets. Finally, we extended all of these results to outline a proof for the rank unimodality of infinite dimensional posets. (Received January 26, 2016)

1119-05-41 **Anne Schilling*** (anne@math.ucdavis.edu), Department of Mathematics, One Shields Avenue, University of California, Davis, CA 95616, and **Nicolas M Thiery**, **Graham White** and **Nathan Williams**. *Braid moves in commutation classes of the symmetric group.*

We prove that the expected number of braid moves in the commutation class of the reduced word $(s_1 s_2 \cdots s_{n-1})(s_1 s_2 \cdots s_{n-2}) \cdots (s_1 s_2)(s_1)$ for the long element in the symmetric group $\mathfrak{S}_n$ is one. This is a variant of a similar result by V. Reiner, who proved that the expected number of braid moves in a random reduced word for the long element is one. The proof is bijective and uses X. Viennot's theory of heaps and variants of the promotion operator. In addition, we provide a refinement of this result on orbits under the action of even and odd promotion operators. This gives an example of a homomesy for a nonabelian (dihedral) group that is not induced by an abelian subgroup. Our techniques extend to more general posets and to other statistics. (Received January 31, 2016)

1119-05-42 **Theodore Molla** and **Michael Santana***, University of Illinois at Urbana-Champaign, and **Elyse Yeager**, University of British Columbia. *A refinement of theorems on chorded cycles.*

In 1963, Corrádi and Hajnal proved a conjecture of Erdős showing that every graph G on at least $3k$ vertices with $\delta(G) \geq 2k$ contains k disjoint cycles. This result was extended by Enomoto and Wang, who independently showed that graphs on at least $3k$ vertices with minimum degree-sum at least $4k - 1$ also contain k disjoint cycles. Both results are best possible, and recently, Kierstead, Kostochka, Molla, and Yeager characterized their sharpness examples. In this talk we will consider analogous statements for chorded cycles. In particular, we will discuss our proof of a chorded cycle analogue to the result of Kierstead et al. (Received February 01, 2016)

1119-05-46 **Kyu-Hwan Lee***, Department of Mathematics, University of Connecticut, Storrs, CT 06269-3009, and **Cristian Lenart** and **Dongwen Liu**. *Whittaker functions and Demazure characters.*

In this talk, we will consider how to express an Iwahori-Whittaker vector through Demazure characters. Under some interesting combinatorial conditions, we will be able to obtain an explicit formula. It can be considered as a generalization of Casselman-Shalika formula. (Received February 01, 2016)

1119-05-54 **Craig Timmons*** (craig.timmons@csus.edu) and **Xing Peng** (x2peng@tju.edu.cn). *A path Turan problem for infinite graphs.*

Let G be an infinite graph whose vertex set is the natural numbers $\{1, 2, \dots\}$. An increasing path of length k is a sequence of $k+1$ vertices $n_1 < n_2 < \cdots < n_{k+1}$ such that $\{n_i, n_{i+1}\}$ is an edge of G for $1 \leq i \leq k$. How many edges can G have if G has no increasing path of length k? Czipszer, Erdős, and Hajnal answered this question in the case when $k \in \{2, 3\}$. Sometime later, Dudek and Rödl constructed an infinite graph that has no increasing path of length 16 and was denser than earlier constructions. Their graph disproved a conjecture of Erdős, however, the conjecture remained open for $4 \leq k \leq 15$. In this talk we will give constructions showing that the conjecture of Erdős is incorrect for $4 \leq k \leq 15$. This is joint work with Xing Peng and is partially supported by a grant from the Simons Foundation (#359419 to Craig Timmons). (Received February 03, 2016)

1119-05-70 **Jonathan Novak*** (jinovak@ucsd.edu), 9500 Gilman Drive, La Jolla, CA 92093. *Monotone walks on the symmetric groups.*

Consider the Cayley graph of the symmetric group $S(d)$, as generated by the conjugacy class of transpositions. This graph carries a natural edge labelling, the Biane-Stanley edge labelling, in which each edge corresponding to the transposition $(s\ t)$ is marked by t, the larger of the two numbers interchanged. A walk on $S(d)$ is monotone if the labels of the edges it traverses form a weakly increasing sequence. Given permutations ρ, σ and a nonnegative integer r, how many monotone r-step walks are there from ρ to σ? We will discuss algebraic and combinatorial approaches to this counting problem, and explain its rather surprising connections to analysis and probability. (Received February 06, 2016)

1119-05-72 **Brendon Rhoades*** (bprhoades@math.ucsd.edu). *A skein action of the symmetric group on noncrossing partitions.*

We introduce a new action of the symmetric group S_n on the vector space spanned by noncrossing partitions of $\{1, 2, \dots, n\}$. The adjacent transpositions $(i, i+1)$ will act using a seemingly novel collection of skein relations which resolve crossings in set partitions. We apply our action to solve cyclic sieving questions of Reiner-Stanton-White and Pechenik. (Received February 06, 2016)

1119-05-73 **David Jordan** and **Monica Vazirani***, Department of Mathematics, One Shields Ave, Davis, CA 95616. *A Schur-Weyl-like construction of $L(k^N)$ for the DAHA.* Preliminary report.

Building on the work of Calaque-Enriquez-Etingof, Lyubashenko-Majid, and Arakawa-Suzuki, Jordan constructed a functor from quantum D-modules on special linear groups to representations of the double affine Hecke algebra (DAHA) in type A. When we input quantum functions on SL(N) the output is $L(k^N)$, the irreducible DAHA representation indexed by an $N \times k$ rectangle. For the specified parameters, $L(k^N)$ is Y-semisimple. We give an explicit combinatorial description of this module via its Y-weight basis.

This is joint work with David Jordan. (Received February 06, 2016)

1119-05-77 **Laura Escobar*** (lescobar@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green Street, Urbana, IL 61801, and **Karola Mészáros**. *Toric matrix Schubert varieties.*

Start with a permutation matrix π and consider all matrices that can be obtained from π by taking downward row operations and rightward column operations; the closure of this set gives the matrix Schubert variety X_π. Such a variety can be written as $X_\pi = Y_\pi \times \mathbb{C}^q$ (where q is maximal). We characterize when Y_π is toric (with respect to a $2n-1$-dimensional torus) and study the associated polytope of its projectivization. We construct regular triangulations of these polytopes which we show are geometric realizations of a family of subword complexes. Based on joint work with Karola Mészáros. (Received February 08, 2016)

1119-05-80 **Michael Young*** (myoung@iastate.edu), Ames, IA 50011. *Polychromatic colorings of the hypercube.* Preliminary report.

Given a graph G which is a subgraph of the n-dimensional hypercube Q_n, an edge coloring of Q_n with $r \geq 2$ colors such that every copy of G contains every color is called *G-polychromatic*. Originally introduced by Alon, Krech and Szabó in 2007 as a way to prove bounds for Turán type problems on the hypercube, polychromatic colorings have proven to be worthy of study in their own right. This talk will survey what is currently known about polychromatic colorings and introduce some open questions. In addition, there are some natural generalizations and variations of the problem that will also be discussed. (Received February 08, 2016)

1119-05-84 **Edward Richmond** (edward.richmond@okstate.edu), **Vasu Tewari*** (vasut@math.washington.edu) and **Steph van Willigenburg** (steph@math.ubc.ca). *A noncommutative geometric Littlewood-Richardson rule.*

The geometric Littlewood-Richardson rule is a combinatorial algorithm for computing Littlewood-Richardson coefficients derived from degenerating the Richardson variety into a union of Schubert varieties in the Grassmannian. Such rules were first given by Vakil, and later generalized by Coskun.

In this talk, we will describe a noncommutative version of the geometric Littlewood-Richardson rule, and use it to establish a geometric explanation for positivity of noncommutative Littlewood-Richardson coefficients in certain cases. (Received February 09, 2016)

1119-05-91 **Oliver Pechenik*** (pecheni2@illinois.edu) and **Alexander Yong**. *Puzzles and equivariant K-theory of Grassmannians.*

The cohomology of the Grassmannian has a basis given by Schubert classes. The structure coefficients of this ring are the celebrated Littlewood-Richardson numbers, and are calculated by any of the Littlewood-Richardson rules. This story has been extended to K-theory by A. Buch (2002) and to torus-equivariant cohomology by A. Knutson-T. Tao (2003). It is natural to unify these theories via a combinatorial rule for structure coefficients in equivariant K-theory. In 2005, A. Knutson-R. Vakil used puzzles to conjecture such a rule. Recently we proved the first combinatorial rule for these coefficients. Using our new rule, we construct a counterexample to the Knutson-Vakil conjecture and prove a mild correction to it. (Received February 09, 2016)

1119-05-92 **Zachary Hamaker**, **Rebecca Patrias**, **Oliver Pechenik*** (pecheni2@illinois.edu) and **Nathan Williams**. *Coincidental types, K-theoretic Schubert calculus, and bijections of plane partitions.*

In 1983, R. Proctor established non-bijectively that the number of plane partitions of height k over a rectangle equals the number of plane partitions of height k over a shifted trapezoid. Explicit bijections were given for the case $k = 1$ by J. Stembridge (1986) and V. Reiner (1997), and for the case $k = 2$ by S. Elizalde (2015).

One consequence of R. Proctor's result is that the two shapes also have the same number of standard Young tableaux. An elegant bijective proof of this latter fact was given by M. Haiman (1992). We use combinatorial technology derived from K-theoretic Schubert calculus to extend M. Haiman's bijection, obtaining the first bijective proof of R. Proctor's result for arbitrary k. Our techniques apply more generally, establishing analogous results for other positive root posets of coincidental type. (Received February 09, 2016)

1119-05-93 **Sara Billey*** (billey@math.washington.edu), Box 354350, Math dept, Seattle, WA 98105, and **Matjaz Konvalinka**, **T. Kyle Petersen**, **William Slofstra** and **Bridget Tenner**. *"Enumeration of parabolic double cosets for coxeter groups".*

Parabolic subgroups W_I of Coxeter systems (W, S) and their ordinary and double cosets W/W_I and $W_I\backslash W/W_J$ appear in many contexts in combinatorics and Lie theory, including the geometry and topology of generalized flag varieties and the symmetry groups of regular polytopes. The set of ordinary cosets wW_I, for $I \subseteq S$, forms the Coxeter complex of W, and is well-studied. In this extended abstract, we look at a less studied object: the set of all double cosets $W_I w W_J$ for $I, J \subseteq S$.

Each double coset can be presented by many different triples (I, w, J). We describe what we call the lex-minimal presentation and prove that there exists a unique such choice for each double coset. Lex-minimal presentations can be enumerated via a finite automaton depending on the Coxeter graph for (W, S).

In particular, we present a formula for the number of parabolic double cosets with a fixed minimal element when W is the symmetric group S_n. In that case, parabolic subgroups are also known as Young subgroups. Our formula is almost always linear time computable in n, and the formula can be generalized to any Coxeter group. (Received February 09, 2016)

1119-05-109 **Steve Butler*** (butler@iastate.edu). *Rainbow arithmetic progressions.*

Ramsey theory considers the problem of finding monochromatic sub-structures of a given coloring. The opposite extreme is to look for sub-structures that are *rainbow* colored, i.e., which have no repeated colors. We consider the rainbow variation of the van der Waerden problem, i.e., the minimum number of colors needed to guarantee the existence of a rainbow arithmetic progression inside a coloring of $[n]$. In particular this has a significant variance between 3-term progressions and 4-term (or higher) progressions.

Joint work with Craig Erickson, Leslie Hogben, Kirsten Hogenson, Lucas Kramer, Richard Kramer, Jephian Lin, Ryan Martin, Derrick Stolee, Nathan Warnberg, and Michael Young. (Received February 10, 2016)

1119-05-110 **Tao Jiang*** (jiangt@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056. *Hypergraph Turan numbers via Lagrangians.*

Given an r-graph H, the Turan number $ex(n, H)$ of H is the maximum size of an n-vertex r-graph G that does not contain H as a subgraph. We discuss some recent work by various authors, including myself and collaborators, on the exact determination (for large n) of $ex(n, H)$ for many r-graphs H of a certain type using the method of hypergraph Lagrangians. We also pose some related problems. (Received February 11, 2016)

1119-05-129 **Sami Assaf** (shassaf@usc.edu), Department of Mathematics, University of Southern California, 3620 S Vermont Ave KAP 104, Los Angeles, CA 90089, and **Dominic Searles*** (dsearles@usc.edu), Department of Mathematics, University of Southern California, 3620 S Vermont Ave KAP 104, Los Angeles, CA 90089. *Schubert polynomials and slide polynomials.*

We introduce the monomial and fundamental slide bases for the polynomial ring. These bases, which are lifted from monomial and fundamental quasisymmetric polynomials, have nonnegative structure constants, and we obtain nonnegative combinatorial formulas for these numbers. We give a nonnegative combinatorial formula for the expansion of a Schubert polynomial into the fundamental slide basis, in terms of quasi-Yamanouchi pipe dreams. We use these formulas to gain a refined understanding of stability of Schubert polynomials. In particular, we tighten a bound of Li for when the Schubert basis expansion of a product of Schubert polynomials stabilizes. (Received February 13, 2016)

1119-05-130 **Ben Salisbury*** (salis1bt@cmich.edu), Department of Mathematics, Central Michigan University, Pearce Hall 206H, Mount Pleasant, MI 48859, and **Travis Scrimshaw** (tscrimsh@umn.edu), Department of Mathematics, University of Minnesota, 204 Vincent Hall, Minneapolis, MN 55455. *Rigged configurations and $B(\infty)$.*

The crystal $B(\infty)$ is a combinatorial skeleton of the negative half of the quantum group, and its importance in the theory of crystal bases has been highlighted since Kashiwara's original papers on the subject. Since then, many combinatorial models for $B(\infty)$ have been developed (i.e., tableaux, MV polytopes, quiver varieties, modified Nakajima monomials, etc). In this talk, we introduce yet another model for $B(\infty)$; one that is uniform across all symmetrizable types. Our new model, denoted $\mathrm{RC}(\infty)$, is a collection of rigged configurations, which are multipartitions whose parts are "rigged" with, or labeled by, integers. The connection between our model and the marginally large tableaux model will be discussed, as well as the calculation of the $*$-involution on $\mathrm{RC}(\infty)$. This is joint work with Travis Scrimshaw. (Received February 13, 2016)

1119-05-131 **Ben Salisbury*** (salis1bt@cmich.edu), Department of Mathematics, Central Michigan University, Pearce Hall 206H, Mount Pleasant, MI 48859, **Adam Schultze** (aschultze@albany.edu), Department of Mathematics and Statistics, Earth Science 110, University at Albany, Albany, NY 12222, and **Peter Tingley** (ptingley@luc.edu), Dept. of Maths and Stats, Loyola University, BVM hall, room 506, 1032 W. Sheridan Road, Chicago, IL 60660. *Crystal structure of certain PBW bases.* Preliminary report.

Lusztig's theory of PBW bases gives a way to realize the crystal $B(\infty)$ for any complex-simple Lie algebra where the underlying set consists of Kostant partitions. In fact, there are many different such realizations: one for each reduced expression of the longest element of the Weyl group. There is an explicit algorithm to calculate the actions of the crystal operators, but it can be quite complicated. For simply-laced types, we give conditions on the reduced expression which ensure that the corresponding crystal operators are given by a simple combinatorial bracketing rule. We then give at least one reduced expression satisfying our conditions in every simply-laced type except E_8, and discuss the resulting combinatorics. Finally, we describe the relationship with more standard tableaux combinatorics in types A and D. (Received February 13, 2016)

1119-05-133 **Jennifer Diemunsch** and **Stephen Hartke** (sogol.jahanbekam@ucdenver.edu), Denver, CO 80217, **Sogol Jahanbekam*** (sogol.jahanbekam@ucdenver.edu), CO , and **Brent Thomas**. *Coloring squares of planar graphs.*

In 1977 Wegner conjectured that the square of any subcubic planar graph is 7-colorable. In this talk we use discharging method and computation to give a proof to this conjecture. This is joint work with Jennifer Diemunsch, Stephen Hartke, and Brent Thomas. (Received February 13, 2016)

1119-05-138 **Ben Brubaker** and **Andrew Schultz*** (andrew.c.schultz@gmail.com). *Ice diagrams and Hamiltonians.* Preliminary report.

We begin the talk with a survey of results that show how statistical mechanical methods — namely the six-vertex model and the Yang-Baxter equation — have been used recently to recover some representation-theoretic

identities like the Weyl character formula. We then show how these same results can be interpreted through the lens of discrete time evolution of the six vertex model. In particular, we show that a certain t-deformation of a known Hamiltonian for the five-vertex model can be used to recover some of the results already established via the Yang-Baxter equation. (Received February 13, 2016)

1119-05-160 **Michael Krivelevich** and **Po-Shen Loh*** (ploh@cmu.edu), Wean 6113, Dept of Math Sciences, Carnegie Mellon Universiy, Pittsburgh, PA 15213, and **Benny Sudakov**. *The matching-number process.*

The matching number of a graph G is the maximum number ν for which there exists a set of ν vertex-disjoint edges contained in G. Let the k-matching process on n vertices be defined as follows: generate a uniformly random permutation of the $\binom{n}{2}$ potential edges. Initially, start with n vertices and no edges. Process the potential edges one at a time, in the order that they appear in the permutation. If at a given iteration, the addition of that edge to the current graph would not increase its matching number above k, then add that edge. We prove that for $k = o(n)$, asymptotically almost surely this process terminates with a graph which consists of some k vertices that are adjacent to all other vertices (including each other), and nothing more. This precisely matches the extremal construction in the classical Erdős-Gallai bound on the maximum number of edges in an n-vertex graph with matching number at most k, in this regime $k = o(n)$.

Joint work with Michael Krivelevich and Benny Sudakov. (Received February 15, 2016)

1119-05-176 **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 with appealing combinatorial structure. We study cellular resolutions of these ideals and seek to interpret their Betti numbers. 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 of 'tropical' hyperplane arrangements. We discuss some combinatorial and algebraic applications of our results, as well as some future directions. This is joint work with Alex Fink and Raman Sanyal. (Received February 15, 2016)

1119-05-177 **Cristian Lenart**, **Daniel Orr*** (dorr@vt.edu) and **Mark Shimozono**. *Compression and combinatorial formulas for Koornwinder polynomials.* Preliminary report.

The Koornwinder polynomials are a six-parameter family of n-variable orthogonal Laurent polynomials, first introduced as BC_n-analogues of Macdonald polynomials. In the general framework of Macdonald-Koornwinder polynomials, Koornwinder's original polynomials are attached to the maximal non-reduced extension of the affine root system of type $D^{(2)}_{n+1}$; via specialization of parameters they recover all Macdonald polynomials of classical type. The Ram-Yip formula gives a combinatorial expression for Macdonald-Koornwinder polynomials as a weighted sum over alcove walks. Using a map from alcove walks to diagram fillings, we compress the Ram-Yip formula for Koornwinder polynomials to a smaller, more explicit combinatorial formula. (Received February 15, 2016)

1119-05-188 **Benjamin J. Wyser*** (bwyser@illinois.edu) and **Alexander Yong**. *Versions of Schubert and Grothendieck polynomials for symmetric orbit closures.*

Schubert polynomials (resp. Grothendieck polynomials) are a particular system of representatives for cohomology (resp. K-theory) classes of Schubert varieties in a flag manifold which possess a number of favorable combinatorial properties. Consider instead the problem of determining a system of cohomological or K-theoretic representatives of the closures of orbits of a symmetric subgroup K of GL_n on the flag manifold, where K is either the symplectic or the orthogonal group. We give solutions to these problems which share many of the favorable combinatorial properties of Schubert polynomials. Namely, our polynomial families are well-defined (or "self-consistent"), have non-negative integer coefficients, and are stable with respect to the containment of one flag manifold into a larger one. (Received February 15, 2016)

1119-05-191 **Cory Palmer*** (cory.palmer@umontana.edu) and **Daniel Gerbner**. *Counting subgraphs in F-free graphs.*

For a fixed graph F we say that a graph is F-free if it contains no copy of F as a subgraph. The standard question in extremal graph theory is to determine the maximum number of edges possible in an n-vertex F-free graph. In this talk we will discuss a generalization of this problem. Given fixed graphs F and H, determine the

maximum number of copies of a subgraph H in an n-vertex F-free graph. We will survey what is known about this problem and present some new results. (Received February 15, 2016)

1119-05-197 **Martha Precup*** (mprecup@math.northwestern.edu) and **Julianna Tymoczko** (jtymoczko@smith.edu). *The Betti numbers of parabolic Hessenberg varieties.*

Hessenberg varieties are subvarieties of the flag variety which generalize Springer fibers. In this talk, I will discuss joint work with J. Tymoczko analyzing the geometric structure of parabolic Hessenberg varieties. We give an explicit combinatorial description in terms of row-strict tableaux of a union of Schubert varieties whose Betti numbers agree with the Betti numbers of each parabolic Hessenberg variety. This characterization combinatorially connects two very well-studied subvarieties of the flag variety, and is especially notable since their geometric descriptions differ greatly. We will also discuss some geometric and combinatorial conjectures which arise from this analysis. (Received February 15, 2016)

1119-05-198 **Lindsey-Kay Lauderdale*** (llauderdale@uttyler.edu), The University of Texas at Tyler, 3900 University Blvd, Tyler, TX 75799, and **Christina Graves** and **Stephen J Graves**. *Smallest graphs with given generalized quaternion automorphism group.*

A smallest graph whose automorphism group is isomorphic to the generalized quaternion group Q_{2^n}, where $n \geq 3$, is constructed. If $n \neq 3$, such a graph has 2^{n+1} vertices and 2^{n+2} edges. In the special case $n = 3$, a smallest graph has 16 vertices but 44 edges. (Received February 15, 2016)

1119-05-200 **Kevin Dilks**, **Oliver Pechenik** and **Jessica Striker***, jessica.striker@ndsu.edu. *Resonance in orbits of plane partitions and increasing tableaux.*

We introduce a new concept of resonance on discrete dynamical systems. This concept formalizes the observation that, in various combinatorially-natural cyclic group actions, orbit cardinalities are all multiples of divisors of a fundamental frequency. Our prototypical example of this phenomenon is B. Wieland's gyration action on alternating sign matrices.

Our main result is an equivariant bijection between plane partitions in a box (or order ideals in the product of three chains) under rowmotion and increasing tableaux under K-promotion. Both of these actions were observed to have orbit sizes that were small multiples of divisors of an expected orbit size, and we show this is an instance of resonance, as K-promotion cyclically rotates the set of labels appearing in the increasing tableaux. We extract a number of corollaries from this equivariant bijection, including a strengthening of a theorem of [P. Cameron–D. Fon-der-Flaass '95] and several new results on the order of K-promotion. Along the way, we adapt the proof of the conjugacy of promotion and rowmotion from [J. Striker–N. Williams '12] to give a generalization in the setting of n-dimensional lattice projections. (Received February 15, 2016)

1119-05-202 **Andrew Berget*** (andrew.berget@wwu.edu). *The internal zonotopal algebra of the dual type B reflection arrangement.* Preliminary report.

If $\mathcal{A}$ is an arrangement of hyperplanes, the *internal zonotopal algebra* of $\mathcal{A}$ is a zero dimensional commutative algebra of degree $\mathrm{Tutte}_{\mathcal{A}}(0,1)$. We consider the case that $\mathcal{A}$ is the Gale dual of the type B reflection arrangement. Examination of an apparent numerical fluke reveals that this algebra has a new and interesting representation theoretical structure. (Received February 15, 2016)

1119-05-203 **Derek Hoeft***, dhoeft@csusm.edu, and **Shahed Sharif**. *Possible matrix representations of connected graph flow spaces.* Preliminary report.

Let Γ be a connected graph and τ be an automorphism on Γ. The integral representation of τ on the flow space of Γ gives rise to a square integer matrix A. We would like to determine what matrices A can arise this way. An obvious necessary condition is that A has finite order. Is this condition sufficient? We show that the answer is no by showing that A cannot have characteristic polynomial $x^4 - x^2 + 1$. (Received February 15, 2016)

1119-05-223 **Edward Richmond*** (edward.richmond@okstate.edu) and **William Slofstra**. *Staircase diagrams and the enumeration of smooth Schubert varieties.*

Staircase diagrams are certain partially ordered sets defined over a graph. When the graph is the Dynkin diagram of a simple Lie group, these diagrams correspond to smooth Schubert varieties of the corresponding flag variety. Staircase diagrams have two applications. First, they encode much of the geometric and combinatorial data of Schubert varieties. Second, these diagrams give a way to calculate the generating series for the number of smooth Schubert varieties of any type. This extends the work of M. Haiman who calculated this generating series in type A. This talk is on joint work with W. Slofstra. (Received February 16, 2016)

1119-05-226 **Kaisa Taipale*** (taipale@umn.edu), **Anna Bertiger** and **Elizabeth Milicevic**.
Quantum equivariant cohomology of Grassmannians via cyclic factorial Schur functions.
Cyclic factorial Schur functions are specializations of usual factorial Schur functions that make (somewhat) evident the affine structure that can be found in the equivariant quantum cohomology of the Grassmannian. This talk will explore several ways in which this connection manifests, focusing on symmetric polynomials. (Received February 16, 2016)

1119-05-230 **Stephen J. Young*** (stephen.young@pnnl.gov), **Paul Bruillard** and **Kathleen Nowak**. *Enumeration of self-dual, multiplicity 1, fusion rings from a graphical perspective.* Preliminary report.
We develop a method to associate a graphical structure with a self-dual, multiplicity 1, fusion ring. Using this graphical structure we can enumerate all such fusion rings with rank at most 8. We also provide a complete characterization of all such fusion rings where the graphical structure is triangle-free. Additionally, we produce a non-trival infinite family of such fusion rings. Joint work with Paul Bruillard and Kathleen Nowak. (Received February 16, 2016)

1119-05-241 **Radoslav Fulek**, IST Austria, Am Campus 1, 3400 Klosterneuburg, Austria, **Michael J Pelsmajer***, Illinois Institute of Technology, Department of Applied Mathematics, 10 W. 32nd St., RE 208, Chicago, IL 60616, and **Marcus Schaefer**, DePaul University, College of Computing and Digital Media, 243 South Wabash, Ste 401, Chicago, IL 60604.
Hanani-Tutte for radial planarity.
Two edges in a drawing of a graph are said to cross *evenly* (*oddly*) if they cross an even (odd) number of times. The Hanani-Tutte Theorem states that if a graph is drawn in the plane such that every pair of non-adjacent edges cross evenly, then the graph is planar. We prove an analogous theorem for radial drawings, which extends an earlier result for monotone drawings. A drawing of a graph is *radial* if its vertices are assigned to concentric circles $C_1, \ldots, C_k$ with common center c, and edges are drawn *radially*: every edge intersects every circle centered at c at most once. (Received February 16, 2016)

1119-05-244 **Zachary Hamaker**, **Eric Marberg** and **Brendan Pawlowski*** (pawlows@umich.edu).
Transitions for involution Schubert polynomials.
Wyser and Yong defined polynomials representing the cohomology classes of the $O(n)$-orbit closures on the type A flag variety—these orbits are indexed by involutions in S_n, and we call Wyser and Yong's representatives involution Schubert polynomials. We give an analogue of Lascoux-Schützenberger's transition recurrence for these polynomials. Our approach is combinatorial, beginning with a Billey-Jockusch-Stanley–type formula expressing involution Schubert polynomials as sums over appropriate analogues of reduced words which we call involution words, introduced by Richardson and Springer. A key tool is a version of the Little map for involution words. By stabilizing involution Schubert polynomials one obtains involution Stanley symmetric functions, to which the transition recurrence also applies, and we use it to show that involution Stanley symmetric functions are P-Schur–positive. As a consequence we recover various identities between P-Schur functions and skew Schur functions, and obtain enumerations of involution words in terms of shifted standard tableaux. (Received February 16, 2016)

1119-05-245 **Alexander K Woo*** (awoo@uidaho.edu), 875 Perimeter Dr MS 1103, Moscow, ID 83844-1103. *Hultman elements for finite reflection groups.* Preliminary report.
Given a permutation (or more generally an element in a finite reflection group) w, one can define a hyperplane arrangement $\mathcal{A}_w \subseteq \mathbb{R}^n$ called the **inversion arrangement**. On the symmetric group (or any finite reflection group), one can define a partial order known as **Bruhat order**. Hultman showed that the number of regions $\mathcal{A}_w$ cuts $\mathbb{R}^n$ into is always at most the number of elements less than or equal to w in Bruhat order, and gave a condition on the Bruhat graph (a graph related to Bruhat order) for when equality occurs.

This result of Hultman generalizes work of Hultman, Linusson, Shareshian, and Sjöstrand in the case of permutations. In this case, they show equality occurs precisely when w **pattern avoids** the 4 permutations 4231, 35142, 42513, and 351624. This set of permutations was earlier studied in a different context by Gasharov and Reiner. I will talk about a potential non-obvious generalization of the Gasharov-Reiner conditions defining this set, which I can prove is equivalent to the Hultman condition for type B (which is the hyperoctahedral group, the symmetry group of the n-cube). The type B elements can also be characterized by a list of 31 pattern avoidance conditions. (Received February 16, 2016)

1119-05-248 **Tom Bohman**, **Dhruv Mubayi** and **Mike Picollelli*** (mpicollelli@csusm.edu), Department of Mathematics, California State University San Marcos, 333 S. Twin Oaks Valley Rd, San Marcos, CA 92096. *The independent neighborhoods process.*

A triangle $T^{(r)}$ in an r-uniform hypergraph is a set of $r+1$ edges such that r of them share a common $(r-1)$-set of vertices and the last edge contains the remaining vertex from each of the first r edges. Our main result is that the random greedy triangle-free process on n vertices terminates in an r-uniform hypergraph with independence number $O((n \log n)^{1/r})$. As a consequence, the hypergraph Ramsey number $r(T^{(r)}, K_s^{(r)})$ has order of magnitude $s^r / \log s$. This answers questions posed by Bohman, Frieze, and Mubayi, and by Kostochka, Verstraëte, and Mubayi, and generalizes the celebrated results of Ajtai-Komlós-Szemerédi and Kim to hypergraphs.

Joint work with Tom Bohman and Dhruv Mubayi. (Received February 16, 2016)

1119-05-250 **Patrick Bennett*** (patrick.bennett@wmich.edu), 4526 Wimbleton Way, Kalamazoo, MI 49009. *The Ramsey-Turán problem with small independence number.*

Let s be an integer, $f = f(n)$ a function, and H a graph. Define the *Ramsey-Turán number* $\mathbf{RT}_s(n, H, f)$ as the maximum number of edges in an H-free graph G of order n with $\alpha_s(G) < f$, where $\alpha_s(G)$ is the maximum number of vertices in a K_s-free induced subgraph of G. In this talk we consider $\mathbf{RT}_s(n, K_t, n^\delta)$ for fixed $\delta < 1$. We show that for an arbitrarily small $\varepsilon > 0$ and $1/2 < \delta < 1$, $\mathbf{RT}_s(n, K_{s+1}, n^\delta) = \Omega(n^{1+\delta-\varepsilon})$ for all sufficiently large s. This is nearly optimal, since a trivial upper bound yields $\mathbf{RT}_s(n, K_{s+1}, n^\delta) = O(n^{1+\delta})$. Furthermore, the range of δ is as large as possible. (Received February 16, 2016)

06 ► Order, lattices, ordered algebraic structures

1119-06-113 **Luke E Nelson*** (luke.nelson@asu.edu), School of Mathematical & Statistical Sciences, Arizona State University, P.O. Box 871804, Tempe, AZ 85287-1804. *A lattice of maximal chains of the Tamari lattice.* Preliminary report.

The family of Tamari lattices Tn, based on a Catalan set of objects, was originally defined on bracketings of a set of n + 1 objects, with a cover relation the associativity rule in one direction. The Tamari lattice is the one-skeleton of the associahedron and is a quotient of the weak Bruhat order. Despite the plethora of papers on this subject, the enumeration of maximal chains in Tamari lattices is still an open problem. This is especially odd, because the numbers of maximal chains in closely related lattices are known. In this talk we define a partially ordered set on equivalence classes of maximal chains of the Tamari lattice and discuss its structure. We call this poset the Tamari Block poset, TBn. We prove that TBn is a graded lattice. Furthermore, we discuss a useful characterization of the elements of TBn and its connections with other known posets. (Received February 11, 2016)

08 ► General algebraic systems

1119-08-144 **Yuri Movsisyan*** (yurimovsisyan@yahoo.com), Alex Manoogian 1, 0025 Yerevan, Armenia. *Idempotent algebras with semigroup operations.*

It is well-known that every idempotent semigroup is locally finite, i.e. every finitely generated idempotent semigroup is finite. We give a general version of this result concerning to idempotent algebras with an associative hyperidentity. (Received February 14, 2016)

11 ► Number theory

1119-11-40 **Igor Szczyrba*** (igor.szczyrba@unco.edu), School of Mathematical Sciences, University of Northern Colorado, Greeley, CO 80639. *What do the Golden Ratio and a crescent moon have in common?*

We introduce geometric representations of the sequence of the n-anacci constants and generalizations thereof that consist of the ratio limits generated by linear recurrences of an arbitrary order n with equal integer weights. We represent the n-anacci constants and their generalizations geometrically by means of the dilation factors of dilations transforming collections of compact *convex* sets with rising dimensions n. For instance, if we dilate unit n-balls with centers at (1,0,...,0), then the n-anacci constants lead to a collection of *non-convex* sets with centers of mass at (2,0,...,0). In particular, for n=2, the Golden Ratio determines the size of a crescent moon with the center of mass at (2,0). (Received January 31, 2016)

1119-11-50 **Yuanqing Cai*** (yuanqing.cai@bc.edu), Department of Mathematics, Boston College, 140 Commonwealth Ave, Maloney 534, Chestnut Hill, MA 02467. *Fourier coefficients for Theta representations on covers of general linear groups.*

We introduce and study two types of Fourier coefficients for the theta representations on covers of general linear groups of arbitrary degree. The first are semi-Whittaker coefficients, which generalize coefficients introduced by Bump and Ginzburg for the double cover. The covers for which these coefficients vanish identically (resp. do not vanish for some choice of data) are determined in full. The second are the Fourier coefficients associated with general unipotent orbits. In particular, we determine the unipotent orbit attached, in the sense of Ginzburg, to the theta representations. Finally, we consider the question of uniqueness, and in certain cases we prove the global uniqueness of each model. (Received February 02, 2016)

1119-11-61 **Baiying Liu*** (liu@ias.edu), School of Mathematics, Institute for Advanced Study, Princeton, NJ 08540. *On the local converse theorem for p-adic GLn.*

In this talk, I will introduce my joint work with Prof. Herve Jacquet on a complete proof of a standard conjecture on the local converse theorem for generic representations of GLn(F), where F is a non-archimedean local field. (http://arxiv.org/abs/1601.03656) (Received February 04, 2016)

1119-11-79 **Amanda Folsom** and **Paul Jenkins*** (jenkins@math.byu.edu). *Zeros of modular forms of half integral weight.*

We study canonical bases for spaces of weakly holomorphic modular forms of level 4 and weights in $\mathbb{Z} + \frac{1}{2}$ and show that almost all modular forms in these bases have the property that many of their zeros in a fundamental domain for $\Gamma_0(4)$ lie on a lower boundary arc of the fundamental domain. Additionally, we show that at many places on this arc, the generating function for Hurwitz class numbers is equal to a particular mock modular Poincaré series, and show that for positive weights, a particular set of Fourier coefficients of cusp forms in this canonical basis cannot simultaneously vanish. (Received February 08, 2016)

1119-11-101 **Anna Puskas***, puskas@ualberta.ca. *Demazure-Lusztig operators, metaplectic Iwahori-Whittaker functions and crystals.*

Demazure-Lusztig operators appear throughout the study of p-adic Whittaker functions, in both the nonmetaplectic and the metaplectic setting. Brubaker, Bump and Licata used them to describe Iwahori-Whittaker functions in the finite-dimensional setting; Manish Patnaik to prove an analogue of the Casselman-Shalika formula for affine Kac-Moody groups. Joint work with Gautam Chinta and Paul E. Gunnells shows that their metaplectic versions behave similarly to the nonmetaplectic ones - in particular, the existence of a metaplectic analogue of the Demazure character formula. We will review a metaplectic version of Tokuyama's theorem that uses Demazure-Lusztig operators as a combinatorial tool. This result links the constructions of Whittaker functions as a sum over a highest weight crystal (Brubaker-Bump-Friedberg and McNamara), and as a sum over a Weyl group (Chinta-Offen and McNamara). Then we will discuss joint work with Manish Patnaik that relates metaplectic Iwahori-Whittaker functions to Demazure-Lusztig operators. We will also report on joint work in progress to establish the same result for Kac-Moody groups. (Received February 10, 2016)

1119-11-146 **Holley Friedlander*** (friedlah@dickinson.edu). *On p-parts of Weyl group multiple Dirichlet series.*

There are two main techniques for constructing p-parts of Weyl group multiple Dirichlet series. The first of Brubaker, Bump, and Friedberg defines the coefficients term by term via Gelfand-Tsetlin patterns, crystal graphs, and related combinatorial devices. The second of Chinta and Gunnells defines the coefficients all at once via an averaging technique analogous to the Weyl character formula. We compare these two techniques and provide evidence that they yield the same series, extending previous results of Chinta, Friedberg, and Gunnells. (Received February 14, 2016)

1119-11-151 **Kimball Martin***, University of Oklahoma, Department of Mathematics, Norman, OK 73019. *Eisenstein congruences and the Jacquet-Langlands correspondence.* Preliminary report.

We will explain how to use the Jacquet-Langlands correspondence to show, in a simple way, the existence of weight 2 elliptic or Hilbert cusp forms which are congruent to a weight 2 Eisenstein series. We will also discuss applications to L-values. This generalizes some results of Mazur and others. (Received February 14, 2016)

1119-11-164 **Joseph A Hundley*** (joseph.hundley@gmail.com), 244 Mathematics Building, University at Buffalo, Buffalo, NY 14260, and **Xin Shen** (shenx125@math.utoronto.ca), Department of Mathematics, University of Toronto, Bahen Centre, 40 St. George St, Room 6290, Toronto, Ontario M5S2E4, Canada. *Multivariable Rankin-Selberg Integral for a product of twisted spinor L functions.*

We consider a new integral representation for $L(s_1, \Pi \times \tau_1)L(s_2, \Pi \times \tau_2)$, where Π is a globally generic cuspidal representation of $GSp4$, and τ_1 and τ_2 are two cuspidal representations of GL_2 having the same central character. As and application, we find a new period condition for two such L functions to have a pole simultaneously. This points to an intriguing connection between a Fourier coefficient of a residual representation on $GSO(12)$ and a theta function on $\widetilde{Sp}(16)$. A similar integral on $GSO(18)$ fails to unfold completely, but in a way that provides further evidence of a connection. (Received February 15, 2016)

1119-11-247 **Dorian Goldfeld** and **Michael Woodbury*** (woodbury@math.uni-koeln.de), Weyertal 86-90, 50931 Cologne, Germany. *A useful integral representation of the $GL(n)$ Whittaker function.* Preliminary report.

We give an integral representation for the $GL(n, \mathbb{R})$ Whittaker function W_n which is particularly suitable to applications in analytic number theory. Two theorems of Stade are used. First, one which gives a formula for the Mellin transform of W_n is combined with Mellin inversion to give a preliminary integral representation. Unfortunately, for applications, this representation in often not sufficient. However, our formula can be obtained from this by shifting the lines of integration and applying a second theorem of Stade on the poles of said Mellin transform. An application is given to the Kuznetsov trace formula for $GL(n)$. (Received February 16, 2016)

13 ► Commutative rings and algebras

1119-13-28 **Andras Lorincz**, **Claudiu Raicu**, **Uli Walther*** (walther@math.purdue.edu) and **Jerzy Weyman**. *Bernstein-Sato polynomials of generic matrices.*

We discuss the Bernstein-Sato polynomial and Monodromy Conjecture in general, and give explicit computations for the ideal of the maximal minors of a generic mxn matrix. (Received January 18, 2016)

1119-13-76 **Alexandra Seceleanu*** (aseceleanu@unl.edu). *The Waldschmidt constant for squarefree monomial ideals.*

The Waldschmidt constant is an asymptotic invariant associated to a homogeneous ideal. It measures the rate of growth of the initial degree of the symbolic powers of the given ideal. The study of Waldschmidt constants is motivated by geometric considerations, i.e. estimating the lowest degree of a hypersurface vanishing at all the points of a variety to a given order.

In this talk, we give several combinatorial interpretations for the Waldschmidt constant of a squarefree monomial ideals. While Waldschmidt constants are generally very difficult to compute, this will allow us to determine them completely in several important cases and to prove a useful general lower bound conjectured by Cooper-Embree- Ha-Hoefel. This is joint work with C. Bocci, S. Cooper, E. Guardo, B. Harbourne, M. Janssen, U. Nagel, A. Van Tuyl and T. Vu. (Received February 08, 2016)

1119-13-82 **Paul C Roberts*** (roberts@math.utah.edu). *The Gabber-Cohen Theorem and the Homological Conjectures.*

In recent years there have been several attempts to prove cases of the Homological Conjectures in mixed characteristic using the Almost Purity Theorem. This has had partial success, in particular for extensions of regular local rings that become étale after inverting p. Recently Gabber proved an extension of the Cohen structure theorems that reduce some of the problems to the case of extensions that become étale after inverting an element prime to p. This talk will present these ideas, show how they relate to the Homological Conjectures, and discuss some new questions that arise. (Received February 15, 2016)

1119-13-85 **Justin Chen***, jchen@math.berkeley.edu. *Invertible sums of matrices.*

Given a finite set of matrices whose sum is invertible, can one always find a (small) subsum among them which is still invertible? I will discuss this question, which leads to a characterization of local rings, and other related problems for semilocal rings. The main technical result is a polynomial determinantal identity, which follows from an abstract combinatorial identity. (Received February 09, 2016)

1119-13-126 **Zach Teitler*** (zteitler@boisestate.edu), 1910 University Drive, Department of Mathematics, Boise State University MS 1555, Boise, ID 83725-1555. *Sufficient condition for Strassen's additivity conjecture for Waring rank.* Preliminary report.

Strassen's additivity conjecture asserts that if $T \in V_1 \otimes \cdots \otimes V_d$ and $T' \in V_1' \otimes \cdots \otimes V_d'$, then $T + T' \in (V_1 \oplus V_1') \otimes \cdots \otimes (V_d + V_d')$ has rank equal to the sum of the ranks of T and T'. A version of the conjecture for symmetric tensors asserts that the Waring rank of a sum of homogeneous forms in independent variables is equal to the sum of the ranks of the summand forms. We give a sufficient condition for a stronger version of Strassen's conjecture for Waring rank. (Received February 12, 2016)

1119-13-134 **Eloísa Grifo*** (er2eq@virginia.edu), 141 Cabell Drive, Kerchof Hall, Charlottesville, VA 22904. *Symbolic powers of prime ideals (preliminary report).* Preliminary report.

An old question of Huneke asks whether the containment $I^{(3)} \subseteq I^2$ is true when I is an equidimensional codimension 2 reduced ideal in a regular local ring. This questions was later extended by Harbourne and Huneke to higher codimension. A counterexample was found by Dumnicki, Szemberg and Tutaj-Gasińskna for special configurations of points in $\mathbb{P}^2$. However, there are no known counterexamples for primes.

Seceleanu has recently given an homological criterion for this containment to hold in $\mathbb{P}^2$. Using a generalization of her ideas, we are able to give a positive answer to Huneke's question for monomial curves in k[x,y,z]. (Received February 13, 2016)

1119-13-149 **Emilie Dufresne** and **Jack Jeffries*** (jackjeff@umich.edu). *Separating sets for actions of tori.*

One modern notion in invariant theory is that of a separating set. A separating set for a group action G on a variety X is a set of invariants such that if there is some $f \in k[X]^G$ such that $f(v) = f(w)$, then there is an $h \in S$ such that $h(v) = h(w)$. This notion has attracted interest because it may be much easier to compute a separating set than to compute the whole ring of invariants, but separating sets still reflect much of the geometry of the group action like invariant rings do. In this talk, I will discuss some new results on separating sets for actions of tori, focusing on connections with local cohomology and secant varieties. This is based on joint work with Emilie Dufresne. (Received February 14, 2016)

1119-13-153 **Youngsu Kim*** (youngsu.kim@ucr.edu), 900 Univ. Ave., Riverside, CA 92521, and **Vivek Mukundan** (vmukunda@purdue.edu), 150 N Univ St, West Lafayette, IN 47907. *Defining ideals of special fiber rings and birational morphisms of projective spaces.*

In algebraic geometry, it is interesting and important to study if a given morphism is birational. Consider a morphism $\phi : \mathbb{P}_k^{n-1} \xrightarrow{[f_0:\cdots:f_n]} \mathbb{P}_k^n$, where k is a field. In this talk, we study a characterization of ϕ being birational to its image. From algebraic perspective, this corresponds to studying the field of fractions of two rings: Let $R = k[x_1, \ldots, x_n]$ be the coordinate ring of $\mathbb{P}_k^{n-1}$ and $I = (f_0, \ldots, f_n)$. The graph of ϕ is the Rees algebra $R[It]$, and the image of ϕ is the special fiber ring $\mathcal{F}(I) := R[It] \otimes_R R/\mathfrak{m}$, where $\mathfrak{m} = (x_1, \ldots, x_n)R$. Then ϕ is birational iff $k[f_0, \ldots, f_n] \subseteq k[x_1, \ldots, x_n]$ have the same field of fractions.

When I is height 2 perfect ideal satisfying $\mu(IR_p) \leq \dim R_p$ for all $p \in \operatorname{Spec} R - \mathfrak{m}$ (here, $\mu(-)$ denotes the minimal number of generators), we will present a characterization of the morphism ϕ being birational in terms of a differential map of a free resolution of the symmetric algebra of I. Our criteria is obtained by studying the degrees of the defining ideal of the special fiber ring $\mathcal{F}(I)$. (Received February 16, 2016)

1119-13-155 **Arindam Banerjee** and **Luis Nunez-Betancourt*** (lcn8m@virginia.edu), Charlottesville, VA 22904. *Binomial edge ideals and graph connectivity.* Preliminary report.

In this talk we will discuss the quotient of a polynomial ring R by a binomial edge ideal J_G associated to a simple graph G. Specifically, a relation between the depth of R/J_G and the vertex-connectivity of G. We will also compute the graph toughness of G, when R/J_G is a Cohen-Macaulay ring (Received February 14, 2016)

1119-13-159 **Milena Hering*** (m.hering@ed.ac.uk) and **Kevin Tucker**. *The F-splitting ratio of a toric variety.* Preliminary report.

The Frobenius morphism is a useful tool in the study of commutative rings and algebraic varieties. One of its uses is to give a measurement of how bad the singularities of a ring are. This measurement is called the the F-splitting ratio, which agrees with the F-signature for normal rings. The F-signature of a normal toric ring was computed by Von Korff. I will give give an introduction to these notions and present the computation of the F-splitting ratio of a seminormal toric ring. This is joint work with Kevin Tucker. (Received February 15, 2016)

1119-13-166 **Sonja Mapes*** (smapes1@nd.edu), 255 Hurley Hall, Notre Dame, IN 46556, and **Timothy Clark**. *The Betti Poset in monomial resolutions.*

Finite atomic lattices, which arise as the lcm-lattice of a monomial ideal, play an important role in studying free resolutions of monomial ideals. In this talk we will discuss the Betti Poset which is a special subset of the lcm-lattice associated to a monomial ideal. In the case of rigid monomial ideals, we use the data of the Betti poset to explicitly construct the minimal free resolution. Subsequently, we introduce the notion of rigid deformation, a generalization of Bayer, Peeva, and Sturmfels' generic deformation. (Received February 15, 2016)

1119-13-195 **Ben Richert*** (brichert@calpoly.edu), Math. Dept., Cal Poly, San Luis Obispo, CA 93407. *Gorenstein rings with Extremal Betti numbers.* Preliminary report.

Recall that a sequence of natural numbers $(h_0, \ldots, h_s)$ is called a SI-sequence (for Stanley Iarrobino) if it is symmetric and its first half is a differentiable O-sequence. Such sequences correspond exactly with the possible Hilbert functions of graded Artinian Gorenstein algebras with the weak Lefschetz property. In their important 2002 paper on Gorenstein schemes, Migliore and Nagel use generalized stick figures to construct an Artinian Gorenstein algebra which has maximal graded Betti numbers among all Artinian Gorenstein algebras with the weak Lefschetz property and Hilbert function equal to a given SI-sequence. In this preliminary report, we describe a different inductive construction of these algebras. (Received February 15, 2016)

1119-13-211 **Michael K Brown**, **Claudia Miller*** (clamille@syr.edu), **Peder Thompson** and **Mark E Walker**. *Adams operations for matrix factorizations and a conjecture of Dao and Kurano.*

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, avoiding simplicial theory altogether.

As an application, we prove a conjecture of Dao and Kurano on the vanishing of Hochster's theta pairing 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 February 15, 2016)

1119-13-212 **Haydee Lindo*** (lindo@math.utah.edu). *Centers of endomorphism rings of modules.*

In this talk, I will present some new results concerning the center of the endomorphism ring of a finitely generated module over a commutative noetherian ring. The gist of the results is that the properties of the center are closely related to the properties of the trace ideal of the module and therefore to those of the module itself. We exploit this relationship, especially in the context of one-dimensional Gorenstein rings. (Received February 16, 2016)

1119-13-219 **Wenliang Zhang*** (wlzhang@uic.edu), 851 S Morgan St, Chicago, IL 60607. *Injective dimension of F-finite F-modules.* Preliminary report.

Theory of F-modules was introduced by Lyubeznik and has found many applications in the study of rings of prime characteristic. For instance, it was shown by Lyubeznik that the injective dimension of an F-module is bounded by the dimension of the support. We will discuss some recent work regarding when the injective dimension of an F-module is the same as the dimension of the support. (Received February 16, 2016)

1119-13-224 **Alexander Engström*** (alexander.engstrom@aalto.fi). *Polytopal resolutions of Stanley-Reisner ideals of polytopes.*

Sometimes a resolution of a monomial ideal is inherited from the boundary maps of a cell complex: it's a cellular resolution. For Stanley-Reisner ideals of polytopes one could expect even more structure. We will discuss some cases where the cellular resolutions can be constructed from polytopes with beautiful symmetries. (Received February 16, 2016)

1119-13-232 **Daniel J. Hernández**, **Luis Núñez-Betancourt**, **Felipe Pérez** and **Emily E. Witt*** (witt@ku.edu), 405 Snow Hall, 1460 Jayhawk Blvd., Lawrence, KS 66045. *Local cohomology and connectivity in mixed characteristic.*

Certain local cohomology modules determine connectivity properties of the spectrum of a ring; some very interesting connections between these have only been shown in the equicharacteristic setting. In this talk, we present a new vanishing theorem for local cohomology modules in mixed characteristic, and discuss what can be said about connectivity in this setting as a consequence. (Received February 16, 2016)

1119-13-234 **Ashley K. Wheeler*** (math@uark.edu), Department of Mathematical Sciences, SCEN 309, University of Arkansas, Fayettevillle, AR 72701. *Principal minor ideals with matroid theory.* Preliminary report.

Let $K[X]$ denote the polynomial ring over an algebraically closed field K whose variables are entries in the generic $n \times n$ matrix X. Little is known about ideals $\mathfrak{B}_t$ given by the size t principal minors of X: $\mathfrak{B}_2$ is a prime, normal complete intersection; $\mathfrak{B}_{n-1}$ has two minimal primes, one is the determinantal ideal $\mathrm{I}_{n-1}(X)$ and the other is given by the Zariski closure of the set of rank n matrices whose size $n-1$ principal minors vanish.

This suggests a strategy for studying $\mathfrak{B}_t$ in general, namely by studying the locally closed sets of rank r matrices whose size t principal minors vanish. In the case where $r = t$, the problem reduces to studying pairs of closed sets in a Grassmannian. We show that if a subset of Plücker coordinates for $\mathrm{Grass}(n-2, n)$ defines an irreducible algebraic set, then it is a positroid variety. It follows by a 2014 result of Knutson, Lam, and Speyer that the Zariski closure of the set of rank t matrices whose size t principal minors vanish is normal, Cohen-Macaulay, and has rational singularities. (Received February 16, 2016)

1119-13-235 **Emily E. Witt** (witt@ku.edu), **Pedro Teixeira** (pteixeir@knox.edu) and **Daniel J Hernández*** (hernandez@ku.edu). *Frobenius powers of ideals in regular rings.*

The p^e-th Frobenius powers of an ideal are ubiquitous in positive characteristic commutative algebra. In this talk, we extend this concept, and define the λ-th Frobenius power of an ideal for any non-negative real parameter λ. We discuss some basic properties of these objects, and use them to give a positive characteristic analog to Howald's theorem relating the multiplier ideal of a generic hypersurface with that of its term ideal. This is joint work with Pedro Teixeira and Emily Witt. (Received February 16, 2016)

14 ► Algebraic geometry

1119-14-9 **Laure Flapan*** (lflapan@math.ucla.edu). *Hodge groups of Hodge structures with Hodge numbers* $(n, 0, \ldots, 0, n)$. Preliminary report.

The Hodge group (or Mumford-Tate group) of a Hodge structure V is a connected algebraic $\mathbb{Q}$-subgroup of $SL(V)$ whose invariants in the tensor algebra generated by V and its dual V^* are exactly the Hodge classes. Thus, Hodge groups are objects of great interest in the context of the Hodge Conjecture. In this talk, we discuss results about the Hodge groups of simple polarizable Hodge structures with Hodge numbers $(n, 0, \ldots, 0, n)$, when n is 1, 4, a prime p, or $2p$. The results when n is 1, 4, or p generalize known results about abelian varieties, whereas the results when n is $2p$ are entirely new. These results for $n = 2p$ yield that both the Hodge and General Hodge Conjectures hold for all powers of certain simple abelian varieties of dimension $2p$. (Received November 12, 2015)

1119-14-29 **Tolga Karayayla*** (tkarayay@metu.edu.tr), Middle East Technical University, Department of Mathematics, Universiteler Mah Dumlupinar Bulv no 1 ODTU, 06800 Cankaya, Ankara, Turkey. *Finite groups which act freely on smooth Schoen 3-folds.* Preliminary report.

A Schoen 3-fold is a fiber product $X = B_1 \times_{\mathbb{P}^1} B_2$ over $\mathbb{P}^1$ of two rational elliptic surfaces B_1 and B_2 with section. If X is smooth, it is a simply connected Calabi-Yau 3-fold. If a finite group G acts freely on X, then the quotient space X/G is a non-simply connected Calabi-Yau 3-fold. In order to list all non-simply connected Calabi-Yau 3-folds which are obtained as quotients of smooth Schoen 3-folds, the finite groups which act freely on Schoen 3-folds must be classified. We consider group actions on X where any element of the group is a product $\tau_1 \times \tau_2$ of automorphisms of the elliptic surfaces B_1 and B_2 so that the automorphisms $\phi(\tau_1)$ and $\phi(\tau_2)$ on the base curve $\mathbb{P}^1$ induced by τ_1 and τ_2 are the same. Each group G acting on X induces a group action on the base curve $\mathbb{P}^1$. The group actions on X which induce cyclic group actions on $\mathbb{P}^1$ were classified by Bouchard and Donagi. In this talk, I will present my recent result that any finite group which acts freely on a smooth Schoen 3-fold induces a cyclic group action on the base curve $\mathbb{P}^1$.This result completes the classification of finite groups which act freely on smooth Schoen 3-folds. (Received January 23, 2016)

1119-14-45 **Dragos Oprea***, 9500 Gilman Drive #0112, La Jolla, CA 92093. *On the tautological ring of the moduli space of K3 surfaces.* Preliminary report.

I will discuss the notion of tautological Chow ring of the moduli space of polarized K3 surfaces, and describe ongoing work with Alina Marian and Rahul Pandharipande aimed at deriving relations between the tautological classes and understanding the structure of the tautological ring. (Received February 01, 2016)

1119-14-56 **Honglu Fan*** (fan@math.utah.edu), 1613 Lone Peak Drive, Holladay, UT 84117. *Chern classes and Gromov-Witten invariants of projective bundles.*

Given the cohomology ring of the base, one can determine the cohomology ring of a projective bundle by its Chern classes. In the past decades, the quantum cohomology ring has arisen as a deformation of the cohomology ring that also contains enumerative information about rational curves. It's natural to ask the following question: Given the quantum cohomology of the base, how much do Chern classes determine the one of a projective bundle? Under a torus action, a parallel statement in equivariant theories can be tested by Atiyah-Bott localization theory, which reduces the problem to sums over decorated graphs that has a combinatorial feature. I would like to survey what is known, and talk about a work in progress in an attempt to prove that the genus-0 equivariant Gromov-Witten theory (thus its quantum cohomology) of a projective bundle is uniquely determined by the equivariant Chern classes, if the base is a GKM manifold. (Received February 07, 2016)

1119-14-57 **Yuan Wang*** (ywang@math.utah.edu), 1211 Medical Plaza, University of Utah, Salt Lake City, UT 84112. *On uniruledness of hypersurfaces.*

Suppose that we have a smooth hypersurface H in a smooth variety X. If $-(K_X + H)$ is ample, then by adjunction formula and a classical result of Kollár-Miyaoka-Mori it is easy to see that H is rationally connected. However if we assume that $-(K_X + H)$ is nef and big instead, then an easy example shows that H is not necessarily uniruled. In this talk I will present a result which is a criterion for uniruledness of hypersurfaces. The result works well for varieties with reasonable singularities. (Received February 03, 2016)

1119-14-103 **Daniel Litt*** (dlitt@math.columbia.edu). *Automorphisms of blowups and the dynamical Mordell-Lang conjecture.*

We use p-adic analytic methods to analyze automorphisms of smooth projective varieties. We prove a version of the dynamical Mordell-Lang conjecture for arbitrary subschemes of a variety. We apply this result (1) to classify automorphisms $\phi : X \to X$ such that there is a divisor D in X whose intersections with its iterates are not dense in D, and (2) to show that various properties of Aut(X) (for example, finiteness of its component group) are not altered by blowups in high codimension. This is joint work with John Lesieutre. (Received February 10, 2016)

1119-14-108 **Katrina Honigs*** (honigs@math.utah.edu). *Derived categories of canonical covers of bielliptic and Enriques surfaces in positive characteristic.*

The derived category of coherent sheaves of a variety is an object that is relevant to the study of moduli spaces, birational geometry, mirror symmetry, and more. Many results characterizing when the derived categories of two complex surfaces are equivalent are known, including a theorem of Sosna that the canonical cover of an Enriques surface is not derived equivalent to any varieties other than itself, and that the canonical cover of a bielliptic surface is derived equivalent to at most one other variety. In this talk I will discuss methods used to prove this result over algebraically closed fields of positive characteristic at least 5.

This work is joint with Luigi Lombardi and Sofia Tirabassi. (Received February 10, 2016)

1119-14-111 **Dan Bates*** (bates@math.colostate.edu). *Choosing a good path for homotopy continuation.*

Given a polynomial system, $F(z, t)$, depending on several variables z and single parameter t, there are almost always some values of t at which the solution set of $F(z, t) = 0$ is degenerate. In the setting of numerical homotopy continuation, these points (and small sets around them) are problematic and should be avoided if possible. This talk will open with a very brief reminder of basic homotopy continuation and an update on recent developments in the Bertini software package. The main portion of the talk will then focus on providing a new heuristic answer to the question of how to find a path through parameter space that avoids these degenerate values of t. (Received February 11, 2016)

1119-14-120 **Gunnar Fløystad** and **Joe Kileel*** (jkileel@math.berkeley.edu), Department of Mathematics, UC Berkeley, CA 94720, and **Giorgio Ottaviani**. *The Chow form of the essential variety in computer vision.*

In computer vision, 3D reconstruction is a fundamental task: starting from photographs of a world scene, taken by cameras in unknown positions, how can we best create a 3D model of that world scene? Algorithms for this are used in Street View (Google Maps) and are embedded in every smart phone. In this talk, we will introduce and answer a basic mathematical problem when the number of cameras is two, left open by Googler Agarwal and his co-authors.

The answer is a determinantal formula for the Chow form of the configuration space of two calibrated cameras, which is a five-dimensional variety in $\mathbb{P}^8$. It is in the spirit of classical Bézoutian formulas for resultants, but we

need representations of GL_4 and the modern theory of Ulrich sheaves to derive it. I will show some examples from numerical linear algebra to illustrate the utility of the result. (Received February 12, 2016)

1119-14-127 **Chih-Chi Chou** (cchou9@math.washington.edu), Seattle, WA 98195, and **Lei Song*** (lsong@ku.edu), Lawrence, KS 66046. *Singularities of secant varieties.*

Given a smooth projective variety X with a very ample line bundle L, the secant variety Σ is the closure of the union of all secant lines to X in the ambient projective space. With a result of B. Ullery on co-normal bundle, we show that in the presence of sufficient positivity of L, Σ is Du Bois but not rational singular in general. (Received February 13, 2016)

1119-14-150 **Dawei Chen** and **Nicola Tarasca*** (tarasca@math.utah.edu), Salt Lake City, UT 84102. *Extremality of Weierstrass points on genus-two curves.*

The locus of genus-two curves with n marked Weierstrass points has codimension n inside the moduli space of genus-two curves with n marked points, for $n \leq 6$. It is well known that the class of the divisor obtained for $n = 1$ spans an extremal ray of the cone of effective divisor classes of the moduli space of stable genus-two curves with one marked point. We generalize this result for all n: we show that the class of the closure of the locus of genus-two curves with n marked Weierstrass points spans an extremal ray of the cone of effective classes of codimension n, for $n \leq 6$. (Received February 14, 2016)

1119-14-157 **Federico Castillo*** (fcastillo@ucdavis.edu), Department of Mathematics, UC Davis, One Shields Ave, Davis, CA 95616, and **Binglin Li** and **Naizhen Zhang**. *The multidegree polytope of an irreducible subvariety of product of projective spaces.*

Recently June Huh classified, up to a multiple, all possible classes in the Chow ring of a product of two projective spaces that can be represented by an irreducible variety. As a first step to generalize this result to any number of copies of projective spaces, we focus only on the support of these classes. It turns out that the support of any irreducible variety can be described naturally as the integer points in a polytope, more precisely a generalized permutohedron. (Received February 15, 2016)

1119-14-169 **Piotr Achinger*** (piotr.achinger@gmail.com), Poland, and **Arthur Ogus**, UC Berkeley. *Monodromy and Log Geometry.*

We study the link between the topology of a log smooth degeneration and the log structure on its special fiber, building on previous results by Illusie, Kato, Nakayama, Ogus and others. This is a joint project in progress with Arthur Ogus. (Received February 15, 2016)

1119-14-172 **Martha Precup*** (mprecup@math.northwestern.edu) and **Edward Richmond** (edward.richmond@okstate.edu). *Generalized Kostant polynomials.* Preliminary report.

Let $\mathfrak{g}$ be a semisimple Lie algebra and W denote the corresponding Weyl group. The Kostant polynomial K_w corresponding to $w \in W$ is a degree $\ell(w)$ polynomial that satisfies certain vanishing properties on the orbit $W \cdot S_r$ of a regular semisimple element of $\mathfrak{g}$. In this talk, we define polynomials that satisfy analogous vanishing conditions on the W-orbit of an arbitrary semisimple element S and use these to analyze the coordinate ring $\mathbb{C}[W \cdot S]$. We are motivated to do so by a result of Jim Carrell proving that in many cases $Gr\,\mathbb{C}[W \cdot S]$ is isomorphic to the cohomology ring of the Springer fiber $\mathcal{B}^N$ where N is a regular nilpotent element of the Levi subalgebra $\mathfrak{z}_{\mathfrak{g}}(S)$ of $\mathfrak{g}$. We give an inductive formula for the Poincaré polynomial of $\mathcal{B}^N$ which holds in these cases. (Received February 15, 2016)

1119-14-186 **Alexander Woo**, **Benjamin J. Wyser*** (bwyser@illinois.edu) and **Alexander Yong**. *Mars-Springer subvarieties of symmetric orbit closures and interval pattern combinatorics.* Preliminary report.

Consider the closure of an orbit of the symmetric subgroup $GL_p \times GL_q$ on the flag variety GL_{p+q}/B. We consider the question of when such an orbit closure possesses one of a certain class of properties P (examples being P="smooth", "normal", "Gorenstein", among others), in terms of the combinatorics of a symbol called a "clan" which parametrizes the orbit. The main result is that such properties can always be characterized by a combinatorial notion called interval pattern avoidance. The proof of this is essentially geometric, relying on an isomorphism between certain locally closed subvarieties or "slices" of the orbit closures which we call Mars-Springer varieties. (Received February 15, 2016)

1119-14-199 **Robert L Williams*** (rwilliams@math.tamu.edu), Mathematics, Mail Stop 3368, Texas A&M University, College Station, TX 77843. *Galois groups of Schubert problems via symbolic computation.* Preliminary report.

The number of solutions to problems in the Schubert calculus is known through combinatorics. However, the actual solution set usually possess additional structure revealed through a Galois group. The method of computing Frobenius lifts from prime characteristic is particularly effective for finding information about this structure for Schubert problems. We use this to determine the Galois groups of all 30,000+ Schubert problems involving 4-planes in 9-dimensional space. (Received February 15, 2016)

1119-14-237 **James McKernan*** (jmckernan@math.ucsd.edu), Department of Mathematics, University of California, San Diego (UCSD), 9500 Gilman Drive # 0112, La Jolla, CA 92093-0112. *Symmetries of algebraic varieties.*

It is a natural question to aks what are the most symmetric varieties. We review some old and new results in this area and how these results relate to the birational classification of varieties. (Received February 16, 2016)

1119-14-242 **Ravi Vakil*** (vakil@math.stanford.edu), Dept. of Mathematics, Stanford University, Stanford, CA 94305, and **Melanie Matchett Wood**. *Cutting and pasting in (algebraic) geometry.*

Given some class of "geometric spaces", we can make a ring as follows.

(i) *(additive structure)* When U is an open subset of such a space X, $[X] = [U] + [(X \setminus U)]$;

(ii) *(multiplicative structure)* $[X \times Y] = [X][Y]$.

In the algebraic setting, this ring (the "Grothendieck ring of varieties") contains surprising "stabilization" structure, connecting geometry to arithmetic and topology. I will discuss some remarkable statements about this ring (both known and conjectural), and present new statements (again, both known and conjectural). A motivating example will be polynomials in one variable. (This talk is intended for a broad audience.) This is joint work with Melanie Matchett Wood. (Received February 16, 2016)

1119-14-249 **Arnav Tripathy*** (tripathy@stanford.edu). *Further counterexamples to the integral Hodge conjecture.*

I'll briefly recall the history of counterexamples to the integral Hodge conjecture, starting with the topological motivations of Atiyah and Hirzebruch. I'll then transition to describing a new class of counterexamples to the integral Hodge and integral Tate conjectures that I show exist according to a conjecture of Ben Antieau. (Received February 16, 2016)

15 ► Linear and multilinear algebra; matrix theory

1119-15-118 **Elina Robeva** and **Anna L Seigal*** (seigal@berkeley.edu). *Singular vectors of tensors.*

The singular valued decomposition (SVD) of a matrix is very useful in a wide range of applications. Recently there has been significant interest in extending key properties of this decomposition to the higher-dimensional tensor setting. In this talk we discuss singular vectors of tensors and describe the geometry of tuples in projective space that can occur as the singular vectors of a tensor. (Received February 12, 2016)

16 ► Associative rings and algebras

1119-16-154 **Tianyuan Xu*** (tianyuan@uoregon.edu), 1150 Darlene Lane, Apartment 346, Eugene, OR 97401. *The subregular part of Lusztig's Asymptotic Hecke Algebra.* Preliminary report.

Given an arbitrary Coxeter system (W, S), G. Lusztig defined its *asymptotic Hecke algebra* J, an associative algebra closely related to the usual Hecke algebra and the category of Soergel bimodules for (W, S). The algebra J decomposes as a direct sum of subalgebras indexed by the 2-sided Kazhdan-Lusztig cells of W, and in this talk we will present some results on the subalgebra J_C corresponding to a particular cell C known as the subregular cell. We show that products in J_C can be computed by repeated use of (variations of) the Clebsch-Gordan formula arising from the representation theory of $\mathfrak{sl}(2, \mathbb{C})$, and we use this multiplication rule to obtain alternative descriptions of J_C for Coxeter systems of certain types such as all simply-laced ones. (Received February 14, 2016)

1119-16-254 **Paul Bruillard**, **Liang Chang**, **Seung-Moon Hong** and **Julia Plavnik*** (julia@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843, and **Eric Rowell** and **Michael Sun**.
Low-dimensional representations of the three component loop braid group.

The loop braid group $\mathcal{LB}_n$ is the motion group of n oriented, unlinked circles in $\mathbb{R}^3$. Recently, physical and topological applications have motivated the study of representations of $\mathcal{LB}_3$.

Since the braid group $\mathcal{B}_3$ is a subgroup of $\mathcal{LB}_3$, our approach is to find out which representations of $\mathcal{B}_3$ can be extended to representations of $\mathcal{LB}_3$. We will discuss some advances in this direction, specially for low-dimensional representations. (Received February 16, 2016)

17 ► Nonassociative rings and algebras

1119-17-65 **Gregory Peter Wene*** (greg.wene@utsa.edu), Department of Mathematics, The University of Texas at San Antonio, One UTSA Circle, San Antonio, TX 78249-0624.
Semifields antiisomorphic to themselves.

D. E. Knuth, D. E., Finite semifields and projective planes, J. Algebra 2 (1965), 182-217, pointed out that his system V is antiisomorphic to itself. Trivially any commutative semifield shares this property as does the unique non-primitive non-commutative semifield of order 64. We construct a large collection of semifields for all prime characteristics, quadratic over a weak nucleus, that are antiisomorphic to themselves. (Received February 05, 2016)

1119-17-201 **Daniele Rosso*** (rosso@math.ucr.edu). *Mirabolic quantum* $\mathfrak{sl}_2$.

Beilinson-Lusztig-MacPherson constructed the quantum enveloping algebra $U_q(\mathfrak{sl}_n)$ (and the q-Schur algebras) as a convolution algebra over the space of pairs of partial n-step flags over a finite field. We will explain how to expand the construction to the mirabolic setting of triples of two partial flags and a vector, and examine the resulting convolution algebra. In the case of n=2, we classify its finite dimensional irreducible representations and we describe a mirabolic version of the quantum Schur-Weyl duality. (Received February 15, 2016)

18 ► Category theory; homological algebra

1119-18-33 **Andrew Schopieray*** (schopier@uoregon.edu), Department of Mathematics, Fenton Hall, University of Oregon, Eugene, OR 97403-1222. *A classification of* $\mathfrak{sl}_3$ *relations in the Witt group of non-degenerate braided fusion categories.* Preliminary report.

The Witt group of non-degenerate braided fusion categories provides an algebraic structure that is one of many tools for organizing braided fusion categories, while relations in this group give a promising method for constructing new examples of fusion categories. Relations between the classes of pseudo-unitary braided fusion categories $[\mathcal{C}(\mathfrak{sl}_2, k)]$, $k \geq 1$ have been completely described in the work of Davydov, Nikshych, and Ostrik. Here we give a complete classification of relations between the classes $[\mathcal{C}(\mathfrak{sl}_3, k)]$, $k \geq 1$ with a view toward extending these methods to arbitrary simple finite dimensional Lie algebras $\mathfrak{g}$ and positive integer levels k. (Received January 25, 2016)

1119-18-86 **Eric C. Rowell***, Mathematics Department, Texas A&M University, College Station, TX 77843-3368. *The current state of the property F conjecture.*

The property F conjecture states that the braid group representations associated with a simple object X in a braided fusion category have finite group images if, and only if, $(FPdim(X))^2 \in \mathbb{Z}$. This conjecture dates back to around 2007 and was discussed at some length in a joint paper with Naidu (arXiv:0903.4157). In this talk I will survey recent progress, generalizations and the outlook on this still very wide open conjecture. (Received February 09, 2016)

1119-18-190 **Andre Henriques** and **David Penneys*** (dpenneys@math.ucla.edu), UCLA Mathematics Department, Box 951555, Los Angeles, CA 90095, and **James Tener**.
Categorified trace for module tensor categories over braided tensor categories.

We will discuss the categorified trace $\mathrm{Tr}_{\mathcal{C}}$ associated to a pivotal module tensor category $\mathcal{M}$ over a braided pivotal tensor category $\mathcal{C}$. By work of Bezrukavnikov, Finkelberg and Ostrik, the trace comes with canonical natural isomorphisms $\mathrm{Tr}_{\mathcal{C}}(x \otimes y) \cong \mathrm{Tr}_{\mathcal{C}}(y \otimes x)$, which we call the traciators. This situation lends itself to a diagrammatic calculus of strings on cylinders, where the traciator corresponds to wrapping a string around the

back of a cylinder. We show that Tr_C has a much richer graphical calculus in which the tubes are allowed to branch and braid. (Received February 15, 2016)

1119-18-218 **Matthew Titsworth*** (matthew.titsworth@gmail.com) and **Tobias Hagge**. *Geometric invariants for fusion categories.*

We treat the problem of determining gauge and monoidal equivalence classes of fusion categories as one of classifying orbits of an algebraic group acting on an an algebraic scheme. By applying the machinery of geometric invariant theory we develop a new class of invariants strong enough to classify arbitrary fusion categories. These invariants are computable and for a large class of fusion categories our method leads to fast algorithms for computing gauge and monoidal classes. (Received February 16, 2016)

1119-18-227 **Scott Morrison** and **Emily Peters***, epeters3@luc.edu, and **Noah Snyder**. *Categories generated by a trivalent vertex.*

We are interested in describing all small trivalent categories: A trivalent category is generated by a single object, and has the property that all morphisms can be draw using trivalent graphs. Why are we interested in trivalent categories? Well, first, a lot of the quantum-group and subfactor fusion categories are trivalent. Second, we have tools of linear algebra and diagrammatic combinatorics that make these calculations fun and easy. In particular, we can prove theorems using the method of discharging (of four-color-theorem fame). (Received February 16, 2016)

1119-18-239 **Daniel Creamer*** (dan1010c@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843. *Classifying low rank modular tensor categories.* Preliminary report.

Modular Tensor Categories (MTC) can be used to model newly found exotic states of matter called Topological States of matter. A classification of MTC's may lead to previously unknown Topological States as well as a greater understanding of their properties. MTC's have two matrices, called its modular data, whose entries generate a Galois group over the rationals. In low rank the number of possible of Galois groups is small and we can take advantage of the strong Galois structure to produce all possible modular data for the given rank. (Received February 16, 2016)

1119-18-251 **Tobias Hagge*** (tobias.hagge@pnnl.gov), **Paul Bruillard**, **César Galindo**, **Richard Ng**, **Julia Yael Plavnik**, **Eric Rowell** and **Zhenghan Wang**. *The sixteen-fold way.* Preliminary report.

The sixteen-fold way conjecture asserts that every supermodular tensor cat- egory has minimal modular extensions to exactly sixteen modular tensor cate- gories. I plan to discuss the status of the conjecture and recent progress, and sketch applications to physics.

This talk covers joint work with Paul Bruillard, César Galindo, Richard Ng, Julia Plavnik, Eric Rowell, and Zhenghan Wang. (Received February 16, 2016)

1119-18-255 **Meng Cheng*** (mcheng@microsoft.com), Elings Hall CNSI Bldg. Rm. 2235, UCSB, Santa Barbara, CA 93106. *Aspects of symmetries in three-dimensional topological phases of matter.*

Two-dimensional topological phases are described by modular tensor categories and the presence of global symmetries leads to the notion of symmetry-enriched topological phases, which can be mathematically described by G-crossed braided tensor categories. I will generalize some of the notions, in particular symmetry fractionalization, to three-dimensional Z_2 topological phases, where there are both point-like quasiparticle excitations and line-like loop excitations. I will propose a partial classification of symmetry actions on the loop excitations. (Received February 16, 2016)

1119-18-256 **Julia Plavnik** and **Henry Tucker*** (htucker@usc.edu), USC Dept. of Mathematics, 3620 S. Vermont Ave. KAP 104, Los Angeles, CA 90089. *Non-degenerate quotients of pivotal tensor categories.* Preliminary report.

Barrett and Westbury showed that the non-degenerate quotient of a spherical tensor category, i.e. the quotient by the tensor ideal of negligible morphisms, yields a semisimple tensor category. We consider here the case of pivotal tensor categories whose pivotal structure is not necessarily spherical (that is, where the left and right categorical quantum dimensions do not necessarily agree) with the goal of finding conditions that will produce semisimple non-degenerate quotients. In particular, we consider the categories of representations of pivotal quasi-Hopf algebras. (Received February 16, 2016)

20 ► Group theory and generalizations

1119-20-17 **Andrew F Misseldine*** (andrewmisseldine@suu.edu), Southern Utah University, Math Department, 351 West University Blvd., Cedar City, UT 84720. *Counting Schur Rings over Cyclic Groups.*

Any Schur ring, an algebraic structure closely related to association schemes, is uniquely determined by a partition of the elements of the group. An open question in the study of Schur rings is determining which partitions of the group induce a Schur ring. Although a structure theorem is available for Schur rings over cyclic groups, it is still a difficult problem to count all the partitions. For example, Kovacs, Liskovets, and Poschel determine formulas to count the number of wreath-indecomposable Schur rings. In this talk we solve the problem of counting the number of all Schur rings over cyclic groups of prime power order and draw some parallels with Higman's PORC conjecture. (Received January 05, 2016)

1119-20-22 **Stephen Humphries*** (steve@mathematics.byu.edu), Department of Mathematics, Brigham Young University, Provo, UT 84602. *Commutative Schur rings over symmetric groups.*

We characterize commutative Schur rings over the symmetric group S_n that contain the sum of the transpositions in S_n, by determining the possibilities for the partition of the class of transpositions that such a Schur ring gives. We note a connection with Gallai colorings of complete graphs. (Received January 13, 2016)

1119-20-89 **Andrew F. Misseldine*** (andrewmisseldine@suu.edu), Southern Utah University, Electronic Learning Center 114, 351 West University Boulevard, Cedar City, UT 84720. *Counting Schur Rings over Cyclic Groups.*

Any Schur ring, an algebraic structure closely related to association schemes, is uniquely determined by a partition of the elements of the group. An open question in the study of Schur rings is determining which partitions of the group induce a Schur ring. Although a structure theorem is available for Schur rings over cyclic groups, it is still a difficult problem to count all the partitions. For example, Kovacs, Liskovets, and Poschel determine formulas to count the number of wreath-indecomposable Schur rings. In this talk we solve the problem of counting the number of all Schur rings over cyclic groups of prime power order and draw some parallels with Higman's PORC conjecture. (Received February 09, 2016)

1119-20-121 **Valentin Buciumas*** (buciumas@stanford.edu). *The free fermionic bialgebra.*

We begin by reviewing the Faddeev-Reshetikhin-Takhtajan (FRT) construction that uses a solution to the Yang-Baxter equation to build a coquasitriangular bialgebra and its relation to a reconstruction theorem for braided categories. We then apply the reconstruction theorem to the parametrized solution of the Yang-Baxter equation corresponding to the quantum group $U_q(\widehat{\mathfrak{sl}_2})$ and to another solution with parameter group $SL(2,\mathbb{C}) \times GL(1,\mathbb{C})$ that doesn't come from any known quantum group. Finally, we describe the representation theory of the newly built objects. (Received February 12, 2016)

1119-20-139 **Bret Benesh**, **Dana Ernst** and **Nándor Sieben*** (nandor.sieben@nau.edu). *Impartial avoidance and achievement games For generating finite groups.*

We study two impartial games introduced by Anderson and Harary and further developed by Barnes. Both games are played by two players who alternately select previously unselected elements of a given finite group. The first player who builds a generating set from the jointly selected elements wins the achievement game. The first player who cannot select an element without building a generating set loses the avoidance game. After a review of the Sprague–Grundy theory of impartial games, we determine the nim-numbers of these games for some finite group families. (Received February 13, 2016)

1119-20-204 **Larissa V. Sbitneva*** (larissa@uaem.mx), Av. Universidad, 1001, CInC, Chamilpa, 62210, Morelos, México, 62210 Cuernavaca, Mexico. *Differential equations of smooth loops with the S. Lie approach.*

It seems natural to obtain the infinitesimal theory of general M-loops as an analogous treatment of the Lie theory. Some results of this approach will be presented.

A brief survey on basic notions and relations between algebraic and geometric structures of smooth M loops, generalizing Bol-Bruck loops, will be presented in order to meet

the interest in recent publications to these loops due to apploications in Special Relativity (arXiv: gr-qc/0407098V126 Julio 2004, Special Relativity as a non commutative geometry: Lessons for Deformed Special Relativity Florian Girelli, Etera R. Livine, p. 15-16), (Jaiyeola, TG, Solarin ART, Adeniran JO. 2014. Some

Bol-Moufang characterizations of the Thomas Precession of a gyrogroup. Algebras, Groups and Geometries. 31(3):341-362). (Received February 15, 2016)

1119-20-222 **Siu-Hung Ng*** (rng@math.lsu.edu). *On the classification of weakly integral modular categories.*

In view of the classification of weakly integral modular categories of rank 6 and 7, we find the less trivial ones are of dimensions 20 and 28 respectively. This observation prompts us to classify weakly integral modular categories of dimension $4p$, where p is an odd prime. In this talk, we will discuss this classification.

This talk is based on joint work with P. Bruillard, C. Galindo, J. Plavnik, E. Rowell, and Z. Wang. (Received February 16, 2016)

22 ► Topological groups, Lie groups

1119-22-75 **Mahdi Asgari** and **Kwangho Choiy*** (kchoiy@siu.edu), 1245 Lincoln Dr., Neckers 283, Mathematics, Southern Illinois University, Carbondale, IL 62901-4408. *Local Langlands conjecture for p-adic GSpin(4), GSpin(6), and their inner forms.*

The local Langlands correspondence for p-adic groups has been established for several cases over decades. As one of such approaches, the restriction of representations from a bigger group G to its closed subgroup H containing the derived group of G was utilized to prove the local Langlands correspondence for H from that for G. In this framework, we shall discuss the local Langlands correspondence for small rank general spin groups $GSpin(4)$ and $GSpin(6)$ as well as their inner forms over a p-adic field of characteristic zero. We will also present some expected properties including the internal structure of L-packets and the equality of local factors. This is joint work with Mahdi Asgari. (Received February 07, 2016)

1119-22-96 **Kathryn Mann*** (kpmann@math.berkeley.edu). *Automatic continuity for homeomorphism groups.*

A Polish group G has *automatic continuity* if every group homomorphism from G to a separable topological group is continuous. In the past 10 years, a surprising number of groups have been shown to have this property. In this talk I'll discuss a new result proving automatic continuity for the groups of self-homeomorphisms of topological manifolds. Although some ingredients will be familiar, this case of automatic continuity also uses fundamental results from manifold topology that help us understand the Polish group structure of homeomorphism groups. (Received February 09, 2016)

1119-22-107 **Shiang Tang*** (shiangtang1989@yahoo.com), 1400 east, 155 south, Salt Lake City, UT 84112. *Eisenstein series and Transfer of Plancherel measures.*

Given a p-adic field F and a ramified principal series representation of the two-fold cover of $SL(2,F)$, we are interested in its Plancherel measure which is related to the reducibility of the representation. To find out the measure, we consider $SL(2,\mathbb{A}_k)$ for some global field k that contains F at its p-adic place, we look into its Eisenstein series and deduce a product formula on the measures at all local places using the functional equation. A similar product formula can be deduced on $PGL(2,\mathbb{A}_k)$. The beauty is, one can compare those two product formulas and solve for the Plancherel measure of the ramified representation. Roughly speaking, we transfer the Plancherel measures from a linear group to a related covering group. (Received February 10, 2016)

1119-22-143 **Vinoth Nandakumar*** (vinoth@math.utah.edu), 155 S 1400 E, Salt Lake City, UT 84112, and **Gufang Zhao**. *Categorifying $U_q(sl_2)$ representations via blocks of modular representations for sl_m.*

Using results of Bernstein-Frenkel-Khovanov, Stroppel, Sussan, etc., one obtains a categorification of tensor products of the standard representation of $U_q(sl_2)$ using singular blocks of category O for sl_m. The simple objects in these categories give us the canonical basis under this categorification. Here we describe a positive characteristic analogue of this picture: we categorify the same tensor product representation of sl_2, using blocks of representations of sl_m in positive characteristic (with zero Frobenius character, and singular Harish-Chandra character). This is closely related to a geometric categorification constructed by Cautis, Kamnitzer and Licata. Joint work with Gufang Zhao. (Received February 13, 2016)

1119-22-217 **Peter E Trapa*** (ptrapa@math.utah.edu), Department of Mathematics, Univerity of Utah, Salt Lake City, UT 84112-0090. *The Lusztig-Vogan bijection.* Preliminary report.

Independently, Lusztig and Vogan conjectured the existence of a natural bijection between dominant weights for a reductive group, and pairs consisting of a nilpotent orbit and an irreducible representation of the isotropy

group. Lusztig was led to the conjecture from the theory of two-sided cells in affine Weyl group; Vogan was motivated by the theory of tempered representations of complex (or, more generally, real) reductive groups. Explicitly computing the conjectured bijection has important consequences.

Bezrukavnikov proved the Lusztig-Vogan conjecture, but the proof didn't shed light on how to compute it. Achar explicitly computed the bijection for GL(n), but progress outside of this case has been limited.

The purpose of this talk is to recall the motivation for the Lusztig-Vogan conjecture (and its more general version due to Vogan), and discuss recent progress on computing the bijection explicitly. (Received February 15, 2016)

32 ► Several complex variables and analytic spaces

1119-32-19 **Song-Ying Li*** (sli@math.uci.edu), 340 Rowland Hall, Department of Math, University of California at Irvine, Irvine, CA , and **Duong Ngoc Son** (son.duong@qatar.tamu.edu), Science Program, P.O. Box 23874, Education City, Doha, Qatar. *Some Rigidity theorems for Harmonic functions and CR Harmonic map.*

This talk will give some rigidity theorems for harmonic functions and CR harmonic maps. It includes CR-version of the Siu's $\partial\overline{\partial}$ formula and its applications. (Received January 11, 2016)

1119-32-21 **John P. D'Angelo*** (jpda@illinois.edu), Dept. of Mathematics, 1409 W. Green St., Urbana, IL 61801. *Rational sphere maps.*

I will discuss a classification result for rational sphere maps that generalizes a result I proved some years ago for polynomial sphere maps. I will emphasize the case when the denominator is of first degree. Given the map, finitely many Whitney tensor product operations convert it into a map that depends on a linear transformation L, and a certain Hermitian form must satisfy a non-negativity condition. The spectrum of L is related to the denominator of the map. (Received January 12, 2016)

1119-32-23 **Ming Xiao*** (mingxiao@illinois.edu), 1409 W.Green Street, Urbana, IL 61801, and **Yuan Yuan**. *Holomorphic isometries from the unit ball into the irreducible classical bounded symmetric domain.*

We will talk about local holomorphic isometries from the unit ball into the irreducible classical bounded symmetric domain, in particular of type IV. We will present a classification result of such holomorphic isometries up to automorphisms in the maximal dimensional case. We also discuss some phenomena of such mappings in contrast with proper mappings between balls. In particular, we will give an answer to a question regarding boundary singularities raised by Mok. It is a joint work with Y. Yuan. (Received January 14, 2016)

1119-32-32 **Hanlong Fang** (longgao1106@gmail.com), Department of Mathematics, New Brunswick, NJ 08903, **Xiaojun Huang*** (huangx@math.rutgers.edu), Department of Mathematics, Belle Mead, NJ 08903, and **Ming Xiao** (mingxiao@illinois.edu), Deparmnet of Mathematics, Urbana-Champaign, IL 61801. *Volume preserving for holomorphic maps bBetween HSS of compact type.* Preliminary report.

We discuss a new rigidity property for local volume preserving maps between HSS of compact type along the lines of recent work of Clozel-Ullmo and Mok-Ng (Received January 25, 2016)

1119-32-37 **Tatyana Barron*** (tatyana.barron@uwo.ca). *Submanifolds of the unit ball in $\mathbb{C}^n$ and vector-valued automorphic forms.*

I will show how to associate a vector-valued automorphic form $F_\Lambda^{(k)}$ of weight $k \in \mathbb{N}$ to a submanifold Λ of an irreducible bounded symmetric domain D. It is an interesting question how the properties of $F_\Lambda^{(k)}$ reflect the properties of Λ (for example, such as Λ being totally real or CR). For $D = \mathbb{B}^n$ I will present some asymptotic results (as $k \to \infty$) and examples. (Received January 28, 2016)

1119-32-39 **Jiri Lebl*** (lebl@okstate.edu), Department of Mathematics, MSCS 401, Oklahoma State University, Stillwater, OK 74078, and **Alan Noell** and **Sivaguru Ravisankar**. *Extensions of CR functions in $\mathbb{C}^n \times \mathbb{R}$.*

We prove a Hartogs-Bochner type theorem for a bounded domain U with smooth boundary in $\mathbb{C}^n \times \mathbb{R}$ with nodegenerate, flat, and elliptic CR singularities (all natural conditions for the problem). That is, a CR function on the boundary ∂U extends to a CR function on U, smooth up to the boundary. (Received January 31, 2016)

1119-32-62 **Jeffrey S. Case*** (jscase@psu.edu). *The Q'-curvature in CR geometry.*
The Q'-curvature is a pseudohermitian invariant of a strictly pseudoconvex CR manifold which behaves nicely with respect to change of contact form; for example, the total Q'-curvature is a CR invariant. I will describe these properties and some classification results involving the total Q'-curvature in dimensions three and five. This talk is based on joint works with Paul Yang and Rod Gover. (Received February 04, 2016)

1119-32-78 **Yunus E. Zeytuncu*** (zeytuncu@umich.edu) and **Sönmez Şahutoğlu**. *Compactness of Hankel and the $\overline{\partial}$-Neumann operators on Hartogs domains in $\mathbb{C}^2$.*
We prove that on smooth bounded pseudoconvex Hartogs domains in $\mathbb{C}^2$ compactness of the $\overline{\partial}$-Neumann operator is equivalent to compactness of all Hankel operators with symbols smooth on the closure of the domain. (Received February 08, 2016)

1119-32-102 **Shif Berhanu*** (berhanu@temple.edu) and **Jorge Hounie**. *On unique continuation for CR mappings.* Preliminary report.
We will discuss a weak Hopf Lemma for holomorphic functions of one variable and its applications to the unique continuation problem for CR mappings. (Received February 10, 2016)

1119-32-115 **Yih Sung***, 150 N. University Street, West Lafayette, IN 47906. *L^2 technique and its applications.*
In this talk, I will talk about two applications of the L^2 method. The main idea of the L^2 method is to solving $\bar{\partial}$-equations. First, I will talk about the division theorems. Suppose $f, g_1, \cdots, g_p$ are holomorphic functions over a pseudoconvex domain $\Omega \subset \mathbb{C}^n$. Then there raises a natural question: when can we find holomorphic functions $h_1, \cdots, h_p$ such that $f = \sum g_j h_j$? The celebrated Skoda theorem solves this question and provides an L^2 sufficient condition. In general, one can consider the vector bundle case, i.e. to determine the sufficient condition of solving $f_i(x) = \sum g_{ij}(x) h_j(x)$ with parameter $x \in \Omega$. Since the problem is related to solving linear equations, the answer naturally connects to the Cramer's rule. The two ingredients of the proof are projectivization technique and the generalized fundamental inequality. The second application is about compact local Hermitian symmetric space of non-compact type. I will consider a tower of compact local Hermitian symmetric spaces $X_{s+1} \longrightarrow X_s \longrightarrow \cdots \longrightarrow X_0 = X$, and study K_s's (N_p) properties when s is sufficient big. The main ingredient of the argument is vanishing theorem. (Received February 11, 2016)

1119-32-116 **Turgay Bayraktar*** (tbayrakt@syr.edu), Syracuse University, Carnegie Building 215, Syracuse, NY 13244. *Universality for zeros of random holomorphic sections.*
The *universality phenomenon* in the context of random polynomials or more generally random holomorphic sections of high powers $L^{\otimes n}$ of positive line bundle $L \to X$ defined over a projective manifold indicates that asymptotic distribution of (appropriately normalized) zeros of random holomorphic sections should become independent of the choice of probability distribution under natural assumptions. In this talk, I will present some recent results on universality of limiting zero distribution of random holomorphic sections. I will also present some results concerned with asymptotic normality of smooth linear statistics for zero sets of codimension one. (Received February 11, 2016)

1119-32-165 **Peter Ebenfelt*** (pebenfelt@ucsd.edu), Department of Mathematics, University of California, San Diego, La Jolla, CA 92093-0112. *Umbilical points on perturbations of the sphere in $\mathbb{C}^2$.* Preliminary report.
The standard CR structure on the three dimensional sphere can be deformed in such a way that the deformed structures have no (CR) umbilical points. A 1-parameter family of such deformations was essentially discovered by E. Cartan (and later studied by Cap, Isaev, Jacobowitz). The CR manifolds in this family, however, cannot be embedded in $\mathbb{C}^2$. It is an open question whether the unit sphere can be perturbed in $\mathbb{C}^2$ such that no umbilical points remain on the perturbed CR manifolds. In this talk, we shall discuss an approach to this problem. (Received February 15, 2016)

1119-32-168 **Adam Coffman*** (coffmana@ipfw.edu), IPFW Dept. of Math. Sci., 2101 E. Coliseum Blvd., Fort Wayne, IN 46805-1499. *Isolated CR singularities of real threefolds in $\mathbb{C}^3$.* Preliminary report.
For a real 3-manifold embedded in $\mathbb{C}^3$, the local geometry at each point is either "totally real" if the tangent plane contains no complex line, or "CR singular" otherwise. Embeddings in general position have a CR singular locus along a curve, but I will show by examples that isolated CR singularities can occur. One such example appears in a refinement of Webster's classification of parabolic CR singularities by cubic normal forms. (Received February 15, 2016)

1119-32-216 **Claudia Miller**, Syracuse University, Department of Mathematics, 215 Carnegie Building, Syracuse, NY 13244, and **Sophia Vassiliadou*** (sv46@georgetown.edu), Georgetown University, Department of Mathematics and Statistics, St. Mary's Hall, Washington, DC 20057. *On torsion and cotorsion of differentials over complete intersection rings.*

Let (X, x) be a germ of a complete intersection singularity over $\mathbb{C}$ and let $\Omega^p_{X,x}$ denote the stalk of the sheaf of Kähler p-forms of X at x. I will discuss some rigidity results on the vanishing of torsion and cotorsion of $\Omega^p_{X,x}$ on such germs. This is joint work with Claudia Miller. (Received February 15, 2016)

1119-32-231 **David E Barrett*** (barrett@umich.edu), University of Michigan Math Dept, 530 Church St, Ann Arbor, MI 48109-1043, and **Dusty Grundmeier**. *Sums of CR functions from competing CR structures.* Preliminary report.

This talk will consider the problem of characterizing the sum of CR functions from two competing (oppositely-oriented) CR structures sharing the same maximal complex subspace, in two specific scenarios.

In the first scenario the two structures are simply conjugate to each other and the functions in question are pluriharmonic boundary values. (This problem has an extensive history, but some new results will be presented.) In the second scenario the two structures are related by projective duality considerations. The two scenarios coincide (precisely) in the classic case of (projective images of) the ball.

In both cases special attention will be paid to two-dimensional circular domains. In this setting, at least, the projective problem has the stronger resemblance to the classic ball case. (Received February 16, 2016)

1119-32-240 **Muhamed A Alan*** (malan@syr.edu), Mathematics Department, 215 Carnegie Building, Syracuse, NY 13244. *Unique extension problem of plurisubharmonic functions to Lelong class.* Preliminary report.

We will define the unique extension problem for Plurisubharmonic functions and give few results based on the total mass of Monge–Ampère measures. (Received February 16, 2016)

1119-32-243 **Emil J. Straube*** (straube@math.tamu.edu). *Two open problems concerning compactness in the $\overline{\partial}$–Neumann problem.* Preliminary report.

I will discuss to what extent compactness in the $\overline{\partial}$–Neumann problem is inherited by the intersection of domains. The second problem concerns the relationship between compactness and the existence of a Stein neighborhood basis for the closure of the domain. (Received February 16, 2016)

34 ► Ordinary differential equations

1119-34-125 **Badal Joshi***, bjoshi@csusm.edu, and **Anne Shiu**. *Identifying multistationary reaction networks.* Preliminary report.

It is an open problem to identify reaction networks that admit multiple positive steady states. Criteria such as deficiency theory and Jacobian criterion help rule out the possibility of multiple steady states. But these tests are not sufficient to establish multistationarity. For fully open networks, we can establish multistationarity by relating the steady states of a reaction network with those of its component "embedded networks". We refer to the multistationary fully open networks that are minimal with respect to the embedding relation as atoms of multistationarity. We identify some families of atoms of multistationarity and show that there exist arbitrarily large (in species, reactions) such atoms. We also classify small reaction networks (not necessarily fully open) by multistationarity. (Received February 12, 2016)

1119-34-167 **Ji Li*** (liji@math.msu.edu). *nonautonomous perturbation and chaotic behavior.*

Nonautonomous perturbation appears in many applications which could be periodic or non periodic. We study the kind without any periodicity, a sample path of a random force driven by stochastic process for instance. We show the existence of a generalized Smale Horseshoe in a 2-D phase space using the Silnikov type variable. (Received February 15, 2016)

35 ► Partial differential equations

1119-35-13 **Chuntian Wang***, Math Dept., UCLA, 520 Portola Plaza, MS 6363, Los Angeles, CA 90095, and **Nathan Glatt-Holtz** and **Roger Temam**. *Time discrete approximation of weak solutions for stochastic equations of geophysical fluid dynamics.*

As a first step towards the numerical analysis of the stochastic primitive equations of the atmosphere and oceans, we study their time discretization by an implicit Euler scheme. From deterministic viewpoint the 3D Primitive Equations are studied with physically realistic boundary conditions. From probabilistic viewpoint we consider a wide class of nonlinear, state dependent, white noise forcings. The proof of convergence of the Euler scheme covers the equations for the oceans, atmosphere, coupled oceanic- atmospheric system and other geophysical equations. We obtain the existence of solutions weak in PDE and probabilistic sense, a result new to the best of our knowledge. (Received November 20, 2015)

1119-35-53 **Kenneth L. Kuttler*** (klkuttle@math.byu.edu), Provo, UT 84602. *Measurable solutions to evolution inclusions.*

A systematic way to study the existence of measurable solutions to stochastic evolution inclusions including those of the form

$$u' + A\left(u\left(\cdot,\omega\right),\omega\right) \ni f\left(\cdot,\omega\right) \text{ in } L^{p'}\left(\left[0,T\right];V'\right),\ u\left(0,\omega\right) = u_0\left(\omega\right)$$

is presented. Here ω is in Ω where $(\Omega,\mathcal{F})$ is a completely arbitrary measurable space. No reference to a measure is needed. It is based on a new result which gives the existence of product measurable selections in a set of weak limits of functions $u_n\left(\cdot,\omega\right)$ each of which is known to be product measurable (solutions to approximate problems). This general approach provides a way to study a variety of processes that are described by stochastic differential inclusions in which the coefficients and the inputs have random components. Examples of some nonlinear problems are described. (Received February 03, 2016)

1119-35-171 **Zhaohu Nie*** (zhaohu.nie@usu.edu), Department of Mathematics and Statistics, Utah State University, Logan, UT 84322-3900. *Classification of solutions to Toda systems of types C and B with singular sources.*

Toda systems are generalizations of the Liouville equation to other simple Lie algebras, and they arise in many physical and geometric problems. For Toda systems of type A, in a fundamental work Lin, Wei and Ye classified their solutions with finite energy and singular sources at the origin among other results. In this talk, we aim to generalize the classification of solutions to Toda systems of types C and B. Like in the A cases, the solutions are parametrized by the corresponding groups. The method is by studying the C and B types as reductions of type A with symmetries. The theories of Toda systems as integrable systems, in particular the W-symmetries and the iterated integral solutions, play essential roles in this work, together with certain characterizing properties of minors of symplectic and orthogonal matrices. (Received February 15, 2016)

1119-35-178 **Nathan E Glatt-Holtz*** (negh@math.vt.edu), Blacksburg, VA 24060. *The Stochastic Boussinesq Equations and Applications in Turbulent Convection.*

Buoyancy driven convection plays a ubiquitous role in physical applications: from cloud formation to large scale oceanic and atmospheric circulation pro- cesses to the internal dynamics of stars. Typically such fluid systems are driven by heat fluxes acting both through the boundaries (i.e. heating from below) and from the bulk (i.e. internal 'volumic' heating) both of which can have an essentially stochastic nature in practice.

In this talk we will review some recent results on invariant measures for the stochastic Boussinesq equations. These measures may be regarded as canonical objects containing important statistics associated with convection: mean heat transfer, small scale properties of the flow and pattern formation. We discuss ergodicity, uniqueness and singular parameter limits in this class of measures. Connections to the hypo-ellipticity theory of parabolic equations and to Wasserstein metrics will be highlighted. (Received February 15, 2016)

1119-35-185 **D. C. Antonopoulou**, Department of Mathematics, University of Chester, **P. W. Bates*** (bates@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824, **D. Blomker**, Institute for Mathematics, Universitat Augsburg, and **G. D. Karali**, Department of Mathematics, University of Crete. *Motion of a droplet for the stochastic mass-conserving Allen-Cahn equation.*

We use the stochastic mass-conserving Allen-Cahn equation to study the motion of a small almost semicircular droplet attached to the smooth boundary of a domain in $\mathbb{R}^2$ and subject to space-time additive noise. We apply Itô calculus to derive the stochastic dynamics of the center of the droplet by utilizing the approximately invariant manifold introduced by Alikakos, Chen and Fusco for the deterministic problem. Under the assumption of a

sufficiently small noise strength, we establish stochastic stability of a neighborhood of the manifold of boundary droplet states in the L^2- and H^1-norms, which means that with overwhelming probability the solution stays close to the manifold for very long time-scales. (Received February 15, 2016)

1119-35-209 **Tadahiro Oh**, **Geordie Richards*** (g.richards@rochester.edu) and **Laurent Thomann**. *On invariant Gibbs measures for generalized KdV.*

We will discuss some recent results on invariant Gibbs measures for the periodic generalized KdV equations (gKdV). Proving invariance of the Gibbs measure for gKdV is nontrivial due to the low regularity of functions in the support of this measure. Bourgain proved this invariance for KdV and mKdV, which have quadratic and cubic nonlinearities, respectively. Previously, we proved invariance of the Gibbs measure for the quartic gKdV by exploiting a nonlinear smoothing induced by initial data randomization. More recently, in joint work with Tadahiro Oh (Edinburgh) and Laurent Thomann (Lorraine), we have established this invariance for gKdV with any odd power (defocusing) nonlinearity. This argument relies on a probabilistic construction of solutions using the Skorokhod representation theorem. (Received February 15, 2016)

1119-35-238 **Jared P Whitehead*** (whitehead@mathematics.byu.edu). *Long time dynamics of a simplified Boussinesq model.*

Although weather forecasts have significantly improved in the last 65 years, it is a certainty that the accurate long-time forecast of time-specific events is impossible for such a chaotic system. Instead of predicting the exact trajectory of the earth's climate, it is believed that certain statistical quantities can be reliably estimated via modeling and numerical simulation. Exactly what these quantities are, and how the relevant statistics are to be collected, is not immediately clear.

As a first step toward toward understanding these issues, we consider the long-time behavior of two distinct versions of a two-dimensional Boussinesq model that incorporate the buoyancy effects of a stably stratified background density profile. In this idealistic setting we find regions of phase space in which the attractor of the system(s) must lie, using two different approaches that illustrate the effects of the stable stratification relative to the 2D Navier-Stokes equations (where the stratification is absent). (Received February 16, 2016)

37 ► Dynamical systems and ergodic theory

1119-37-26 **Brandon Edwards*** (edwardbr@math.oregonstate.edu). *A new characterization for elements of a Veech Group.* Preliminary report.

Translation surfaces are topological surfaces that when punctured are equipped with an atlas of local charts to the complex plane for which the transition functions are translations. This atlas gives us a well defined notion of whether or not a map from one translation surface to another has a constant Jocobian or is 'affine'. The Veech group of a translation surface is the group of Jacobians of orientation preserving affine homeomorphisms of the surface. The size of this group can inform us on the dynamics (periodic/ergodic) of the geodesic flow in a given direction [Veech 1989]. I will discuss an equivalent condition for Veech group membership that I use in an algorithm for computing generators of lattice Veech groups. (Received January 15, 2016)

1119-37-27 **Jayadev Siddhanta Athreya*** (jathreya@uw.edu), Department of Mathematics, University of Wash, Box 354350, Seattle, WA 98195, and **Gregory Margulis**. *Logarithm laws for unipotent flows.*

We study how unipotent flows on non-compact finite volume homogeneous spaces and moduli spaces of differentials visit the cusp. Some of this is joint work with G. Margulis. (Received January 16, 2016)

1119-37-47 **Elizabeth Sattler*** (elizabeth.sattler.1@ndsu.edu). *Dimension calculation for an invariant measure supported on a subfractal.* Preliminary report.

In this talk, we will examine properties, including fractal dimensions, of subfractals induced by subshifts of finite type or sofic subshifts. We will construct an invariant measure supported on a subfractal induced by a subshift of finite type and discuss a method for calculating the Hausdorff dimension of such a measure. (Received February 02, 2016)

1119-37-63 **Ben Webb*** (bwebb@mathematics.byu.edu), 308 TMCB, Brigham Young University, Provo, UT 84602. *Intrinsic stability of time-delayed dynamical networks and multidimensional systems.*

In real networks the time it takes to send and process information inevitably leads to time delays in the network's dynamics. These time-delays are important to the network's dynamics as they are often the source of instability

and poor performance. In fact, the introduction of time delays can both destabilize a stable system and stabilize one that is unstable depending on the system and where these delays are placed. In this talk we introduce a stronger form of stability that is preserved under changes to a network's structure of time delays. This we call intrinsic stability, which can be used to simplify the stability analysis for both dynamical networks and multidimensional systems. This is joint work with L. A. Bunimovich. (Received February 04, 2016)

1119-37-67 **Hari Sivakumar*** (hari@ece.ucsb.edu), **Stephen Proulx** and **Joao Hespanha**. *A modular perspective of the evolution of the p53 network.*

p53 is a tumor suppressor gene that is known to be a central hub of the DNA damage response network. It plays a critical role in guarding against cancer development and the loss of p53 function is involved in most human cancers.

In humans, p53 is part of a sophisticated network of proteins that mediate cell fate decisions such as the initiation of cell-cycle arrest, DNA repair, senescence and apoptosis. Aside from p53, this network includes the proteins MDM2, PTEN, and ARF among a host of other upstream, downstream and intermediate species involved in sensing, transduction and regulation.

In this talk we explore the evolutionary history of the p53 protein network. While homologs of the p53 gene seem to have been preserved over one billion years, this is not the case for the other proteins in the network; one can find organisms that express a p53 homolog together with different combinations of the remaining genes.

We use the evolutionary analysis as the starting point to partition the p53 network into independent modules and then attempt to infer the function of each module within the network. Our results show an evolutionary path towards networks with an increasingly complex structure of multi-stability, which we conjecture is associated with cell fate decisions. (Received February 05, 2016)

1119-37-71 **Andy Zucker*** (zucker.andy@gmail.com). *Ultrafilters and structural Ramsey theory.*

We will consider Ramsey objects and objects of finite Ramsey degree in a Fraisse class $\mathcal{K}$. We will show that an element of $\mathcal{K}$ is a Ramsey object if and only if a certain kind of ultrafilter exists, also providing a similar characterization of having finite Ramsey degree. Time permitting, we will discuss applications to the dynamics of the automorphism group of the Fraisse limit. (Received February 06, 2016)

1119-37-98 **Hieu Do** and **Thomas A Schmidt*** (toms@math.orst.edu), Department of Mathematics, Oregon State University, Corvallis, OR 97331. *Characterization of pseudo-Anosov homeomorphisms with vanishing Sah-Arnoux-Fathi invariant.* Preliminary report.

Interval exchange transformations (IET) form a group under composition. There is a natural homomorphism from this group to the wedge product of $\mathbb{R}$ with itself (over $\mathbb{Q}$), whose value on an IET is called the Sah-Arnoux-Fathi (SAF) invariant. By taking a full transversal to the linear flow in a fixed direction on a flat (actually, translation) surface, one obtains an IET. The SAF-invariant is independent of choice of full transversal, and in particular to each (orientable) pseudo-Anosov (pA) on a translation surface we can associate the SAF-invariant of its stable flow. We show that a pA has vanishing SAF-invariant if and only if the minimal polynomial of the dilatation of the pA is not reciprocal of even degree. We sketch some applications. (Received February 10, 2016)

1119-37-100 **Lennard F Bakker*** (bakker@mathematics.byu.edu), 366 TMCB, Department of Mathematics, Brigham Young University, Provo, UT 84602, and **Pedro Martins Rodrigues**. *Block conjugacy of irreducible toral automorphisms.*

We show that there exists topologically non-conjugate irreducible Anosov diffeomorphisms f and g on the n-torus, both having the same entropy, with the property that $f \times f$ and $g \times g$ are topologically conjugate on the $2n$-torus. The proof of this existence is a consequence of an algebraic number theory characterization of when two non-conjugate irreducible toral automorphisms $A, B \in \mathrm{GL}_n(\mathbb{Z})$ with the same characteristic polynomial are block conjugate, meaning there are toral automorphisms $A', B' \in \mathrm{GL}_n(\mathbb{Z})$ such that $A \oplus A'$ is conjugate to $B \oplus B$ and $A \oplus A$ is conjugate to $B \oplus B'$ in $\mathrm{GL}_{2n}(\mathbb{Z})$. (Received February 10, 2016)

1119-37-106 **Hieu Trung Do*** (doh@math.oregonstate.edu). *New families of pseudo-Anosov homeomorphisms with vanishing Sah-Arnoux-Fathi invariant.*

Translation surfaces can be viewed as polygons with parallel and equal sides identified. A homeomorphism on a translation surface to itself is called pseudo-Anosov if its derivative is a constant 2x2 matrix with trace larger than two. We apply Veech's construction of pseudo-Anosov homeomorphisms (by Rauzy-Veech induction) to produce infinite families of pseudo-Anosov maps in the stratum $\mathcal{H}(2,2)$ (thus with particular singularity combinatorics)

with vanishing Sah-Arnoux-Fathi invariant, as well as sporadic examples in other strata. (Received February 10, 2016)

1119-37-140 **Ammon SI Lam*** (lamsiyuen@gmail.com), 992 N 900 E Apt 28, Provo, UT 84604, and **Lennard F Bakker**. *Existence of symmetric singular periodic brake orbits in fully symmetric planar four body problem.* Preliminary report.

We investigate the existence of symmetric singular periodic brake orbits in the equal mass, fully symmetric planar four body problem. Using regularized coordinates, we remove the singularity of binary collision for each symmetric pair. We use topological and symmetry tools in our investigation. (Received February 13, 2016)

1119-37-152 **Peter Burton*** (pjburton@caltech.edu), **Martino Lupini** and **Omer Tamuz**. *Furstenberg entropy and weak equivalence.*

Furstenberg entropy is an invariant of stationary dynamical systems which quantifies how far the system is from being measure preserving. An important open problem in the theory of stationary systems is to understand the possible values of Furstenberg entropy on ergodic stationary systems corresponding to a given group and probability measure. In this talk we will describe how to use the notion of weak equivalence of stationary systems and the omitting types theorem from model theory to show that the set of values of Furstenberg entropy on factors of the Poisson boundary is closed. This is joint work with Martino Lupini and Omer Tamuz. (Received February 14, 2016)

1119-37-173 **Fabien Durand**, Amiens, France, **Nicholas Ormes*** (normes@du.edu), Denver, CO 80208, and **Samuel Petite**, Amiens, France. *Self-induced systems.*

In this paper, we characterize minimal Cantor systems that are *self-induced*. We call a topological system is self-induced if it contains a proper clopen subset such that the induced map on that clopen set is conjugate to the original system. It is well known substitution systems and certain odometers are examples of self-induced systems. We show that an expansive minimal Cantor systems is self-induced if and only if it is conjugate to a substitution system. Similarly, an equicontinuous minimal Cantor systems is self-induced if and only if it is an odometer that contains a prime factor of infinite multiplicity. Beyond this, we provide several examples of non-expansive, non-equicontinuous self-induced systems, including those that are non-uniquely ergodic and those with infinite entropy. We go on to characterize all self-induced minimal Cantor systems as generalized substitutions, by which we mean substitutions defined on a compact (but not necessarily finite) alphabet. (Received February 15, 2016)

1119-37-175 **Ronnie Pavlov*** (rpavlov@du.edu). *Almost specification and intrinsic ergodicity for subshifts.*

The specification property has been fundamental in the study of topological dynamical systems since its introduction by Bowen, and in particular is known to imply intrinsic ergodicity, i.e. uniqueness of the measure of maximal entropy. Almost specification is a weakening of specification which allows for concatenation of arbitrary words in the language if a "small" number of letters are changed in each, parametrized by a "mistake function" $g(n) = o(n)$.

It has been an open question whether almost specification implies intrinsic ergodicity. I will discuss the recent negative answer to this question, in particular showing that even the constant function $g(n) = 4$ does not imply intrinsic ergodicity. If time permits, I will also discuss current work (with Vaughn Climenhaga) on a one-sided version of almost specification, which as a corollary implies that $g(n) = 1$ does imply intrinsic ergodicity. (Received February 15, 2016)

1119-37-179 **Jinqiao Duan*** (duan@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616. *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 February 15, 2016)

1119-37-193 **Thomas French***, Thomas.French@du.edu. *Follower and extender set sequences of one-dimensional shifts.*

Given a one-dimensional shift X, let $|F_X(\ell)|$ be the number of follower sets of words of length ℓ in X. We call the sequence $\{|F_X(\ell)|\}_{\ell\in\mathbb{N}}$ the follower set sequence of the shift X. Extender sets are a generalization of follower sets, and we define the extender set sequence similarly. We show some connections between follower and extender set sequences and complexity sequences of one-dimensional shifts, but also some surprising differences. In particular, the follower and extender set sequences of a one-dimensional shift need not be monotone increasing, and even when the shift is sofic, they may be eventually periodic rather than eventually constant. (Received February 15, 2016)

1119-37-196 **Jaroslaw Kwapisz*** (jarek@math.montana.edu), Department of Mathematical Sciences, Montana State University, P.O. Box 172400, Bozeman, MT 59717. **L-cut conjecture and non-injectivity of Abel-Franks map**. Preliminary report.

Let M be a translation surface of genus $g \geq 1$. An L-*cut* is an oriented curve K tracing a vertical segment followed by a horizontal segment. Two L-cuts K, K' are *parallel* iff they begin at the same point z_0 and end at the same point z_1 and the loop $K'K^{-1}$ is null-homologous. The z_i must be *saddles* (singularities of M), possibly $z_0 = z_1$. You may exclude M with vertical or horizontal saddle connections.

Conjecture: If $g > 1$ then there is a pair of (distinct) parallel L-cuts K, K'.

Slicing along K and K' (and regluing) decomposes M into two simpler translation surfaces. The conjecture implies that any M arises from genus one surfaces by repeated connected sums along L-cuts. This parallels the classical result about topological surfaces but is more delicate. With Andy Bouwman, we only tackled $g = 2$.

I will discuss different approaches to the conjecture as well as its applications, including the open question (going back to R. Bowen and M. Hirsch in 1960's) about embedding of pseudo-Anosovs into hyperbolic toral automorphisms. The candidate embedding is a dynamical analogue of the classical Abel-Jacobi map (baptized *Abel-Franks map* by M. Gromov). (Received February 15, 2016)

1119-37-208 **Robin D Tucker-Drob*** (rtuckerd@math.tamu.edu), College Station, TX 77843. *Weak containment rigidity for distal actions.*

We prove that if a measure distal action α of a countable group Γ is weakly contained in a strongly ergodic probability measure preserving action β of Γ, then α is a factor of β. In particular, this applies when α is a compact action. As a consequence, we show that the weak equivalence class of any strongly ergodic action completely remembers the weak isomorphism class of the maximal distal factor arising in the Furstenberg-Zimmer Structure Theorem. This is joint work with Adrian Ioana. (Received February 15, 2016)

1119-37-221 **Benjamin Dozier*** (bdozier@stanford.edu), Stanford University Department of Mathematics, Building 380, Stanford, CA 94305. *Counting saddle connections whose holonomies lie in a strip.* Preliminary report.

Given a translation surface, the problem of counting saddle connections with certain properties leads naturally to questions about dynamics on the moduli space of translation surfaces. Many interesting results have been proved about the number of saddle connections of length at most R; this turns out to be intimately connected to the Teichmüller geodesic flow. I will consider the problem of counting saddle connections whose holonomy vectors in $\mathbb{R}^2$ lie in a rectangle, centered at the origin, with fixed height and growing width. I will prove a lower bound for this count that is linear in the width of the rectangle. This involves studying non-divergence properties of the horocycle flow on the space of translation surfaces. (Received February 16, 2016)

1119-37-228 **Zeng Lian** (zenglian@gmail.com), School of Mathematics, Sichuan University, Chengdu, Sichuan 610064, Peoples Rep of China, **Peidong Liu** (lpd@pku.edu.cn), School of Mathematics, Peking University, Beijing, Beijing 100871, Peoples Rep of China, and **Kening Lu*** (klu@math.byu.edu), Department of Mathematics, Brigham Young University, Provo, UT 84602, Peoples Rep of China. *SRB measures for a class of partially hyperbolic attractors in Hilbert spaces.*

We study the existence of SRB measures and their properties for infinite dimensional dynamical systems in a Hilbert space. We show several results including (i) if the system has a partially hyperbolic attractor with nontrivial finite dimensional unstable directions, then it has at least one SRB measure; (ii) if the attractor is uniformly hyperbolic and the system is topological mixing and the splitting is Hölder continuous, then there

exists a unique SRB measure which is mixing; (iii) if the attractor is uniformly hyperbolic and the system is non-wondering and and the splitting is Hölder continuous, then there exists at most finitely many SRB measures; (iv) for a given hyperbolic measure, there exist at most countably many ergodic components whose basin contains an observable set. (Received February 16, 2016)

39 ► Difference and functional equations

1119-39-24 **Mostafa Ghandehari***, ghandeha@uta.edu, and **Fred Kashefi**. *An application of Z transform in pharmacokinetics.* Preliminary report.

Discrete Z transform is used to solve difference equations in pharmacokinetics for constant dosage in fixed time intervals. Difference equations for half dosage and fractional dosage are analyzed. Clinical applications are discussed. (Received January 15, 2016)

45 ► Integral equations

1119-45-141 **Vira Babenko*** (babenko@math.utah.edu), The University of Utah, Department of Mathematics, 155 S 1400 E ROOM 233, Salt Lake City, UT 84112. *Volterra and Fredholm integral equations for functions with values in L-spaces.*

We explore nonlinear Volterra and Fredholm integral equations for functions with values in L-spaces (which are generalizations of set-valued and fuzzy-valued functions). We prove theorems of existence and uniqueness of the solution for such equations. In addition, we study the dependence of solutions of such equations on variations in the data. The exploration of these equations is of great importance given the wide variety of their applications in biology, physics, and engineering among others. (Received February 13, 2016)

46 ► Functional analysis

1119-46-60 **Michal Odyniec*** (m.odyniec@ieee.org), 161 Vasco Rd, Livermore, CA 94550. *Uncertainty analysis in signal detection.*

We are concerned with measurements of relative timing of irregularly and differently shaped signals with compact support. A (believed to be new) definition of the time reference, applicable to smooth but otherwise arbitrary pulses, results in the time uncertainty estimates that are much smaller what one might expect with a casual analysis. These estimates are easily calculable given the noise level of the recording device and the pulse shape. (Received February 03, 2016)

1119-46-194 **Bruno de Mendonça Braga***, demendoncabraga@gmail.com. *Uniform and coarse embeddings.*

In this talk, we will explain the concepts of uniform and coarse embeddings, and talk about some results regarding those two concepts. For example, let X and Y be Banach spaces. It is still unknown whether the existence of a coarse embedding $X \to Y$ is equivalent to the existence of a uniform embedding $X \to Y$. We will provide some examples where the answer to this question is known and give other partial results on this problem. (Received February 15, 2016)

47 ► Operator theory

1119-47-81 **Waleed Al-Rawashdeh*** (walrawashdeh@mtech.edu), 1300 West Park Street, Butte, MT 59701. *Composition operators on weighted Hilbert Spaces.*

Let φ be an analytic self-map of open unit disk $\mathbb{D}$. A composition operator is defined as $(C_\varphi f)(z) = f(\varphi(z))$, for $z \in \mathbb{D}$ and f analytic on $\mathbb{D}$. Given an admissible weight ω, the weighted Hilbert space $\mathcal{H}_\omega$ consists of all analytic functions f such that $\|f\|^2_{\mathcal{H}_\omega} = |f(0)|^2 + \int_{\mathbb{D}} |f'(z)|^2 w(z) dA(z)$ is finite. In this talk, we study composition operators in weighted Bergman space A^2_α and weighted Hilbert space $\mathcal{H}_\omega$. Using generalized Nevalinna counting functions associated with ω, we characterize the boundedness and compactness of these composition operators. (Received February 08, 2016)

49 ► Calculus of variations and optimal control; optimization

1119-49-187 **Michael Chi** (mchi1@ualberta.ca), 632CAB University of Alberta, Edmonton, Alberta T6G 2G1, Canada, **François Gay-Balmaz** (gaybalma@lmd.ens.fr), 24 Rue Lhomond, 75231 Paris Cedex 05, France, **Vakhtang Putkaradze** (putkarad@ualberta.ca), 632CAB University of Alberta, Edmonton, Alberta T6G 2G1, Canada, **Nima Fathi** (nima.fathi145@gmail.com), 1 University of New Mexico, MSC01 1150, Albuquerque, NM 87131, and **Peter Vorobieff*** (kalmoth@unm.edu), 1 University of New Mexico, MSC01 1150, Albuquerque, NM 87131. *Control of a flexible chimney under wind loading.*

A flexible, inflatable design has been recently proposed for tall, free-standing structures such as chimneys or solar updraft towers. A theory describing the behavior of such a flexible structure (a stack of toroidal bladders) under wind loading is developed using Lagrangian reduction by symmetry. By varying pressure inside individual bladders, structure deflection can be controlled. A geometric theory of optimal deflection control is also presented. Theoretical and numerical results are compared with experimental data from a prototype. (Received February 15, 2016)

51 ► Geometry

1119-51-55 **Zbigniew Oziewicz*** (oziewicz.zbigniew@gmail.com), Ex-Hacienda San Miguel, Calle Roble 13 A, 54715 Cuautitlan Izcalli, Mexico, Mexico. *Affine space with non-reciprocal vectors and the mass centre for the finite light speed.*

Elie Cartan introduced in 1908 the concept of affine space consisting of points and reciprocal vectors given by the ordered pair of points. I am pointing that a hyperboloid of all normalized time-like vectors is an example of the Cartan affine space. Then each point possesses many presentations (called translations) relative to the different reference points. I am relaxing reciprocity restriction. Let a co-vector be associative to a vector, i.e. vector is a crest in the kernel of associated vector. This do not implies that the corresponding observed and reference points must be in the same crest of this co-vector. In this way the Cartan concept of the affine space with reciprocal vectors is generalized to affine space with non-reciprocal vectors. Such generalization allows to determine the intrinsic mass centre for arbitrary set of points, as a point on hyperboloid, using barycentric coordinates introduced by Mobius in 1827. I am showing that the non-reciprocity is equivalent to the finite light speed, and reciprocity corresponds to infinite light speed. (Received February 03, 2016)

52 ► Convex and discrete geometry

1119-52-68 **Joseph T Lee*** (joseph.tj.lee@gmail.com). *On the smallest quadrilateral containing a convex disc.*

A *convex disc* is a compact convex set in the plane with nonempty interior. For a given *unit area* convex disc K, let $\rho_4(K)$ be the area of a convex quadrilateral of *minimum area* that contains K. How large can $\rho_4(K)$ be?

A 1983 result shows that $\rho_4(K) < \sqrt{2}$ for all unit area convex discs K. On the other hand, if K is a unit area regular pentagon, it is known that $\rho_4(K) = 3/\sqrt{5} = 1.341\ldots$. A long standing conjecture of Kuperberg states that $\rho_4(K) \leq 3/\sqrt{5}$ for all unit area convex discs K.

In this paper we prove that every unit area convex *pentagon* is contained in a quadrilateral of area $\leq 3/\sqrt{5}$, thus making a first step towards solving this problem. (Received February 06, 2016)

1119-52-74 **Stefan O Tohaneanu*** (tohaneanu@uidaho.edu), Department of Mathematics, University of Idaho, Moscow, ID 83844. *The set-theoretic complete intersection property of some subspace arrangements.*

In the 60's Hartshorne gave a counter-example to the conjecture from the XIX century that every variety is the intersection of as many hypersurfaces as the codimension is (i.e., set-theoretic complete intersection). The counter-example is a union of two complex 2-planes in $\mathbb{P}^3$. This counter-example led to the very difficult conjecture (named after Hartshorne) that every complex irreducible curve in $\mathbb{P}^3$ is the interesction of two hypersurfaces. Also, it led to the study of classes of subspace arrangements that have or do not have the property of being set-theoretic complete intersection. In this presentation we show that star configuration are set-theoretic complete intersections, yet some other subspace arrangements defined similarly do not have this property. (Received February 07, 2016)

53 ► Differential geometry

1119-53-158 **Zhiqin Lu** and **Hang Xu***, hangx@math.uci.edu. *L^2 estimates on noncomplete Kähler manifolds.*

I will introduce the L^2 estimates on noncomplete Kähler manifold whose boundary has zero capacity. As an application, the moduli space of polarized Calabi-Yau manifolds satisfies such a condition and we can do L^2 estimates on it. This is a joint work with Zhiqin Lu. (Received February 15, 2016)

54 ► General topology

1119-54-123 **Zhiyun Cheng**, **Sujoy Mukherjee*** (sujoymukherjee@gwu.edu), **Józef H. Przytycki**, **Xiao Wang** and **Seung Yeop Yang**. *From Gaussian polynomials to plucking polynomials.*

The plucking polynomial is an invariant of rooted trees with connections to knot theory. It can be defined in terms of products of Gaussian polynomials (q-binomial coefficients). We will discuss whether or not every product of Gaussian polynomials is realizable as a plucking polynomial of a rooted tree and discuss criteria determining this. Further, we will discuss uniqueness of the realization when it exists. (Received February 12, 2016)

55 ► Algebraic topology

1119-55-142 **Paul Gustafson*** (pgustafs@math.tamu.edu). *Towards finiteness for mapping class group representations from group-theoretical categories.* Preliminary report.

Given a spherical category $\mathcal{C}$ and an oriented surface with boundary Σ, the Turaev-Viro TQFT gives a projective representation of the mapping class group $\mathrm{MCG}(\Sigma)$. One question motivated from topological quantum computation is the following: when is the image of this representation finite? Etingof, Rowell, and Witherspoon showed that the image is finite when $\mathcal{C}$ is group-theoretical and $\mathrm{MCG}(\Sigma)$ is the braid group B_n. Fjelstad and Fuchs proved that the image is finite when $\mathcal{C}$ is the representation category for a finite group and Σ is a surface with at most one boundary component. In this talk, I will work through the case where $\mathcal{C}$ is an arbitrary group-theoretical category and Σ is a genus-2 closed surface. (Received February 13, 2016)

57 ► Manifolds and cell complexes

1119-57-48 **Louis H Kauffman*** (kauffman@uic.edu), Math UIC, 851 South Morgan Street, Chicago, IL 60607-7045. *Octonionic belt tricks.* Preliminary report.

This talk will discuss ways to use the topology of braided belts to model the octonions. This is based on work begun with Jonathan Hackett. <http://arxiv.org/pdf/1010.2979.pdf> (Received February 02, 2016)

1119-57-148 **Seung Yeop Yang*** (syyang@gwu.edu) and **J. Scott Carter** (carter@southalabama.edu). *Periodic surface-knots and quandle extensions.*

Periodicity is one of the most interesting and important concepts in mathematics pervading both science and nature. In classical knot theory, periodicity has been well studied. Higher dimensional periodic knots are introduced by Cruz in 1991. In this talk, we focus on surface-knots, i.e. smooth embeddings of connected and closed surfaces into a 4-dimensional space, and study periodicity. We moreover discuss some quandle extensions to color periodic surface-knots. (Received February 14, 2016)

1119-57-161 **Zhiyun Cheng**, **Sujoy Mukherjee**, **Józef H. Przytycki**, **Xiao Wang*** (wangxiao@gwu.edu) and **Seung Yeop Yang**. *Strict unimodality of plucking polynomials of rooted trees.*

We study strict unimodality of plucking polynomials by classifying strict unimodality of product of Gaussian polynomials. We also give criteria for a trapezoidal shape of a plucking polynomial. We generalize results of Pak and Panova on strict unimodality of q-binomial coefficients. (Received February 15, 2016)

1119-57-214 **Jozef H. Przytycki*** (przytyck@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *A few problems in knot theory or motivated by knot theory.*

We propose several problems which are either directly involving knots or are motivated by them. We list five of them below:

1. Find a short skein relation for the number of Fox n colorings. The starting point is the formula $col_3(D) = 3|V(e^{pi/3}|^2$; Jaeger and Jones were interested in this problem.

2. Prove or disprove Nakanishi 4-move conjecture. In particular, show that the 2-cable of the pentafoil knot can be reduced by 4-moves.

3. Understand the multiplication in the Kauffman bracket skein algebra of $F_{0,4} \times [0, 1]$ (in analogy of the Gelca-Frohman noncommutative torus result).

4. Let G be a (bipartite) circle graph, Show that the independence simplicial complex I_G is homotopy equivalent to a wedge of spheres (a joint project with Marithania Silvero Casanova).

5. Study unimodality of a plucking polynomial of a rooted tree with a delay function (a joint project with Mathathoners). (Received February 15, 2016)

60 ► Probability theory and stochastic processes

1119-60-11 **Chia Ying Lee** and **Leila Setayeshgar***, lsetayes@providence.edu. *Large deviations for a stochastic Korteweg-de Vries equation with additive noise.*

We prove the large deviations principle for the law of the solutions to a stochastic Korteweg-de Vries (KdV) equation in the presence of an additive noise. Our proof is based upon the weak convergence approach. (Received November 14, 2015)

1119-60-16 **Yu Gu*** (yg@math.stanford.edu) and **Jean-Christophe Mourrat**. *Scaling limits of fluctuations in stochastic homogenization.*

Equations with small scales abound in physics and applied science. When the coefficients vary on microscopic scales, sometimes we expect local fluctuations to average out and the coefficients have some equivalent homogeneity on large scales. The goal of homogenization is to find an equivalent homogeneous media to replace the heterogeneous one with small effects on the solutions. In this talk, I will try to explain some probabilistic approaches we use to obtain the first order fluctuations in stochastic homogenization. The main ingredients include the invariance principle of a diffusion in random environment, the Helffer-Sjöstrand covariance representation and the Stein's method. (Received January 03, 2016)

1119-60-18 **Angel Chavez*** (angel.chavez@pomona.edu), 610 N. College Ave., Claremont, CA 91711, and **Doug Pickrell**. *Werner's measure on self-avoiding loops and representations of the Virasoro algebra.* Preliminary report.

Werner has proven the existence and essential uniqueness of a conformally invariant family of measures on self-avoiding loops on Riemann surfaces. This family is determined by a single measure on loops in the plane which surround the origin. Riemann's mapping theorem can be used to define a probability measure on coefficients of univalent holomorphic functions on the disk. We will discuss how one can compute moments of these coefficients using invariance with respect to an action of the Virasoro algebra. (Received January 11, 2016)

1119-60-20 **Janos G. Englander*** (janos.englander@colorado.edu), 5527 Homestead Way, Boulder, CO 80301, and **Renming Song** and **Yanxia Ren**. *Weak extinction versus global exponential growth of total mass for SPDE's and super-Brownian motions.*

We study the behavior of the total mass for a class of SPDE's which describe the density (in one-dimension) of certain super-Brownian motions. In higher dimensions this still makes sense, although there are no weak functional solutions any more – the solutions will be distribution-valued.

This is joint work with Renming Song (Urbana) and Yanxia Ren (Beijing University). (Received January 11, 2016)

1119-60-35 **Mei Yin*** (mei.yin@du.edu), 2280 S Vine St, Denver, CO 80208. *Large deviations in exponential random graphs.*

The exponential random graph model has been a topic of continued research interest. This talk will concentrate on the applications of large deviation theory in the study of this classic model. (Received January 26, 2016)

1119-60-38 **Samy Tindel*** (stindel@purdue.edu), Department of Mathematics, 150 N. University Street, W. Lafayette, IN 47907. *Rough conservation laws.*

Conservation laws are a class of PDEs which includes Burgers' equation (in its inviscid form), and whose solutions are known to develop discontinuities. Methods based on regularization by a semigroup are thus ruled out in this context, which makes the study of conservation equations very different from the usual parabolic setting. After reviewing some of the recent advances in the theory of stochastic conservation laws, we will introduce a setting which allows for a definition and resolution of a general class of rough conservation laws. The main tools are (i) A convenient notion of rough kinetic solution (ii) An estimate of Gronwall type, related to some structures called unbounded rough drivers. According to time, we will try to introduce some of these notions. This presentation is based on a joint work with A. Deya, M. Gubinelli and M. Hofmanova. (Received January 30, 2016)

1119-60-43 **Sean D O'Rourke*** (sean.d.orourke@colorado.edu), Department of Mathematics, University of Colorado Boulder, Campus Box 395, Boulder, CO 80309-0395, and **Van Vu** and **Ke Wang**. *Eigenvectors of random matrices.*

Eigenvectors of large matrices (and graphs) play an essential role in combinatorics and theoretical computer science. The goal of this talk is to present several properties of the eigenvectors when the matrix (or graph) is random. In particular, I will address the largest coordinate, smallest coordinate, joint distribution of several coordinates, ℓ^p-norm, and amount of mass contained in a subset of coordinates. (Received February 01, 2016)

1119-60-44 **Krzysztof Bogdan** and **Bartłomiej Siudeja*** (siudeja@uoregon.edu). *Transition densities and trace estimates for a broad class of Lévy processes.*

Transition density of a stochastic process allows one to quantify the dynamics of the process. Yet, except for Brownian motion and a very few special cases, there is no closed formula for the density, which is usually defined via a characteristic function. The problem is exacerbated for killed processes (confined to bounded domains), where even the Brownian case is not explicit.

We will discuss recent progress on bounding the transition probabilities of a class of killed Lévy processes using geometric properties of their domains. We will use these to estimate their traces, the quantities revealing so-called heat invariants. In the classical, Brownian case, the first two invariants are the volume and the surface area of the domain. Surprisingly, we will find the same simple quantities in traces of very general Lévy processes. (Received February 01, 2016)

1119-60-49 **Hakima Bessaih*** (bessaih@uwyo.edu), Department of Mathematics, Dept. 3036, 1000 East University Avenue, Laramie, WY 82071, and **Yalchin Efendiev** and **Florian Maris**. *Homogenization of Brinkman flows in heterogeneous dynamic media.*

We study Brinkman's equations with microscale properties that are highly heterogeneous in space and time. The time variations are controlled by a stochastic particle dynamics described by an SDE. The particle dynamics can be thought as particle deposition that often occurs in filter problems. Our main results include the derivation of macroscale equations and showing that the macroscale equations are deterministic. The latter is important for our (also many other) applications as it greatly simplifies the macroscale equations. We use the asymptotic properties of the SDE and the periodicity of the Brinkman's coefficient in the space variable to prove the convergence result. The SDE has a unique invariant measure that is ergodic and strongly mixing. The macro scale equations are derived through an averaging principle of the slow motion (fluid velocity) with respect to the fast motion (particle dynamics) and also by averaging the Brinkman's coefficient with respect to the space variable. Our results can be extended to more general nonlinear diffusion equations with heterogeneous coefficients. (Received February 02, 2016)

1119-60-52 **Xin Guo**, **Zhao Ruan** and **Lingjiong Zhu*** (zhu@math.fsu.edu). *Dynamics of order positions and related queues in a limit order book.*

In this talk, we will present some of our recent progress regarding the limiting behavior of the dynamics of order positions in a limit order book. In particular, we will obtain a fluid limit and study the fluctuations about the fluid limit for the system, as well as the execution time. Some open problems will be discussed. (Received February 03, 2016)

1119-60-58 **Eviatar B Procaccia*** (procaccia@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843. *Can one hear the shape of a random walk?*

We consider a Gibbs distribution over random walk paths on the square lattice, proportional to the cardinality of the path's boundary . We show that in the zero temperature limit, the paths condensate around an asymptotic shape. This limit shape is characterized as the minimizer of the functional, mapping open connected subsets of

the plain to the sum of their principle eigenvalue and perimeter (with respect to some norm). A prime novel feature of this limit shape is that it is not in the class of Wulff shapes. (Received February 03, 2016)

1119-60-69 **Carl Mueller***, Dept. of Mathematics, University of Rochester, Rochester, NY 14627, and **Leonid Mytnik** and **Edwin Perkins**. *The boundary of the support of super-Brownian motion.* Preliminary report.

Super-Brownian motion is one of the most important stochastic PDE and measure-valued processes, with a strong motivation from population biology. However, uniqueness for the equation describing this process is still unknown. Since the coefficients are at their worst when the solution is close to 0, studying the boundary of the support of the solution seems like a reasonable strategy for establishing uniqueness. We compute the Hausdorff dimension of the boundary of the support, but we do not yet have a proof of uniqueness. (Received February 06, 2016)

1119-60-88 **Eka Oche Ogbaji*** (ogbajieka@yahoo.com), Department of Mathematics and Statistics, Federal university Wukari, Wukari, 96000001, Nigeria, and **E.S Onah** (emmanuelinnocent@yahoo.com), Department of Maths/Stat/Comp.Sc, University of Agriculture Makurdi, Makurdi, 96000001. *A four-compartment stochastic differential equation model of a stock market.* Preliminary report.

This research work is centred on the return on investment that informs investors and entrepreneurs on general performance of a company. The research problem was a modification of an existing model. This was done by incorporating rate of reinvestment of return and return on investment that follow random process. In addition to the modification, the existing model was extended from a two to four compartment stochastic differential equation. Formulation of a four- compartment stock market model was based on a four dimensional geometric Brownian motion. Data were collected from Nigerian Stock Exchange (NSE) for the period of 2007 -2014 to validate the model formulated. Transition probability of stock price and its volatility was zero (0) at 19th long run (iteration) from where the transition probability became stable. Also, the transition probability of return on investment and its volatility was 0.5 at 19th long run (iteration).This implies that stock price and its volatility became unstable on the long run while return on investment and its volatility became stable on the long run with a probability of 0.5. We concluded that return on investment was considered to be the best index to use to study the general performance of companies rather than stock price. (Received February 09, 2016)

1119-60-90 **Le Chen**, **Yaozhong Hu**, **Kamran Kalbasi** and **David Nualart*** (nualart@ku.edu), University of Kansas, Department of Mathematics, Lawrence, KS 66047. *Stochastic heat equation driven by a rough time-fractional noise.*

In this talk we present some recent results on the stochastic heat equation on $\mathbb{R}^d$ driven by a Gaussian noise which is a fractional Brownian motion in the time variable with Hurst parameter $H \in (0, 1/2)$. We derive a Feynman-Kac formula for the solution and we use this representation to establish matching lower and upper bounds for the $L^p(\Omega)$ moments of the solution that lead to intermittency properties. (Received February 09, 2016)

1119-60-97 **Yevgeniy Kovchegov*** (kovchegy@math.oregonstate.edu) and **Ilya Zaliapin** (zal@unr.edu). *Hierarchical Branching Processes.*

We introduce a class of stochastic processes that we call hierarchical branching processes. By construction, the processes satisfy the Tokunaga, and hence Horton, self-similarity constraints. Taking the limit of averaged stochastic dynamics, we obtain the deterministic system of differential equations that describe the temporal dynamics of a Tokunaga branching system. In particular, we study the averaged tree width function to establish a phase transition in the Tokunaga dynamics that separates fading and explosive branching. We then describe a class of critical hierarchical branching processes (that happen at the phase transition boundary) that includes as a special case the celebrated critical Galton-Watson branching process. We illustrate efficiency of the critical hierarchical branching processes in describing diverse observed dendritic structures, and discuss the related critical phenomena from the point of view of respective applications. (Received February 10, 2016)

1119-60-128 **Riddhipratim Basu*** (rbasu@stanford.edu), **Shirshendu Ganguly** and **Christopher Hoffman**. *Non-fixation for Activated Random Walk on the Line.*

We consider Activated Random Walk (ARW), a model which generalizes the Stochastic Sandpile, one of the canonical examples of self organized criticality. Informally ARW is a particle system on $\mathbb{Z}$ with mass conservation. One starts with a mass density $\mu > 0$ of initially active particles, each of which performs a continuous time nearest neighbour symmetric random walk at rate one and falls asleep at rate $\lambda > 0$. Sleepy particles become active on coming in contact with other active particles. We investigate the question of fixation/non-fixation of the

process and show for small enough λ the critical mass density for fixation is strictly less than one. Moreover, the critical density goes to zero as λ tends to zero. This positively answers two open questions from Dickman, Rolla, Sidoravicius (J. Stat. Phys., 2010) and Rolla, Sidoravicius (Invent. Math., 2012). (Received February 13, 2016)

1119-60-132 **Mackenzie Simper*** (mackenzie.simper@utah.edu), **Tom Alberts** (alberts@math.utah.edu) and **Ga Yeong Lee**. *Bak-Sneppen backwards.*

The Bak-Sneppen model is a Markov chain which serves as a simplified model of evolution in a population of spatially interacting species. We study the backwards Markov chain for the Bak-Sneppen model, and derive its corresponding reversibility equations. We show that, in contrast to the forwards Markov chain, the dynamics of the backwards chain explicitly involve the stationary distribution of the model, and from this we derive a functional equation that the stationary distribution must satisfy. We use this functional equation to derive differential equations for the stationary distribution of Bak-Sneppen models in which all but one or all but two of the fitnesses are replaced at each step. (Received February 13, 2016)

1119-60-145 **Xia Chen*** (xchen@math.utk.edu), Department of Mathematics, University of Tennessee, Knoxville, TN 37996, and **Tuoc Phan**. *Free energy in a mean field of Brownian particles.* Preliminary report.

We compute the limit of the free energy of the mean field generated by the independent Brownian particles interacting through a non-negative definite function. Our main theorem is relevant to the high moment asymptotics for the parabolic Anderson models with Gaussian noise that is white in time, white or colored in space. Our approach makes a novel connection to the celebrated Donsker-Varadhan's large deviation principle for the i.i.d. random variables in infinite dimensional spaces. As an application of our main theorem, we provide a probabilistic treatment to the Hartree's theory on the asymptotics for the ground state energy of bosonic quantum system. (Received February 14, 2016)

1119-60-162 **Jack Hanson*** (jhanson@ccny.cuny.edu), Department of Mathematics, CCNY, NAC 8/133, Convent Ave at 138th Street, New York, NY 10031. *Chemical distance in 2d percolation.*

In critical two-dimensional Bernoulli percolation, fraction 1/2 of the edges of the graph $\mathbb{Z}^2$ are erased independently. The resulting graph has connected components and "holes" appearing on all scales. As a result, the chemical (graph) distance inside large connected components is conjectured to grow superlinearly in the Euclidean distance according to a chemical distance exponent, and some results in this direction are known. For instance, the shortest crossing of the box $[-n, n]^2$ has length $S_n > n^{1+\epsilon}$ with high probability, and is no longer than the unique lowest crossing, whose length L_n is known to scale as $n^{4/3}$. Kesten and Zhang asked whether $S_n = o(L_n)$; we will discuss recent work which gives an affirmative answer to this question, as well as some results on point-to-point and point-to-box distances.

Joint work with M. Damron and P. Sosoe. (Received February 15, 2016)

1119-60-170 **Christopher D Sinclair*** (csinclai@uoregon.edu), Department of Mathematics, University of Oregon, Eugene, OR 97403. *Zeros of random p-adic polynomials.* Preliminary report.

I'll talk about the probability that a polynomial with p-adic integer coefficients has all of its zeros in Q_p. The recurrence defining this probability has been known for several years, but I will give an easy proof of this recurrence and talk about how this calculation differs from the situation for polynomials with real coefficients. (Received February 15, 2016)

1119-60-183 **Le Chen*** (chenle02@gmail.com), 405 Snow Hall, 1460 Jayhawk Blvd, Lawrence, KS 66045-7594, **Yaozhong Hu** (yhu@ku.edu), 405 Snow Hall, 1460 Jayhawk Blvd, lawrence, KS 66045-7594, and **David Nualart** (nulart@ku.edu), 405 Snow Hall, 1460 Jayhawk Blvd, lawrence, KS 66045-7594. *Regularity and positivity of densities for the stochastic (fractional) heat equation.*

In this talk, I will present a recent study on the the density of the solution to a semilinear stochastic (fractional) heat equation (SHE), which includes the *parabolic Anderson model* as a special case. In the first part, we prove that the solution to a semilinear SHE with measure-valued initial data has a smooth joint density at multiple points. This result extends the work by Mueller and Nualart [EJP'08] from the density at single point to the joint density at multiple points and from function-valued initial data to more general initial data. This is achieved by proving that solutions to a related stochastic partial different equation have negative moments of all orders. In the second part, we establish the strict positivity of the density in the interior of the support of the joint law.

This result extends the known results to allow measure-valued initial data and unbounded diffusion coefficient (e.g., the parabolic Anderson model). This talk is based on a joint work with Yaozhong Hu and David Nualart. (Received February 15, 2016)

1119-60-189 **Daniel Conus*** (daniel.conus@lehigh.edu), Mathematics Department / Lehigh University, Christmas-Saucon Hall, 14 East Packer Avenue, Bethlehem, PA 18015.
Intermittency properties for a class of SPDEs driven by fractional noise.

A space-time random-field is called physically intermittent if it develops high-valued *peaks* concentrated on small spatial *islands* as time gets large. In this talk, we will illustrate this notion by discussing several examples of intermittent random fields given by solutions to a class of parabolic and hyperbolic SPDEs. In particular, we will present some results related to equations driven by fractional noise. (Received February 15, 2016)

1119-60-207 **Nathan E Glatt-Holtz**, **Jonathan C Mattingly** and **Geordie Richards*** (g.richards@rochester.edu).
On unique ergodicity for nonlinear SPDEs.

We will describe a simplified framework through asymptotic coupling for establishing the existence of a unique ergodic invariant measure (unique ergodicity) for nonlinear SPDEs. To illustrate, we will provide a relatively short proof of unique ergodicity for the 2D stochastic Navier-Stokes equations on a domain with "effectively elliptic" random forcing. (Received February 15, 2016)

1119-60-213 **Jingyu Huang**, **Khoa Le*** (khoa.le@ucalgary.ca) and **David Nualart**.
Propagation of high moments for parabolic Anderson model.

The parabolic Anderson model is the heat equation perturbed by a multiplicative noise. In case of Gaussian noise with non-trivial constant initial datum, the n-th moment of the solution grows exponentially fast in long term over the whole spatial domain. If the initial datum is localized, the moment grows exponentially only inside a space-time cone. Outside of the cone, the moment decays exponentially in long term. We will discuss how to specify these cones. The talk is based on a joint work with Jingyu Huang and David Nualart (available on arXiv:1509.00897). (Received February 15, 2016)

1119-60-215 **Konstantin Matveev*** (kosmatveev@gmail.com) and **Leonid Petrov** (lenia.petrov@gmail.com).
Random polymers and q-deformed RSK algorithms.

Some "integrable" or "exactly solvable" probabilistic models are amenable to analysis, because the underlying algebraic structure allows to express certain correlations and moments via exact formulas. We will see how this "integrability" manifests itself in particular models of random polymers (of log-Gamma and strict weak type) and interacting particle systems (of q-TASEP and q-PushTASEP type), and how q-deformed Robinson-Schensted-Knuth algorithms arise as unifying constructions. (Received February 15, 2016)

1119-60-220 **Michael C Cranston***, 28 Frost.
Path-wise localization in the Anderson polymer model.

We consider large time behavior of typical paths under the Anderson polymer measure. If P^x_κ is the measure induced by rate κ, simple, symmetric random walk on $\mathbf{Z^d}$ started at x, this measure is defined as

$$d\mu^x_{\kappa,\beta,T}(X) = Z_{\kappa,\beta,T}(x)^{-1} \exp\left\{\beta \int_0^T dW_{X(s)}(s)\right\} dP^x_\kappa(X)$$

where $\{W_x : x \in \mathbf{Z^d}\}$ is a field of *iid* standard, one-dimensional Brownian motions, $\beta > 0, \kappa > 0$ and $Z_{\kappa,\beta,T}$ a normalizing constant. We establish that the polymer measure gives a macroscopic mass to a typical path as $T \to \infty$. The mass grows to 1 as $\frac{\beta^2}{\kappa} \to \infty$, giving a rigorous approach to the polymer localization. This is done by considering the overlap between two independent samples drawn under the Gibbs measure $\mu^x_{\kappa,\beta,T}$, which can be estimated by the integration by parts formula for the Gaussian environment. The talk is based on joint work with Francis Comets. (Received February 16, 2016)

1119-60-260 **Yaozhong Hu*** (yhu@ku.edu) and **Khoa Le**.
Density of parabolic Anderson field.
Preliminary report.

Let u satisfy the stochastic heat equation $\frac{\partial}{\partial t}u = \frac{1}{2}\Delta u + u\dot{W}$, where Δ is the Laplacian and W is a general Gaussian noise. It is known that under certain condition, the probability law of $u(t,x)$ has a density with respect to Lebesgue measure. We shall study some asymptotic properties of this density. (Received February 17, 2016)

65 ► Numerical analysis

1119-65-104 **Jennifer L Schei*** (jlschei@lanl.gov) and **Christopher D Tomkins**. *Comparison of calibration targets used to infer radiographic spot size.*

Robust radiographic image reconstruction is dependent on the ability to accurately model the radiographic system physics. The x-ray spot size impinging on the object of interest can affect the resulting image resolution such that smaller spots allow for the resolution of finer features. Accurately measuring the source spot size allows for more accurate image reconstruction and information extraction. Several different targets have been utilized to measure the source spot, each with theoretical strengths and weaknesses. We compared the performance of six different targets used to measure the source spot size: the air force target (AFT), circular resolution target (CRT), radiographic grid, rolled edge (RE), rolled L (RL), and Tungsten ball. We found that the AFT, CRT, and Tungsten ball inferred spot sizes within 3% median difference of each other. The grid inferred spot sizes 6% larger than the other three targets, and the RE and RL inferred spot sizes approximately 10% larger. The RE and RL did not resolve the high frequency features as well as the other targets. Using targets that accurately measure the source spot size can improve image reconstruction and feature extraction, as well as reduce the number of pre-shot measurements. (Received February 10, 2016)

68 ► Computer science

1119-68-229 **James L Carroll*** (jlcarroll@lanl.gov). *Radiographic assessment from static object measurements using a sensitivity study.*

One approach to solving the inverse problem from a given radiograph is the forward modeling approach (sometimes called analysis by synthesis). In this presentation we explore the task of determining uncertainties in a given radiographic system, using radiographs of known characterization objects. Uncertainties could then be assessed by reconstructing the object from the radiograph, and then comparing the reconstruction with the known features of the object. However, another approach would involve performing a sensitivity study on the radiograph. We show that the forward modeling technique for solving the inverse problem is especially amenable to the use of sensitivity studies. This approach has several potential advantages, which we will demonstrate. (Received February 16, 2016)

70 ► Mechanics of particles and systems

1119-70-64 **Martin M Schauer*** (schauer@lanl.gov), **William T Buttler**, **Shabnam Monfared**, **Daniel Sorenson**, **Daniel Frayer**, **Brandon Lalone**, **Gerald Stevens** and **William Turley**. *Particle size distributions from angular light scattering data.*

The angular intensity distribution of light scattered from a particle is strongly dependent on the size of that particle and can be calculated using the solution to Maxwell's equations due to Gustav Mie. The angular intensity distribution of light scattered from a collection of particles with different sizes will be the sum of the contributions from each particle size weighted by the abundance of particles in that size range. This problem is not uniquely invertible: that is, different distributions of particle sizes can result in the same angular light intensity distribution. We report here on measurements of size distributions for particles ejected from tin target surfaces subjected to explosively-driven shock waves. In this work a least-squares method was used to extract the size distribution from the light scattering pattern with constraints on the size and form of the distribution provided by data from optical holography experiments. I will show the results of these experiments, in particular as to how they relate to results of other measurements and how the surface features on the tin targets influence the size distribution. (Received February 05, 2016)

81 ► Quantum theory

1119-81-94 **Marcel Bischoff*** (marcel.bischoff@vanderbilt.edu), Vanderbilt University, Department of Mathematics, 1326 Stevenson Center, Nashville, TN 37203. *Conformal nets and unitary fusion categories.* Preliminary report.

Completely rational conformal nets axiomatize rational chiral conformal field theory using von Neumann algebras and the representation category $\mathrm{Rep}(\mathcal{A})$ of such a net $\mathcal{A}$ is a unitary modular tensor category by Kawahigashi, Longo and Müger. We discuss the structure and examples of conformal nets, where $\mathrm{Rep}(\mathcal{A})$ is braided equivalent

to the Drinfeld center $Z(\mathcal{F})$ of a unitary fusion category $\mathcal{F}$. In this case, $\mathcal{F}$ physically arises from $\mathcal{A}$. Namely, $\mathcal{F}$ is contained in a certain 2-category associated with Rep($\mathcal{A}$) (Ocneanu's maximal atlas) "containing all fusion categories related to Rep($\mathcal{A}$)", which classifies certain defects of full conformal nets on Minkowski space associated with $\mathcal{A}$. (Received February 09, 2016)

1119-81-105 **Daniel Bump*** (bump@math.stanford.edu), Department of Mathematics, Stanford Building 380, Stanford, CA 95305-2125. *From Whittaker functions to Quantum Groups.*

This talk has connections with both number theory and mathematical physics. *Weyl group multiple Dirichlet series*, whose coefficients involve Gauss sums and whose groups of functional equations are Weyl groups have applications in number theory. They can be studied as Whittaker functions of Eisenstein series on metaplectic groups. We will focus on the Whittaker functions on the n-fold metaplectic covers of $GL(r)$ over a p-adic field. These have remarkable properties that can be proved using difficult combinatorial arguments but which suggest a connection with quantum groups. To investigate the implications of this we will focus on the Whittaker functions on the n-fold metaplectic covers of $GL(r)$ over a p-adic field. In 2012, Brubaker, Bump, Friedberg, Chinta and Gunnells showed that these Whittaker functions could be expressed as partition functions of statistical mechanical systems similar to the well-known 6-vertex or ice-type models. Recently Buciumas, Brubaker and Bump found a Yang-Baxter equation for this "metaplectic ice" and related it to the known R-matrix of the quantum affine Lie superalgebra $\mathfrak{gl}(n|1)$. (Received February 10, 2016)

1119-81-192 **Samuel J. Lomonaco*** (lomonaco@umbc.edu), University of Maryland Baltimore County, CSEE Dept., 1000 Hilltop Circle, Baltimore, MD 21250. *Quantum logic revisited.* Preliminary report.

We propose an approach to quantum logic not based on distributed lattices. (Received February 15, 2016)

82 ► Statistical mechanics, structure of matter

1119-82-95 **Zhenghan Wang*** (zhenghwa@microsoft.com), Microsoft Station Q, UC Santa Barbara, Santa Barbara, CA 93106. *Bulk-edge Correspondence in 2D Topological Phases of Matter.* Preliminary report.

A 2D topological phase of matter is modelled in the bulk by a unitary modular category, while the edge theory of a 2D topological phase is a conformal field theory. We will discuss how to classify all conformal field theories with the same bulk. This is a preliminary report. (Received February 09, 2016)

1119-82-135 **Robert Owczarek*** (rowczare@unm.edu), 505 Oppenheimer #320, Los Alamos, NM 87544. *On topology, geometry, and condensed matter.* Preliminary report.

There is increasing understanding of the role of topology and geometry in the description of condensed matter systems. I will talk about some applications of topology and geometry in such systems with the main example of superfluid helium. (Received February 13, 2016)

83 ► Relativity and gravitational theory

1119-83-156 **Jerzy Kocik*** (jkocik@siu.edu), Department of Mathematics, Southern illinois University, Mail Stop 4408, Carbondale, IL 62901. *Celestial sphere, spinors and relativistic composition of velocities.*

The geometric method of velocity composition obtained from the analysis of the transformations of the celestial sphere is revisited and summarized in terms of group homeomorphisms. In particular, it is contrasted with the seemingly similar "spinor–celestial sphere" correspondence popularized by R. Penrose. (Received February 14, 2016)

85 ► Astronomy and astrophysics

1119-85-25 **Hanna E. Makaruk*** (hanna_m@lanl.gov), Apied Modern Physics Group, P-21, MS T080, Los Alamos National Laboratory, Los Alamos, NM 87-545, and **James R. Langenbrunner**. *Nuclear fusion –study of a semi-empirical equation.* Preliminary report.

Nuclear fusion of two heavy isotopes of hydrogen: deuterium and tritium is the reaction supplying energy to the Main Sequence stars, including our Sun. It is also experimentally investigated at National Ignition Facility (US)

and is going to be investigated at proposed High Power Laser Energy Research (HiPER)(Europe) for a possibility of becoming an energy source on Earth. A semi-empirical equation describing the efficiency of this reaction as a function of kinetic energy of the reaction components is presented, analytically solved, and solutions behavior is investigated. This solution may potentially help in understanding the equilibrium conditions inside the stars as well as in optimizing conditions for the future controlled fusion on Earth. (Received January 15, 2016)

90 ► Operations research, mathematical programming

1119-90-31 **Shafiu Jibrin***, Department of Mathematics & Statistics, Northern Arizona University, PO Box 5717, Flagstaff, AZ 86011-5717. *Comparing search directions in infeasible Newton's Method for Weighted Analytic Center for Linear Matrix Inequalities.*

We study different search directions for Infeasible Newton's method in computing the weighted analytic center for linear matrix inequalities. The search directions methods considered are the ZY, ZY+YZ, Z^{-1} and NT methods that have been used in the more general problem of semidefinite programming. Our numerical results indicate that the ZY method converges more rapidly and it handles weights better compared to the other methods when some of the weights are very large relative to the other weights. This is followed by ZY+YZ, then NT and then Z^{-1} methods. This contrasts with what is known in semidefinite programming, where ZY+YZ is found to be more efficient than the other methods. (Received January 24, 2016)

1119-90-114 **Kaie Kubjas** and **Elina Robeva*** (erobeva@gmail.com), 150 Panoramic Way, Berkeley, CA 94704, and **Richard Z Robinson**. *Positive Semidefinite Rank and Nested Spectrahedra.*

The set of matrices of given positive semidefinite rank is semialgebraic. In this work we study its geometry and in small cases we describe its boundary. For general psd rank we give a conjecture for its boundary and for its semialgebraic description. Our proof techniques are based on studying nested spectrahedra and spectrahedral shadows. (Received February 11, 2016)

92 ► Biology and other natural sciences

1119-92-59 **Chris J Myers*** (myers@ece.utah.edu), 50 S. Central Campus Dr., Rm. 3280, Salt Lake City, UT 84112. *Efficient methods of abstraction of Stochastic genetic circuit models.*

Researchers are beginning to be able to engineer synthetic genetic circuits for a range of applications in the environmental, medical, and energy domains. Crucial to the success of these efforts is the development of efficient methods and tools for the analysis of these genetic circuit designs. Genetic circuits are composed of very noisy components making their behavior stochastic in nature. Exact analysis methods are limited to very small circuits with no major time scale separations. Our research applies automatic abstraction techniques to simplify models of these genetic circuits making analysis more efficient while retaining important phenotypic behavior. This talk will present these methods, as well as their application to several interesting synthetic genetic circuits designs. (Received February 03, 2016)

1119-92-87 **Matthew D Johnston*** (matthew.johnston@sjsu.edu), One Washington Square, Duncan Hall 215, San Jose, CA 95192. *Network approaches to the dynamics of biochemical reaction systems.*

In the emerging field of systems biology, networks of biochemical interactions are often modeled using systems of ordinary differential equations. Classical analysis approaches such as numerical simulation and bifurcation analysis, however, are hindered by: (a) the size of the systems; (b) the abundant nonlinearities; and (c) the typically unknown parameter values. Network-based analysis methods have consequently become popular due to their ability to scale efficiently to large problems, identify recurring motifs and patterns, and, surprisingly, identify parameter-independent conditions for many classical dynamical properties.

In this talk, I will introduce and explain some recent applications of network-based approaches to the analysis of biochemical reaction systems. An emphasis will be placed on recurring motifs such as enzymatic cascades and signaling pathways. Some recent work highlighting alternating network representations of biochemical reaction systems will also be introduced. (Received February 09, 2016)

1119-92-210 **Mark K Transtrum*** (mktranstrum@byu.edu), N241 ESC, Provo, UT 84602. *Revealing emergent biological structures through model reduction.*

Mathematical models of biological systems often have many parameters. Available measurements are usually insufficient to accurately constrain these parameters. I discuss a new method for removing irrelevant parameters from complex biological models known as the Manifold Boundary Approximation Method. The method employs an information geometric approach by interpreting the Fisher Information Matrix as a Riemannian metric on the space of all possible models with parameters as coordinates. This interpretation recasts the model reduction problem as a manifold approximation problem. The coarse-grained models vividly reveal the emergent control mechanisms (e.g. feedback loops) that govern the system's behavior but remain expressed in terms of the microscopic parameters (i.e., no black boxes). I demonstrate with several examples. (Received February 15, 2016)

1119-92-225 **Laura F Strube*** (strube@math.utah.edu), University of Utah, Mathematics Department, 155 S 1400 E, Room 233, Salt Lake City, UT 84112-0090, and **Frederick R Adler** (adler@math.utah.edu), University of Utah, Mathematics Department, 155 S 1400 E, Room 233, Salt Lake City, UT 84112-0090. *A mathematical model of translational regulation by the integrated stress response.* Preliminary report.

The Integrated Stress Response (ISR) is a protective mechanism that is activated in response to a wide variety of intracellular stresses. Cells use the ISR to temporarily attenuate canonical translation while simultaneously upregulating the translation of stress response genes via a non-canonical pathway. The key proteins in this system are the eukaryotic initiation factor eIF2α, its recycler eIF2B, a stress-detecting eIF2α kinase, and the transcription factor ATF4. We describe a non-linear ODE model of ISR-induced translation regulation that describes canonical translation and ATF4 translation as a function of stress level. We show that the model exhibits three qualitative behaviors corresponding to degree of stress. When stress levels are low, the system acts as a filter and maintains general translation while exhibiting minimal translation of ATF4. Under intermediate levels of stress, the system produces ATF4 protein while reducing general translation. When stress levels are high both general translation and ATF4 translation fail. This model demonstrates that the stochastic mechanism underlying ATF4 translation allows the cell to differentially regulate two translation mechanisms despite their reliance on the same initiation factors. (Received February 16, 2016)

1119-92-258 **A Hoffmann***, UCLA, Institute for Quantitative and Computational, Los Angeles, CA 90095. *Understanding how cells respond to pathogens - mathematical modeling of a biological system.*

All cells are capable of sensing pathogen and they respond dramatically and appropriately to defend themselves, and communicate with neighbors and the system-wide mine system. Constrained by detailed experimental work, we have developed a mathematical model of an intra-cellular molecular network that is critical for the cell's pathogen responses. Numerous iterations have provided new insights, and allowed for virtual experimentation and evaluation of "systems properties". A key hypothesis of this work is that dynamic control of the network constitutes a dynamical code that allows one pathway to convey multiple and distinct information about the environment and direct stimulus-specific gene expression responses. I will discuss how mathematical modeling and analysis tools have aided our understanding on how cells respond appropriately to a variety of environmental stimuli. (Received February 17, 2016)

93 ► Systems theory; control

1119-93-14 **Paul A Fuhrmann*** (fuhrmannbgu@gmail.com), Professsor Paul A Fuhrmann, Department of Mathematics, Ben Gurion University of the Negev, Beer Sheva, Israel. *Partial state reachability of linear systems connected in series.* Preliminary report.

Abstract: In this talk, we describe a solution of the problem of partial state reachability in the case of series connection of linear systems. P.A. Fuhrmann and U. Helmke, *The Mathematics of Networks of Linear Systems*, Springer, New York, 2015, serves as reference to the background information and terminology. Let Σ_i, be the shift realization associated with the right coprime factorization $G_i = N_i D_i^{-1}$, $i = 1, \dots, q$. The series connection $\Sigma_1 \wedge \cdots \wedge \Sigma_i$ with transfer function $G_{1,\dots,i} = G_i \cdots G_1 = N_i D_i^{-1} \cdots N_1 D_1^{-1}$, may not be reachable due to possible zero-pole cancellations. We say the series connection $\Sigma_1 \wedge \cdots \wedge \Sigma_q$ is $(i_1, i_2, \dots, i_r)$-partial state reachable if, for all $1 \leq j \leq r$, the series connection $\Sigma_{i_j} \wedge \Sigma_{1,\dots,i_j-1}$ is reachable. Letting $N_{1,\dots,i} D^{-1}_{1,\dots,i}$ be a right coprime factorization of $G_{1,\dots,i}$, this is the case if and only if, for all $1 \leq j \leq r$, the polynomial matrices $D_{i_j}, N_{1,\dots,i_j-1}$

are left coprime. This is the basis for a recursive algorithm that produces an open loop controller. (Received December 07, 2015)

1119-93-236 **Vasu N Chetty*** (chettyv@byu.edu). *Identification of dynamical structure functions: a systems theoretic approach to network reconstruction.*

Linear systems theory details different mathematical representations of systems which define the same behavior, but different notions of structure. For example, the transfer function, which captures the input-output behavior of a system with little structural information, and the state space representation, which captures all structural information. Thus, reconstruction of a system is representation-dependent. Network reconstruction of any representation beyond the transfer function is ill-posed, meaning that a priori information is required in order to determine the internal structure. The minimum amount of information required to ensure well-posedness is known as the cost of reconstruction.

Although the state space representation of a system contains more structural information about a system than its transfer function, the associated cost of reconstruction is very high. Many algorithms attempt to avoid this cost by making assumptions about the system that may not always be reasonable, such as parsimony. In this work, we discuss the dynamical structure function, which is a partial structure representation of a system that contains more structural information than a system's transfer function and has a lower cost of reconstruction than the state space representation. (Received February 16, 2016)

94 ► Information and communication, circuits

1119-94-163 **Vladimir D Tonchev*** (tonchev@mtu.edu), 1400 Townsend Drive, Houghton, MI 49931. *The weight distribution of the self-dual [128,64] polarity design code.*

The weight distribution of the binary self-dual [128,64] code being the extended code of the code spanned by the incidence vectors of the blocks of the polarity design in PG(6,2) is computed. (Received February 15, 2016)

97 ► Mathematics education

1119-97-15 **Terry L. Barron*** (tbarron@ggc.edu), Georgia Gwinnett College, School of Science and Technology, 1000 University Center Lane, Lawrenceville, GA 30043. *Engaging the introverted learner: the Gillespie-Barron Introverted Learner Model.*

Introverted learners typically do not participate in traditional lecture-type classes. Extroverted, gregarious students usually answer questions even when engaging teachers try everything possible to actively involve introverted learners. Introverted learners are typically deep thinkers and excellent problem solvers who will effective express their knowledge if educators use appropriate engaging techniques. The Flipped Classroom is a proven method of engaging students that results in deeper learning and higher achievement. Students seek feedback and introverted learners especially prefer one-on-one feedback. When educators use the Flipped Classroom pedagogy, they have time to talk with at least a few students individually each class while others work board problems, work in groups, etc. The Gillespie-Barron Introverted Learner Model (G-BILM) couples developmental/progress counseling and Flipped Classroom pedagogy in an innovative, dynamic, cyclic illustration of how introverted students process information, learn and seek feedback. The G-BILM focuses on engaging introverted learners using methods that supplement their personality traits; directly contributing to higher achievement. The model sets the foundation for educators at all levels to engage introverted learners. (Received December 22, 2015)

FARGO, ND, April 16–17, 2016

Abstracts of the 1120th Meeting.

00 ► General

1120-00-32 **Cheng Cheng*** (cheng.cheng@knights.ucf.edu), 3919 Whittington DR, Orlando, FL 32817. *Spatially distributed sampling and reconstruction.*

A spatially distributed system contains a large amount of agents with limited sensing, data processing, and communication capabilities. We introduce a graph structure for such distributed sampling and reconstruction systems (DSRS) by coupling agents in a spatially distributed system with innovative positions of signals. A fundamental problem in sampling theory is the robustness of signal reconstruction in the presence of sampling noises. For a distributed sampling and reconstruction system, the robustness could be reduced to the stability of its sensing matrix. We split a distributed sampling and reconstruction system into a family of overlapping smaller subsystems, and we show that the stability of the sensing matrix holds if and only if its quasi-restrictions to those subsystems have uniform stability. This new stability criterion could be pivotal for the design of a robust distributed sampling and reconstruction system against supplement, replacement and impairment of agents. We also propose an exponentially convergent distributed algorithm for signal reconstruction, that provides a suboptimal approximation to the original signal in the presence of bounded sampling noises. (Received January 26, 2016)

05 ► Combinatorics

1120-05-8 **Jia Huang*** (huangj2@unk.edu), Department of Mathematics and Statistics, Kearney, NE 68849. *Hecke algebras with independent parameters.*

We study the Hecke algebra $\mathcal{H}(\mathbf{q})$ over an arbitrary field $\mathbb{F}$ of a Coxeter system (W, S) with independent parameters $\mathbf{q} = (q_s \in \mathbb{F} : s \in S)$ for all generators. This algebra always has a spanning set indexed by the Coxeter group W, which is indeed a basis if and only if every pair of generators joined by an odd edge in the Coxeter diagram receive the same parameter. In general, the dimension of $\mathcal{H}(\mathbf{q})$ could be as small as 1. We construct a basis for $\mathcal{H}(\mathbf{q})$ when (W, S) is simply laced. We also characterize when $\mathcal{H}(\mathbf{q})$ is commutative, which happens only if the Coxeter diagram of (W, S) is simply laced and bipartite. In particular, for type A we obtain a tower of semisimple commutative algebras whose dimensions are the Fibonacci numbers. We show that the representation theory of these algebras has some features in analogy/connection with the representation theory of the symmetric groups and the 0-Hecke algebras. (Received December 14, 2015)

1120-05-24 **Kirsten Hogenson*** (kahogens@iastate.edu) and **Ryan R Martin** (rymartin@iastate.edu). *A random version of the r-fork-free theorem.*

Let $\mathcal{P}(n)$ denote the set of all subsets of [n] and let $\mathcal{P}(n,p)$ be the set obtained from $\mathcal{P}(n)$ by selecting elements independently at random with probability p. The r-fork poset is the family of distinct sets $F, G_1, ..., G_r$ such that $F \subset G_i$ for all i. De Bonis and Katona showed that, for fixed r, any (r+1)-fork-free family in $\mathcal{P}(n)$ has size at most $(1+o(1))\binom{n}{\lfloor n/2 \rfloor}$. In this talk, I will discuss a similar result for (r+1)-fork-free families in $\mathcal{P}(n,p)$. In particular, if $pn \to \infty$, then with high probability, the largest (r+1)-fork-free set in $\mathcal{P}(n,p)$ has size at most $(1+o(1))p\binom{n}{\lfloor n/2 \rfloor}$. This result is influenced by the work of Balogh, Mycroft and Treglown, who proved a random version of Sperner's theorem using the hypergraph container method. (Received January 20, 2016)

1120-05-34 **Zhanar Berikkyzy** and **Ryan R. Martin*** (rymartin@iastate.edu), 396 Carver Hall, Department of Mathematics, Iowa State University, Ames, IA 50011, and **Chelsea Peck**. *On the edit distance for powers of cycles.*

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 January 28, 2016)

1120-05-35 **Matthew Jenssen** and **Jozef Skokan*** (jozef@member.ams.org), Department of Mathematics, London School of Economics, Houghton Street, London, WC2A 2AE, United Kingdom. *The multicolour Ramsey number of a long odd cycle.*

For a graph G, the k-colour Ramsey number $R_k(G)$ is the least integer N such that every k-colouring of the edges of the complete graph K_N contains a monochromatic copy of G. Let C_n denote the cycle on n vertices. We show that for fixed $k \geq 3$ and n odd and sufficiently large,

$$R_k(C_n) = 2^{k-1}(n-1)+1.$$

This generalises a result of Kohayakawa, Simonovits and Skokan and resolves a conjecture of Bondy and Erdős for large n. We also establish a surprising correspondence between extremal k-colourings for this problem and perfect matchings in the hypercube Q_k. This allows us to in fact prove a stability-type generalisation of the above. The proof is analytic in nature, the first step of which is to use the Regularity Lemma to relate this problem in Ramsey theory to one in convex optimisation. (Received January 28, 2016)

1120-05-52 **David Galvin*** (dgalvin1@nd.edu). *Maximizing colorings of a regular graph — results and questions.*

Alon speculated in 1991 that among all d-regular graphs, the ones that admit the most independent sets are the disjoint unions of complete bipartite graphs; this speculation was confirmed by Kahn in 2001 (for bipartite graphs) and Zhao in 2011 (in general).

With Tetali in 2004 we raised the more general question: for each H, which d-regular graphs admit the most H-colourings (adjacency-preserving maps to H)? There has been some recent progress — Sernau has a nice construction showing that a complete answer will be quite involved, and Cohen, Perkins and Tetali have settled the case when H is the Widom-Rowlinson graph (the completely looped path on three vertices).

In this talk I'll survey what we know and don't know about this question. (Received February 06, 2016)

1120-05-54 **Theodore Molla** and **Michael Santana***, University of Illinois at Urbana-Champaign, and **Elyse Yeager**, University of British Columbia. *Refining a mixed result on cycles and chorded cycles.* Preliminary report.

In 1963, Corrádi and Hajnal proved a conjecture of Erdős showing that every graph G on at least $3k$ vertices with $\delta(G) \geq 2k$ contains k disjoint cycles. A chorded cycle analogue was proven by Finkel in 2008, who showed that every graph G on at least $4k$ vertices with $\delta(G) \geq 3k$ contains k disjoint chorded cycles. Both results are best possible, leading Kierstead, Kostochka, and Yeager to characterize the sharpness examples to Corrádi-Hajnal, and Molla, Santana, and Yeager to characterize the sharpness examples to Finkel's result.

In 2010, Chiba, Fujita, Gao, and Li proved a mixed version of the aforementioned results. In particular, they show that for integers r and s with $r+s \geq 1$, every graph G on at least $3r+4s$ vertices with $\delta(G) \geq 2r+3s$ contains $r+s$ disjoint cycles, s of which are chorded. In this talk we will discuss a characterization of the sharpness examples to this statement. This result will in turn provide a transition between the results of Kierstead et al. and Molla et al. (Received February 06, 2016)

1120-05-58 **Laura Escobar*** (lescobar@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 W. Green Street, Urbana, IL 61801, and **Karola Mészáros**. *Toric matrix Schubert varieties.*

Start with a permutation matrix π and consider all matrices that can be obtained from π by taking downward row operations and rightward column operations; the closure of this set gives the matrix Schubert variety X_π. Such a variety can be written as $X_\pi = Y_\pi \times \mathbb{C}^q$ (where q is maximal). We characterize when Y_π is toric (with respect to a $2n-1$-dimensional torus) and study the associated polytope of its projectivization. We construct regular triangulations of these polytopes which we show are geometric realizations of a family of subword complexes. Based on joint work with Karola Mészáros. (Received February 08, 2016)

1120-05-65 **Lindsay A Erickson*** (lindsay.erickson@augie.edu), 2001 S Summit Avenue, FSC #383, Sioux Falls, SD 57197, and **Bryce Allen Christopherson**. *Edge Nim on trees and its surprising connections to commutative algebra.*

Edge Nim is a combinatorial game played on finite regular graphs with positive, integrally weighted edges. Two players alternately begin from a fixed starting vertex and move to an adjacent vertex, decreasing the weight of the incident edge to a strictly non-negative integer as they travel across it. The game ends when a player is confronted by a position where no incident edge has a nonzero weight (or, that is to say, when the player is

unable to move). In the normal form, this player loses, and in the misére form, this player wins. In all previous literature, methods employed for finding solutions were limited to graph theoretic structural arguments and Nim sums. We present an alternate, algebraic approach to edge Nim on graphs for both the normal and misére forms, revealing not only a new method for attacking combinatorial games, but a complete, computationally inexpensive solution to Nim on tree graphs. This approach also suggests that the solution to Nim on trees may be a component of a larger algebraic structure resolving Nim on all graphs. (Received February 12, 2016)

1120-05-66 **Oliver Pechenik*** (pecheni2@illinois.edu) and **Alexander Yong**. *Puzzles and equivariant K-theory of Grassmannians.*

The cohomology of the Grassmannian has a basis given by Schubert classes. The structure coefficients of this ring are the celebrated Littlewood-Richardson coefficients, and are calculated by any of the Littlewood-Richardson rules. This story has been extended to K-theory by A. Buch (2002) and to torus-equivariant cohomology by A. Knutson-T. Tao (2003). It is natural to unify these theories via a combinatorial rule for structure coefficients in equivariant K-theory. In 2005, A. Knutson-R. Vakil used puzzles to conjecture such a rule. Recently we proved the first combinatorial rule for these coefficients. Using our new rule, we construct a counterexample to the Knutson-Vakil conjecture and prove a mild correction to it. (Received February 09, 2016)

1120-05-77 **David Galvin*** (dgalvin1@nd.edu). *Long-range influence in colorings of the cube.*

Choose an independent set uniformly in the d-dimensional hypercube. The probability that a particular vertex, say $v_1 = (1, \ldots, 1)$, is in the independent set is roughly $1/4$ (though this is far from obvious). We also know that there is long-range influence: if we condition on $(0, \ldots, 0)$ being in the independent set, then the probability of v_1 being in the set changes dramatically, dropping to nearly 0 if d is odd and jumping to nearly $1/2$ if d is even.

Similar long-range influence results can be established if "independent set" is replaced by "proper q-colouring". I'll discuss these results, and highlight a question relating to mixing time of Glauber dynamics for sampling proper q-colourings of the cube, which we can resolve for $q = 3$ but remains open for $q > 3$. Partly joint work with John Engbers. (Received February 12, 2016)

1120-05-81 **Jennifer Diemunsch** and **Stephen Hartke** (sogol.jahanbekam@ucdenver.edu), Denver, CO 80217, **Sogol Jahanbekam*** (sogol.jahanbekam@ucdenver.edu), CO , and **Brent Thomas**. *Chromatic number of squares of planar graphs.*

In 1977 Wegner conjectured that the square of any subcubic planar graph is 7-colorable. In this talk we use discharging method and computations to give a proof to this conjecture. (Received February 13, 2016)

1120-05-93 **Péter Csikvári*** (peter.csikvari@gmail.com). *Extremal regular graphs.* Preliminary report.

Let $P(G)$ be a graph parameter which has size roughly $c^{v(G)}$, where $v(G)$ is the number of vertices of a graph G. Examples include the number of spanning trees, number of (perfect) matchings or the number of homomorphisms of G into a fixed graph H. We will be interested in the following type of questions: what is $\sup P(G)^{1/v(G)}$ or $\inf P(G)^{1/v(G)}$ among d–regular (bipartite) graphs. In many (but far from all) instances the extremal graph is one of the following three graphs: the complete graph K_{d+1}, the complete bipartite graph $K_{d,d}$, and perhaps surprisingly, the infinite d–regular tree $\mathbb{T}_d$. We will be especially interested in the latter case as this requires some intricate ideas like combinations of extremal and graph limit theoretical arguments.

This talk will be a survey talk based on many papers. Some of the papers are joint with Emma Cohen, Will Perkins and Prasad Tetali. (Received February 15, 2016)

1120-05-96 **John Engbers*** (john.engbers@marquette.edu), Milwaukee, WI 53201. *Extremal H-colorings of graphs with fixed minimum degree.*

Given a family of graphs, which graph in the family has the most number of H-colorings (homomorphisms to H, or adjacency-preserving maps to H)? We will focus on the family of n-vertex graphs with fixed minimum degree δ. Galvin, and then Cutler and Radcliffe, fully answered this question when H is chosen so that H-colorings correspond to independent sets. For all other choices of H, answers are known for $\delta = 1$ and (when n is large) for $\delta = 2$. For $\delta > 2$, much less is known.

Here we investigate what happens when we impose various connectedness requirements within the family. This naturally leads to considering the family of trees (where Sidorenko provided a complete answer), 2-connected graphs (which is joint work with Galvin), and connected graphs with minimum degree δ; in these families, for all non-regular H and n sufficiently large the unique maximizing graph is $K_{\delta,n-\delta}$. Numerous open questions remain. (Received February 15, 2016)

1120-05-98 **Kyungyong Lee*** (klee24@unl.edu), **Li Li** and **Nicholas A Loehr**. *A combinatorial approach to the symmetry of q,t-Catalan numbers.*

The *q,t-Catalan numbers* $C_n(q,t)$ are polynomials in q and t that reduce to the ordinary Catalan numbers when $q = t = 1$. These polynomials have important connections to representation theory, algebraic geometry, and symmetric functions. Haglund and Haiman discovered combinatorial formulas for $C_n(q,t)$ as weighted sums of Dyck paths (or equivalently, integer partitions contained in a staircase shape). This paper undertakes a combinatorial investigation of the joint symmetry property $C_n(q,t) = C_n(t,q)$. We conjecture some structural decompositions of Dyck objects into "mutually opposite" subcollections that lead to a bijective explanation of joint symmetry in certain cases. A key new idea is the construction of infinite chains of partitions that are independent of n but induce the joint symmetry for all n simultaneously. Using these methods, we prove combinatorially that for $0 \leq k \leq 9$ and all n, the terms in $C_n(q,t)$ of total degree $\binom{n}{2} - k$ have the required symmetry property. (Received February 16, 2016)

1120-05-102 **Charles Brittenham**, **Andrew Carroll** and **T. Kyle Petersen***, Department of Mathematical Sciences, 2320 N. Kenmore, Chicago, IL 60614, and **Connor Thomas**. *Unimodality the hard way.*

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 February 16, 2016)

1120-05-106 **Travis Scrimshaw*** (tscrimsh@umn.edu), School of Mathematics, 127 Vincent Hall, 206 Church Street S.E., Minneapolis, MN 55455, and **Ben Salisbury** (ben.salisbury@cmich.edu), Central Michigan University, Pearce Hall 214, Mount Pleasant, MI 48859. *Crystals, rigged configurations, and the star involution.*

Highest weight crystals describe, combinatorially, a basis for highest weight representations. The crystal $B(\infty)$ corresponds to the lower half of the quantum group. We give a model for highest weight crystals and $B(\infty)$ using rigged configurations. Moreover, we describe the $*$-involution on rigged configurations and the $*$-crystal operators. (Received February 16, 2016)

1120-05-114 **Laura Felicia Matusevich*** (laura@math.tamu.edu), Department of Mathematics, Texas A&M University, Mailstop 3368, College Station, TX 77843-3368. *Decompositions of binomial ideals.*

A binomial is a polynomial (in several commuting variables) with at most two terms. Binomial ideals, ideals generated by binomials, turn out to have a very rich combinatorial structure. I will illustrate this by showing different ways of decomposing a binomial ideal as an intersection of (simpler) binomial ideals. How we define "simpler" is very important: the more combinatorial requirements we ask for, the more challenging the computation becomes. The surprising fact that meaningful and effectively computable binomial decompositions exist is due to Eisenbud and Sturmfels. I will recall their results, and then survey the combinatorial progress that has occurred in the last ten years. (Received February 17, 2016)

1120-05-116 **James Haglund**, **Jeffrey Remmel**, **Brendon Rhoades*** (bprhoades@math.ucsd.edu) and **Andrew Timothy Wilson**. *Invariant ideals and the Delta conjecture.*

The ring of polynomials $\mathbb{Q}[x_1, \ldots, x_n]$ carries an action of the symmetric group S_n by subscript permutation. The ideal I generated by invariant polynomials with vanishing constant term, as well as the associated coinvariant ring $\mathbb{Q}[x_1, \ldots, x_n]/I$, enjoy many remarkable combinatorial properties. We will pose the problem of finding a generalization of the ideal I which extends these properties to the context of the recent *Delta conjecture* of Haglund, Remmel, and Wilson. (Received February 17, 2016)

1120-05-136 **Tri Lai*** (tmlai@ima.umn.edu), 207 Church Street SE, 306 Lind Hall, Minneapolis, MN 55455. *Double Aztec Rectangles.*

We investigate the connection between lozenge tilings and domino tilings by introducing the "*double Aztec rectangles*", a new family of regions obtained by attaching two different Aztec rectangles.

We prove a simple product formula for the generating function of domino tilings of a double Aztec rectangle, which involves the statistics as in the Aztec diamond theorem by Elkies, Kuperberg, Larsen, and Propp. Moreover, we consider the connection between the generating function and MacMahon's q-enumeration of plane partitions fitting in a given box. (Received February 18, 2016)

1120-05-138 **Noga Alon**, **Alexandr Kostochka**, **Benjamin Reiniger*** (reiniger@ryerson.ca), **Douglas West** and **Xuding Zhu**. *Coloring, sparseness, and girth via augmented trees.*

An r-augmented tree is a rooted tree plus r edges added from each leaf to ancestors. For $d, g, r \in \mathbb{N}$, we construct a bipartite r-augmented complete d-ary tree having girth at least g. The height of such trees must grow extremely rapidly in terms of the girth.

Using the resulting graphs, we construct sparse non-k-choosable bipartite graphs, showing that maximum average degree at most $2(k-1)$ is a sharp sufficient condition for k-choosability in bipartite graphs, even when requiring large girth. We also give a new simple construction of non-k-colorable graphs and hypergraphs with any girth g. (Received February 19, 2016)

1120-05-146 **Tri Lai** (tmlai@ima.umn.edu) and **Gregg Musiker*** (musiker@math.umn.edu). *Beyond Aztec Castles: toric cascades in the dP3 quiver.*

Given one of an infinite class of supersymmetric quiver gauge theories, string theorists can associate a corresponding toric variety (which is a Calabi-Yau 3-fold) as well as an associated combinatorial model known as a brane tiling. In combinatorial language, a brane tiling is a bipartite graph on a torus and its perfect matchings are of interest to both combinatorialists and physicists alike. A cluster algebra may also be associated to such quivers and in this paper we study the generators of this algebra, known as cluster variables, for the quiver associated to the cone over the del Pezzo surface dP3. In particular, mutation sequences involving mutations exclusively at vertices with two in-coming arrows and two out-going arrows are referred to as toric cascades in the string theory literature. Such toric cascades give rise to interesting discrete integrable systems on the level of cluster variable dynamics. We provide an explicit algebraic formula for all cluster variables which are reachable by toric cascades as well as a combinatorial interpretation involving perfect matchings of subgraphs of the dP3 brane tiling for these formulas in most cases. (Received February 19, 2016)

1120-05-156 **Zachary Hamaker** (patri080@umn.edu), **Adam Keilthy**, **Rebecca Patrias*** (patri080@umn.edu), **Lillian Webster**, **Yinuo Zhang** and **Shuqi Zhou**. *Shifted Hecke insertion and the K-theory of OG(n,2n+1).*

We use shifted Hecke insertion, a K-theoretic analogue of Sagan-Worley insertion, to construct symmetric function representatives for the K-theory of the orthogonal Grassmannian. These representatives are closely related to the shifted Grothendieck polynomials of Ikeda and Naruse. We then recover the K-theoretic Littlewood-Richardson rules of Clifford-Thomas-Yong and Buch-Samuel by introducing a shifted K-theoretic Poirier-Reutenauer algebra. (Received February 20, 2016)

1120-05-157 **Cara P Monical*** (cmonica2@illinois.edu), 1409 W. Green St, Urbana, IL 61801. *K-theoretic Demazure atoms and set-valued skyline diagrams.* Preliminary report.

Demazure characters and atoms are well-studied specializations of Macdonald polynomials with combinatorial descriptions in terms of semistandard skyline fillings. We study a "K-theoretic" generalization of these polynomials and give a conjectural description in terms of set-valued semistandard skyline fillings. We show that this combinatorial description provides a generalization of several known results of Demazure atoms, including a decomposition of the Grothendieck polynomial G_λ. (Received February 20, 2016)

1120-05-164 **Karen Gunderson*** (karen.gunderson@umanitoba.ca), Department of Mathematics, 420 Machray Hall, 186 Dysart Road, University of Manitoba, Winnipeg, MB R3T 2N2, Canada. *Independence of random sets in hypergraphs.*

The independence density of a countable graph, introduced by Bonato, Brown, Kemkes, and Prałat, is the probability that a subset of vertices is independent when each vertex is included independently with probability 1/2. The independence density of a countable hypergraph is defined similarly. In this talk, I will present new results on some generalizations and on the sets of real numbers that are independence densities of some countably infinite hypergraph. Joint work with P. Balister and B. Bollobás. (Received February 20, 2016)

1120-05-183 **Deepak Bal***, 1 Normal Ave, Montclair, NJ 07043, and **Patrick Bennett**. *The greedy matching algorithm in random regular hypergraphs.* Preliminary report.

A matching in a hypergraph is a collection of vertex disjoint edges. The random greedy algorithm starts with an empty matching M, and at each step inserts one edge into M, chosen uniformly at random from the set of edges that are vertex disjoint from all edges in M. In this talk we will discuss the performance of the greedy matching algorithm on the random k-uniform, r-regular hypergraph. We use the differential equations method to determine asymptotically the number of edges in the resulting matching. (Received February 21, 2016)

1120-05-189 **Andrzej Dudek*** (andrzej.dudek@wmich.edu) and **Patrick Bennett** (patrick.bennett@wmich.edu). *On the Ramsey-Turán number with small s-independence number.*

Let s be an integer, $f = f(n)$ a function, and H a graph. Define the *Ramsey-Turán number* $\mathbf{RT}_s(n, H, f)$ as the maximum number of edges in an H-free graph G of order n with $\alpha_s(G) < f$, where $\alpha_s(G)$ is the maximum number of vertices in a K_s-free induced subgraph of G. The Ramsey-Turán number attracted a considerable amount of attention and has been mainly studied for f not too much smaller than n. In this talk, we consider $\mathbf{RT}_s(n, K_t, n^\delta)$ for fixed $\delta < 1$. In particular, we show that for an arbitrarily small $\varepsilon > 0$ and $1/2 < \delta < 1$, $\mathbf{RT}_s(n, K_{s+1}, n^\delta) = \Omega(n^{1+\delta-\varepsilon})$ for all sufficiently large s. This is nearly optimal, since a trivial upper bound yields $\mathbf{RT}_s(n, K_{s+1}, n^\delta) = O(n^{1+\delta})$. Furthermore, the range of δ is as large as possible. We also discuss a phase transition of $\mathbf{RT}_s(n, K_{2s+1}, f)$ extending some recent result of Balogh, Hu and Simonovits. (Received February 21, 2016)

1120-05-199 **Anna Weigandt*** (weigndt2@illinois.edu), 1409 W. Green St, Urbana, IL 61801, and **Alexander Yong** (ayong@illinois.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 $\mathbb{Z}[x_1, x_2, \ldots]$. We suggest the "prism tableau model" for these polynomials. This alternative to earlier results directly invokes semistandard tableaux; it does so as part of a colored tableau amalgam. In the Grassmannian case, a prism tableau with colors ignored is a semistandard Young tableau. Our arguments are developed from the Gröbner geometry of matrix Schubert varieties. We also describe a new class of prism tableaux which model multidegrees of ideals associated to alternating sign matrices. (Received February 22, 2016)

1120-05-207 **Trevor McGuire*** (trevor.mcguire@ndsu.edu). *Join-preserving embeddings of discrete posets.*

The work of Dushnik and Miller in the 1940s gives us a nice way to embed posets into $\mathbb{Z}^n$, and the minimal value of n is now called the dimension of a poset. However, these embeddings do not preserve many desirable properties of posets. In this talk, we will examine one way in which we can modify the Dushnik-Miller embedding into a join-preserving embedding. The same technique may be used to preserve other properties, as well. We will discuss what properties the poset must have in order for this modification to work. (Received February 22, 2016)

1120-05-209 **Sara L Solhjem*** (sara.solhjem@ndsu.edu) and **Jessica Striker** (jessica.striker@ndsu.edu). *Semistandard Young tableaux polytopes.*

We define a new family of polytopes as the convex hull of certain $\{0, 1, -1\}$ matrices in bijection with semistandard Young tableaux. We investigate various properties of these polytopes, including their inequality descriptions, vertices, and facets. (Received February 22, 2016)

1120-05-214 **Neal Owen Bushaw*** (neal@asu.edu), **Andrzej Czygrinow** and **Jangwon Yie**. *Minimum codegree conditions for tiling by tight cycles.* Preliminary report.

We discuss recent work on tilings in 3-uniform hypergraphs. Let C be any tight cycle on $3k$ vertices. We show that for n sufficiently large and divisible by $3k$, every order n hypergraph with minimum co-degree at least $\frac{n}{2}$ contains a perfect C-tiling. A major tool in our proof is the absorption method, introduced by Rödl, Rucińksi, and Szemerédi. This is joint work with Andrzej Czygrinow and Jangwon Yie. (Received February 22, 2016)

1120-05-215 **Luke J Postle*** (lpostle@uwaterloo.ca), 200 University Ave West, Waterloo, ON N2N 3L8, Canada. *On Reed's conjecture.*

In 1998, Reed proved that the chromatic number of a graph is bounded away from its trivial upper bound, its maximum degree plus one, and towards its trivial lower bound, its clique number. Reed also conjectured that the chromatic number is at most halfway in between these two bounds. We prove that for large maximum degree, that the chromatic number is at least 1/25th in between. Joint work with Marthe Bonamy and Tom Perrett. (Received February 22, 2016)

1120-05-221 **Anna Stokke*** (a.stokke@uwinnipeg.ca), Department of Mathematics and Statistics, University of Winnipeg, Winnipeg, Manitoba R3M 3J8, Canada. *Lattice path constructions for orthosymplectic determinantal formulas.*

Characters of irreducible representations of orthosymplectic Lie algebras can be described as hybrids of symplectic Schur functions and (general linear) Schur functions involving tableaux that have both a symplectic part and a

row-strict part. I will discuss lattice path proofs for orthosymplectic Jacobi-Trudi and Giambelli formulas. This is joint work with Terry Visentin. (Received February 22, 2016)

1120-05-227 **Andrzej Czygrinow**, **Louis DeBiasio**, **Theodore Molla*** (molla@illinois.edu) and **Andrew Treglown**. *Tiling directed graphs with tournaments.* Preliminary report.

The Hajnal–Szemerédi theorem is a celebrated theorem in extremal graph theory. It states that for any integer $r \geq 1$ and any multiple n of r, if G is a graph on n vertices and $\delta(G) \geq (1-1/r)n$, then G can be partitioned into n/r vertex-disjoint copies of the complete graph on r vertices. We will discuss a very general analogue of this result for directed graphs: for any integer $r \geq 4$ and any sufficiently large multiple n of r, if G is a directed graph on n vertices and every vertex is incident to at least $2(1-1/r)n-1$ directed edges, then G can be partitioned into n/r vertex-disjoint subgraphs of size r each of which contain every tournament on r vertices. (Received February 22, 2016)

1120-05-228 **Beth Bjorkman**, **Garner Cochran**, **Wei Gao** and **Lauren Keough***, lakeough@davidson.edu, and **Rachel Kirsch**, **Mitch Phillipson**, **Danny Rorabaugh**, **Heather Smith** and **Jennifer Wise**. *The Combinatorics of RNA.* Preliminary report.

Biologically, RNA is comprised of four nucleotides: adenine, guanine, uracil, and cytosine. We can model RNA by a string of the letters A, G, U, and C. RNA often folds on itself where A may bond with U and C may bond with G. Folding of RNA results in a plane tree with each side of each edge labeled. One can generalize this model of RNA by thinking about a finite set of letters and their complements. A string is folded around a plane tree in a way that each letter may only bond to its complement. We are interested in counting certain subsets of $S(n,m)$ where $S(n,m)$ is the collection of strings of length $2n$ on an alphabet of m letters and their complements. For example, we can count the number of strings that fold around a given plane tree or the number of strings that k-foldable (where a string is k-foldable if it folds around k non-isomorphic plane trees). (Received February 22, 2016)

1120-05-231 **Florian Pfender*** (florian.pfender@ucdenver.edu) and **Bernard Lidicky**. *Inducibility of short cycles and paths.*

We determine the highest numbers of induced copies of several graphs, mostly short cycles and paths, with the help of the Flag Algebra method. (Received February 22, 2016)

1120-05-246 **Rosa C Orellana*** (rosa.c.orellana@dartmouth.edu), Mathematics Department, 6188 Kemeny Hall, Hanover, NH 03755, and **Mike Zabrocki**. *Symmetric group characters as symmetric functions.* Preliminary report.

The characters of the general linear group are symmetric functions. The irreducible characters are found by evaluating Schur polynomials at eigenvalues of matrices. In this talk I will introduce a new basis for symmetric functions such that when evaluated at the eigenvalues of a permutation matrix we get the irreducible characters of the symmetric group. This basis has as structure coefficients the stable (reduced) Kronecker coefficients.

This is joint work with Mike Zabrocki. (Received February 22, 2016)

1120-05-247 **Jessica C De Silva*** (jessica.desilva@huskers.unl.edu). *Computational complexity of Hamiltonian ℓ-cycles.* Preliminary report.

A hamiltonian ℓ-cycle in an n-vertex k-uniform hypergraph is a cyclic ordering of the vertices such that every edge consists of k consecutive vertices and every pair of consecutive edges overlap in exactly ℓ vertices. Karpiński, Ruciński, and Szymańska studied the computational complexity of hamiltonian ℓ-cycles in dense hypergraphs for $\ell = k-1$. Their results extend to all ℓ such that $(k-\ell)$ divides k. We study the case for ℓ such that $(k-\ell)$ does not divide k. (Received February 22, 2016)

1120-05-259 **Kevin Dilks*** (kevin.dilks@ndsu.edu), **Oliver Pechenik** and **Jessica Striker**. *Resonance in orbits of plane partitions.*

In this talk, we introduce a new concept of resonance on discrete dynamical systems. This concept formalizes the observation that, in various combinatorially-natural cyclic group actions, orbit cardinalities are all multiples of divisors of a fundamental 'frequency' ω. Our main result is an equivariant bijection between plane partitions in a box (or order ideals in the product of three chains) under rowmotion and increasing tableaux under K-promotion. Both of these actions were observed to have orbit sizes that were small multiples of divisors of an expected orbit size, and we show this is an instance of resonance, as K-promotion cyclically rotates the set of labels appearing in the increasing tableaux. We extract a number of corollaries from this equivariant bijection, including new proofs of plane partition results of [A. Brouwer–A. Schrijver '74] and [P. Cameron–D. Fon-der-Flaass '95], a strengthening of a theorem of [P. Cameron–D. Fon-der-Flaass '95] and several new results on the

order of K-promotion. Along the way, we adapt the proof of the conjugacy of promotion and rowmotion from [J. Striker–N. Williams '12] to give a generalization in the setting of n-dimensional lattice projections. (Received February 23, 2016)

1120-05-270 **Hemanshu Kaul*** (kaul@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616, and **Jeffrey Mudrock**. *On the list chromatic number of the Cartesian product with a traceable graph.* Preliminary report.

Borowiecki, Jendrol, Kral, and Miskuf (2006) proved that the list chromatic number of the Cartesian product of two graphs can bounded in terms of the list chromatic number and the coloring number of the factors, implying a bound exponential in the list chromatic number of the factors. They conjecture that the bound can be improved to a constant times the sum of the list chromatic numbers. With this in mind, we study the list coloring of the Cartesian product of a strong critical graph and a traceable graph (i.e. a graph containing a Hamilton path). We show families of graphs where our result improves upon known bounds for the list chromatic number. Strong critical graphs, a generalization of color criticality to list coloring introduced by Stiebitz, Tuza, and Voigt in 2008, include families of graphs such as odd cycles, complete graphs, Dirac graphs, and more. We also utilize a connection between choosability and unique list colorability discovered by Akbari, Mirrokni, and Sadjad in 2006. (Received February 23, 2016)

1120-05-271 **Michael S Chmutov*** (mchmutov@umn.edu), **Pavlo Pylyavskyy** and **Elena Yudovina**. *Matrix ball construction for affine Robinson-Schensted correspondence.*

In his study of Kazhdan-Lusztig cells in affine type A, Shi has introduced an affine analog of Robinson-Schensted correspondence. We generalize the Matrix-Ball Construction of Viennot and Fulton to give a more combinatorial realization of Shi's algorithm. As a byproduct, we also give a way to realize the affine correspondence via the usual Robinson-Schensted bumping algorithm. Next, inspired by Honeywill, we extend the algorithm to a bijection between the extended affine symmetric group and collection of triples (P, Q, ρ) where P and Q are tabloids and ρ is a dominant weight. (Received February 23, 2016)

1120-05-280 **Emily Gunawan*** (egunawan@umn.edu), 206 Church St SE, Vincent Hall, Minneapolis, MN 55455. *Notched arcs and atomic bases of cluster algebras from twice-punctured polygons and other punctured surfaces.* Preliminary report.

Cluster algebras, introduced by Fomin and Zelevinsky at the beginning of this century, are commutative rings which are defined combinatorially by an iterated process. An important class of cluster algebras arise from triangulations of surfaces with marked points. We generalize Ralf Schiffler and Hugh Thomas' combinatorial T-path formula to tagged arcs (possibly with decorations called notchings at their endpoints) of punctured surfaces. We use this to investigate the existence of atomic bases for cluster algebras arising from twice-punctured disks and other punctured surfaces. (Received February 23, 2016)

1120-05-281 **Elizabeth Drellich*** (elizabeth.drellich@unt.edu) and **Anne Shepler**. *Complex reflection groups and GKM splines.*

The torus equivariant cohomology of Schubert varieties, flag varieties, and Grassmannians can be presented as the collections of allowed labels on the vertices of particular graphs, called GKM graphs for Goresky, Kottwitz, and MacPherson. Which labels are allowed depend on the orbits of the variety under the torus action, which in turn correspond to reflections in the Weyl group. Similar graphs and collections of allowed labels can be constructed corresponding to complex reflection groups. Omar Ortiz showed that those constructed using the complex reflection group $G(r, p, n)$ correspond to p-compact groups. This talk will discuss recent work towards generalizing these results to other complex reflection groups. (Received February 23, 2016)

1120-05-282 **Pavlo Pylyavskyy*** (ppylyavs@umn.edu), **Thomas Lam** and **Reiho Sakamoto**. *Rigged configurations and cylindric loop Schur functions.*

Box-ball systems are remarkable discrete dynamical systems introduced by Takahashi and Satsuma. They exhibit solitonic behavior, providing a combinatorial model for deep phenomena is non-linear science. I will explain in simple terms how box-ball systems are defined and how to think of them as of combinatorial models for KdV. I will explain then how to solve the "forward scattering problem": for a given initial state, I will write down explicit formulas for the sizes of solitons that come out of it under time evolution. This is joint work with Thomas Lam and Reiho Sakamoto. (Received February 23, 2016)

1120-05-283 **Max Glick*** (mglick@umn.edu) and **Pavlo Pylyavskyy**. *Y-meshes and generalized pentagram maps.*

We introduce a rich family of generalizations of the pentagram map sharing the property that each generates an infinite configuration of points and lines with four points on each line. These systems all have a description as Y-mutations in a cluster algebra and hence establish new connections between cluster theory and projective geometry. Our framework incorporates many preexisting generalized pentagram maps due to M. Gekhtman, M. Shapiro, S. Tabachnikov, and A. Vainshtein and also B. Khesin and F. Soloviev. (Received February 23, 2016)

1120-05-284 **Derrick Stolee** and **Paul S Wenger*** (pswsma@rit.edu). *Saturation multiplicity of graphs.*

Given a graph F, a graph G is *F-saturated* if G does not contain F as a subgraph but the addition of any edge to G completes some copy of F. For an F-saturated graph G, the *F-saturation multiplicity* of G is the average number of copies of F that are completed when an edge is added to G. In this talk we present initial results on the minimum and maximum values of the saturation multiplicity of F-saturated graphs for fixed F. In particular, we will explore the maximum value of this parameter when F is a tree. (Received February 23, 2016)

1120-05-289 **Corey Vorland*** (corey.vorland@ndsu.edu). *Toggle group dynamics of multidimensional posets.* Preliminary report.

We study dynamical properties, including orbit structure and homomesy, of toggle group actions on tetrahedral posets and plane partitions. (Received February 23, 2016)

1120-05-295 **Victor Falgas-Ravry**, **Kelly O'Connell**, **Johanna Strömberg** and **Andrew Uzzell***, andrew.uzzell@unl.edu. *Multicolor hypergraph containers and multicolor graph limits.* Preliminary report.

Alekseev and, independently, Bollobás and Thomason determined the asymptotic size of any hereditary class of graphs $\mathcal{P}$. Hatami, Janson, and Szegedy later gave a new proof of this result using graph limits. They also showed that the asymptotic size of $\mathcal{P}$ is determined by the maximum entropy of a graph limit that may arise from $\mathcal{P}$. Saxton and Thomason later used hypergraph containers to prove a special case of the result.

We study both limits and containers for graphs whose edges are labeled with one of k colors. In particular, we give two proofs of the existence of small container families for hereditary classes of k-colored graphs. Our work provides a very general method of transferring between hypergraph containers and graph limits in the context of counting graphs in a hereditary class.

Our first proof uses existing hypergraph container results and supersaturation. We then use our container result to generalize the entropy results of Hatami et al. to limits of sequences of multicolored graphs. Our second proof directly extends the entropy results of Hatami et al. to the multicolored setting and then uses these results to construct container families for hereditary classes of k-colored graphs. (Received February 23, 2016)

1120-05-296 **Patrick Bennett*** (patrick.bennett@wmich.edu) and **Mike Molloy** (molloy@cs.toronto.edu). *Space bounds for resolution in random $(2+p)$-SAT.*

Resolution is a rule of inference for boolean formulas in conjunctive normal form, and it can be used to prove that a formula is unsatisfiable (such a proof is called a resolution refutation). The resolution space of an unsatisfiable formula is the amount of memory required to verify a resolution refutation. A $(2+p)$-SAT formula consists of clauses of size 2 and 3. We show that a random (unsatisfiable) instance of $(2+p)$-SAT on n variables has resolution space quadratic in n. This is worst possible, up to a constant. (Received February 23, 2016)

1120-05-299 **Patrick Bennett*** (patrick.bennett@wmich.edu), **Andrzej Dudek** (andrzej.dudek@wmich.edu), **Alan Frieze** (af1p@andrew.cmu.edu) and **Laars Helenius** (laars.c.helenius@wmich.edu). *The 1-2-3 conjecture for uniform hypergraphs.*

Given an r-uniform hypergraph $H=(V,E)$ and a weight function $\omega : E \to \{1,\dots,w\}$, a coloring of vertices of H, induced by ω, is defined by $c(v)=\sum_{e\ni v} w(e)$ for all $v \in V$. If there exists such a coloring that is strong (that means in each edge no color appears more than once), then we say that H is strongly w-weighted. Similarly, if the coloring is weak (that means there is no monochromatic edge), then we say that H is weakly w-weighted. In this talk we will discuss the strong- and weak-weightedness of k-uniform hypergraphs, particularly random hypergraphs. (Received February 23, 2016)

1120-05-304 **Michelle Delcourt*** (delcour2@illinois.edu), 1409 W Green St., Urbana, IL 61801, and **Luke Postle**. *Claw decompositions of random 4-regular graphs.*

In 2005, Barat and Thomassen conjectured that the edges of every planar 4-regular 4-edge-connected graph can be decomposed into claws; shortly afterwards, Lai constructed a counterexample to this conjecture. Using the small subgraph conditioning method of Wormald, we show that a.a.s. a random 4-regular graph has such a claw decomposition. This is joint work with Luke Postle. (Received February 23, 2016)

1120-05-305 **József Balogh** and **Cory Palmer*** (cory.palmer@umontana.edu). *On the tree packing conjecture.*

A set of graphs is said to pack into the complete graph, K_n, if the graphs can be found as edge-disjoint subgraphs of K_n. In 1978, Gyárfás conjectured that for any set of $n-1$ trees $T_1, T_2, \ldots, T_{n-1}$ such that T_i has $n-i$ edges packs into K_n. Even when we weaken the statement to claim that the largest $t > 3$ trees $T_1, T_2, \ldots, T_t$ pack into K_n the conjecture remains open. Among others we will discuss our result that any set of $t = \frac{1}{10}n^{1/4}$ trees $T_1, T_2, \ldots, T_t$ such that T_i has $n-i$ edges packs into K_{n+1} (for n large enough). We will also survey the history of this conjecture and discuss several related packing problems. (Received February 23, 2016)

1120-05-306 **József Balogh**, **Michelle Delcourt**, **Bernard Lidický** and **Cory Palmer*** (cory.palmer@umontana.edu). *Rainbow copies of C_4 in edge-colored hypercubes.*

For positive integers k and d such that $4 \leq k < d$ and $k \neq 5$, we determine the maximum number of rainbow colored copies of C_4 in a k-edge-coloring of the d-dimensional hypercube $\mathcal{Q}_d$. We will also discuss a generalization of this problem concerning rainbow copies of Q_s in a k-edge-coloring of Q_d. (Received February 23, 2016)

1120-05-308 **Charles Tomlinson*** (ctomlinson2@math.unl.edu) and **Philip DeOrsey**. *Fast percolation on the hexagonal lattice.* Preliminary report.

In r neighbor bootstrap percolation one considers the evolution of a cellular automaton consisting of cells where new cells become infected if at least r of their neighbors are already infected. Classical interest was in the model where cells were selected for inclusion in the initially infected set, seed, independently at random with probability p. The effects of p on expected percolation time and the probability of percolation have been studied extensively. We approach the model from an extremal perspective, asking how fast a convex region in a hexagonal lattice can be percolated by a minimum size seed 3-neighbor percolation. The fastest time is known for squares in a square lattice with 2 neighbor percolation. In a regular hexagon whose sides contain n sites, the n-hex, we show that the fastest percolation can occur is in $2n+1$ steps. Unlike the extremal examples for the square grid, the seed does not reside in n-hex. When the seed is entirely contained in the n-hex we show that the fastest percolation time, t satisfies $2n+1 \leq t \leq \frac{7}{3}(n-2)+3$. The upper bound comes via construction which we conjecture, and are working to show, is optimal. (Received February 23, 2016)

1120-05-311 **Adam Berliner**, **Chassidy Bozeman**, **Steve Butler**, **Minerva Catral**, **Leslie Hogben** and **Brenda K Kroschel*** (bkkroschel@stthomas.edu), Mail #OSS 201, 2115 Summit Ave., St. Paul, MN 55105, and **Jephian Chin-Hung Lin**, **Nathan Warnberg** and **Michael Young**. *Zero forcing propagation time on oriented graphs.* Preliminary report.

Zero forcing is an iterative coloring procedure on a graph, G, that starts by initially coloring vertices white and blue and then repeatedly applies the following rule: if any blue vertex has a unique (out-)neighbor that is colored white, then that neighbor is forced to change color from white to blue. An initial set of blue vertices that can force the entire graph to blue is called a zero forcing set. The minimum cardinality of a zero forcing set on a graph, G, is the zero forcing number, $Z(G)$. This graph parameter was first introduced by the AIM Special Graphs Work Group in 2008 for undirected graphs and later extended to simple digraphs. It is of interest because there is a relationship between the zero forcing number and the geometric multiplicity of the eigenvalue 0 for a matrix associated with the graph. In this paper we consider the minimum number of iterations needed for this color change rule to color all of the vertices blue, also known as the propagation time, for oriented graphs. (Received February 23, 2016)

1120-05-314 **Heather C Smith*** (heather.smith@math.gatech.edu), **László Székely** (szekely@math.sc.edu), **Hua Wang** (hwang@georgiasouthern.edu) and **Shuai Yuan** (syuan@math.sc.edu). *Extremal properties of vertex attributes in trees.*

For tree T and vertex v, define the eccentricity $ecc(v) := \max_{u \in V(T)} d(u,v)$, the distance $d(v) := \sum_{u \in V(T)} d(u,v)$ and the number of subtrees $F(v)$ containing vertex v. Each defines a "middle" of the tree consisting of the vertices with the maximum (or minimum) value.

First, we explore the interactions of $ecc(v)$ and the total eccentricity $Ecc(T) := \sum_{v \in V(T)} ecc(v)$ by examining extremal values and structures for the ratios $\frac{ecc(v)}{ecc(u)}$ and $\frac{Ecc(T)}{ecc(v)}$, the behavior of which is more delicate that of the numerator or the denominator alone. Analogous studies have been done for distance [Barefoot, Entringer, Székely, Discrete Appl. Math. **80** (1997), 37-56] and number of subtrees [Székely, Wang, Electron. J. Combin. **20** (2013) 1-20]. We also compare the three different middles, determining how far apart they can appear in a single tree and characterizing many of the extremal structures. (Received February 23, 2016)

1120-05-316 **Thomas A McConville*** (thomasmcconvillea@gmail.com), 182 Memorial Drive, Cambridge, MA 02139, and **Al Garver**. *Flip graphs of polygonal subdivisions and noncrossing tree partitions.*

Given a tree embedded in a disk, we introduce two partial orders - the oriented flip graph of polygonal subdivisions and the lattice of noncrossing tree partitions. These posets generalize the Tamari order and the lattice of noncrossing set partitions, respectively. Our first main result is that the poset of polygonal subdivisions is a lattice. To prove this, we identify this poset as a lattice quotient of a lattice of biclosed sets. The lattice of polygonal subdivisions has the additional structure of a congruence-uniform lattice. Consequently, it admits an alternate poset structure known as the shard intersection order. Our second main result is an isomorphism between the shard intersection order with the lattice of noncrossing tree partitions. This is joint work with Al Garver. (Received February 23, 2016)

1120-05-317 **Kirk Boyer**, **Paul Horn*** (paul.horn@du.edu) and **Mario Lopez**. *Combinatorics of ray-sensor networks.*

Imagine an intruder, attempting to infiltrate a point, and with their path blocked by a number of rays. A single ray cannot block the intruder, as the intruder can simply walk around, but a pair of rays can. The pairs of blocking rays give rise to a graph, and this graph caries information on the sensor network. In this talk, we discuss properties of these graphs (giving a structural 'rigidity' result, which can be used, for instance, to study which graphs can arise as such 'barrier graphs'). Related questions also lead to some interesting problems in combinatorial geometry, which we also discuss. (Received February 24, 2016)

1120-05-318 **Guantao Chen*** (gchen@gsu.edu), Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303, **Zhiquan Hu**, School of Mathematics and Statistics, Central China Normal University, Wuhan, Peoples Rep of China, and **Feifei Song**, School of Mathematics and Statistics, Central China Normal University, Wuhan, Peoples Rep of China. *A degree condition for knitted graphs.* 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 $|S| = \ell$. Clearly, a $2k$-knitted graph is k-linked. In this talk, we give a new sufficient condition for ℓ-knitted graphs. Our result generalizes a sufficient degree condition for k-linked graphs obtained by Kawarabayashi, Kostochka and Yu. (Received February 24, 2016)

1120-05-319 **Michael Young*** (myoung@iastate.edu). *Polychromatic colorings of the hypercube.*

Given a graph G which is a subgraph of the n-dimensional hypercube Q_n, an edge coloring of Q_n with $r \geq 2$ colors such that every copy of G contains every color is called *G-polychromatic*. Originally introduced by Alon, Krech and Szabó in 2007 as a way to prove bounds for Turán type problems on the hypercube, polychromatic colorings have proven to be worthy of study in their own right. This talk will survey what is currently known about polychromatic colorings and introduce some open questions. In addition, there are some natural generalizations and variations of the problem that will also be discussed. (Received February 24, 2016)

06 ► Order, lattices, ordered algebraic structures

1120-06-73 **Robert Amzi Jeffs** (rjeffs@g.hmc.edu), 301 Platt Boulevard, Claremont, CA 91786, and **Mohamed Omar*** (omar@g.hmc.edu), 301 Platt Boulevard, Claremont, CA 91711. *Convex incidences, neuroscience, and ideals.* Preliminary report.

Neural rings were introduced by Curto et. al as a means of studying convex incidence questions arising from neuroscience through an algebraic lens. We study ideals in these rings and classify homomorphisms that preserve neural ideals. (Received February 10, 2016)

13 ► Commutative rings and algebras

1120-13-19 **Guillermo Alesandroni*** (alesangc@wfu.edu), 631 Chester Rd, Winston-Salem, NC 27104. *Dominant, semidominant, and GNP ideals.*

Dominant, semidominant, and GNP ideals are classes of monomial ideals originated in the study of free resolutions. Because they are defined by simple combinatorial properties, these families are good for making computations. In particular, dominant ideals give a complete characterization of when the Taylor resolution is minimal, and semidominant ideals are used to construct some interesting examples and counterexamples within the topic of monomial resolutions. GNP ideals extend the class of generic ideals, a concept introduced by Bayer, Peeva, and Sturmfels. Like generic ideals, GNP ideals are minimally resolved by the Scarf complex. (Received January 17, 2016)

1120-13-38 **Lars Winther Christensen*** (lars.w.christensen@ttu.edu) and **Srikanth B Iyengar**. *Tests for injectivity of modules over commutative rings.* Preliminary report.

Let R be a commutative ring. In cohomological terms, Baer's criterion says that an R-module M is injective if $\operatorname{Ext}^1_R(R/\mathfrak{a}, M) = 0$ holds for every ideal $\mathfrak{a}$ in R. When R is also noetherian, it suffices to test against prime ideals and locally. Indeed, M is injective if either of the following conditions holds:

- $\operatorname{Ext}^1_R(R/\mathfrak{p}, M) = 0$ for every prime ideal $\mathfrak{p}$ in R;
- $\operatorname{Ext}^1_{R_\mathfrak{p}}(k(\mathfrak{p}), M_\mathfrak{p}) = 0$ for every prime ideal $\mathfrak{p}$ in R.

Here $k(\mathfrak{p})$ denotes the field $(R/\mathfrak{p})_\mathfrak{p}$. The theorem I will discuss says that injectivity can be detected by vanishing of Ext globally against these fields. It leads to the following characterization of injective modules: If F is faithfully flat, then a module M such that $\operatorname{Hom}_R(F, M)$ is injective and $\operatorname{Ext}^i_R(F, M) = 0$ for all $i \geq 1$ is injective. (Received January 29, 2016)

1120-13-40 **Stefan Bock**, Department of Mathematical Sciences, Martin Hall O-10, Clemson University, Clemson, SC 29634, and **Jim Coykendall*** (jcoyken@clemson.edu), Department of Mathematical Sciences, Martin Hall O-10, Clemson University, Clemson, SC 29634. *Cohen-Kaplansky Domains.*

An integral domain is called a *Cohen-Kaplansky domain* (CK-domain) if it is atomic (that is, every nonzero, nonunit element can be factored into a finite product of irreducibles) and has only finitely many irreducible elements up to associates. CK-domains have strong structural requirements. For example, they must be of dimension no more than 1 and be semilocal. Additionally, the integral closure of a CK-domain is a PID with only finitely many primes.

But the "counting" part of CK-domains can be maddeningly difficult. In this talk we will discuss a two major questions. The first is "given a natural number n can one build a CK-domain with precisely n nonprime irreducibles (up to associates)?" The second question is "if we can build such a domain for a given n what is the most efficient way to do so?"

There will be numerous examples along the way to convey the difficulty of this problem. (Received January 29, 2016)

1120-13-68 **Chris Francisco*** (chris.francisco@okstate.edu), Department of Mathematics, 401 MSCS, Oklahoma State University, Stillwater, OK 74078, and **Jeffrey Mermin** and **Jay Schweig**. *Pure resolutions of monomial ideals.*

We describe which LCM lattices support a pure resolution of a monomial ideal. (Received February 09, 2016)

1120-13-76 **Christopher A Francisco**, **Jeff Mermin*** (mermin@math.okstate.edu) and **Jay Schweig**. *The smallest borel ideal containing the product of the variables.*

We study principal borel ideals from the perspective of the borel generator, and show that most traditional invariants can be read off from the borel generator more efficiently than the monomial generators can be listed.

We compute various invariants of the principal Borel ideal generated by $x_1x_2\dots x_n$, and argue that it is "central" to the theory of combinatorial ideals. (Received February 11, 2016)

1120-13-86 **Emilie Dufresne** and **Jack Jeffries*** (jackjeff@umich.edu). *Separating sets for actions of tori.*

One modern notion in invariant theory is that of a separating set. A separating set for a group action G on a variety X is a set of invariants such that if there is some $f \in k[X]^G$ such that $f(v) = f(w)$, then there is an $h \in S$ such that $h(v) = h(w)$. This notion has attracted interest because it may be much easier to compute a separating set than to compute the whole ring of invariants, but separating sets still reflect much of the geometry

of the group action like invariant rings do. In this talk, I will discuss some new results on separating sets for actions of tori, focusing on connections with local cohomology and secant varieties. This is based on joint work with Emilie Dufresne. (Received February 14, 2016)

1120-13-92 **Thomas M Polstra*** (tmpxv3@mail.missouri.edu), 1107 North College Ave, Columbia, MO 65201. *Uniform bounds in F-finite rings and their applications.*

We will discuss uniform bounds found in all F-finite rings of prime characteristic p. More importantly, we will discuss their applications, including uniform convergence results involving Hilbert-Kunz length and Frobenius splitting number functions. We will also discuss how a significant weakening of the uniform bounds to be discussed provides an affirmative answer to a question of Watanabe and Yoshida from 2004. (Received February 15, 2016)

1120-13-97 **Stefan O. Tohaneanu*** (tohaneanu@uidaho.edu), Department of Mathematics, University of Idaho, Moscow, ID 83844, and **Mehdi Garrousian** and **Ben Anzis**. *Generalized Star Configurations.* Preliminary report.

Generalized star configurations are projective subschemes of $\mathbb{P}^{k-1}$ with defining ideal generated by all the $a-$fold products of n given linear forms. If any k of the given linear forms are linearly independent, then this ideal will define a (usual) star configuration. The defining ideals of star configurations have very nice homological features, and most of the time these are conjecturally preserved when studying generalized star configurations. The main conjecture is that the defining ideal of any generalized star configuration has linear graded minimal free resolution. In our opinion, the conjecture is very challenging, and once resolved it will also answer some questions that are related to the linear codes associated to generalized star configurations. (Received February 16, 2016)

1120-13-100 **Sean Sather-Wagstaff** and **Jonathan Totushek*** (jtotushe@uwsuper.edu). *Complete intersection injective dimension and the Chouinard Formula.* Preliminary report.

Let $(R, \mathfrak{m}, k)$ be a local ring and let X be an R-complex. It is known that $\operatorname{Gfd}_R(X) \leq \text{CI-fd}_R(X) \leq \operatorname{fd}_R(X)$ where fd is the classical flat dimension, CI-fd is the complete intersection flat dimension of Sather-Wagstaff, and Gfd is the Gorenstein flat dimension of Enochs, Jenda, and Xu. However, it remains an open question if $\operatorname{Gid}_R(X) \leq \text{CI-id}_R(X) \leq \operatorname{id}_R(X)$ where id is the classical injective dimension, CI-id is the complete intersection injective dimension of Sather-Wagstaff, and Gid is the Gorenstein injective dimension of Enochs, and Jenda. In this talk we will investigate how the Chouinard formula relates to the complete intersection dimension and show some special cases when the latter set of inequalities hold. (Received February 16, 2016)

1120-13-109 **Daniel J. Hernández**, **Luis Núñez-Betancourt**, **Felipe Pérez** and **Emily E. Witt*** (witt@ku.edu), 1460 Jayhawk Blvd, 405 Snow Hall, Lawrence, KS 66045. *Local cohomology and connectivity in mixed characteristic.*

Certain local cohomology modules determine connectivity properties of the spectrum of a ring; some very interesting connections between these have only been shown in the equicharacteristic setting. In this talk, we present a new vanishing theorem for local cohomology modules in mixed characteristic, and discuss what can be said about connectivity in this setting as a consequence.

This is joint work with Daniel J. Hernández, Luis Núñez-Betancourt, and Felipe Pérez. (Received February 16, 2016)

1120-13-117 **Luchezar Avramov**, **Courtney Gibbons** and **Roger Wiegand***, Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130. *Betti tables over short Gorenstein rings.*

Let $R = k \oplus R_1 \oplus k$ be a short graded Gorenstein k-algebra with embedding dimension $e = \dim_k R_1 \geq 2$. When $e \geq 3$, R has wild representation type. Nonetheless, we give necessary and sufficient conditions for a column-finite $\mathbb{Z} \times \mathbb{N}_0$ matrix of non-negative integers to be the Betti table of some finitely generated graded R-module. We describe the semigroup S of Betti tables of modules, and identify its atoms and also its *strong* atoms (the ones that generate extremal rays in the rational cone C of Betti diagrams). The atoms generate S, though they are somewhat sparse. The strong atoms, on the other hand, do *not* generate S if $e \geq 3$. The corresponding paucity of extremal rays in C prohibits any sort of Boij-Söderberg theory when $e \geq 3$. (Received February 17, 2016)

1120-13-119 **Melissa C. Menning*** (mcm146@umkc.edu), Kansas City, MO 64110, and **Liana M. Sega** (segal@umkc.edu), Kansas City, MO 64110. *Cohomology of finite modules over short Gorenstein rings.*

Let R be a Gorenstein local ring with maximal ideal $\mathfrak{m}$ satisfying $\mathfrak{m}^3 = 0 \neq \mathfrak{m}^2$. Set $\mathsf{k} = R/\mathfrak{m}$ and $e = \operatorname{rank}_{\mathsf{k}}(\mathfrak{m}/\mathfrak{m}^2)$. If $e > 2$ and M, N are finitely generated R-modules, we show that the formal power series

$$\sum_{i=0}^{\infty} \operatorname{rank}_{\mathsf{k}} \left(\operatorname{Ext}^i_R(M,N) \otimes_R \mathsf{k}\right) t^i \quad \text{and} \quad \sum_{i=0}^{\infty} \operatorname{rank}_{\mathsf{k}} \left(\operatorname{Tor}^R_i(M,N) \otimes_R \mathsf{k}\right) t^i$$

are rational, with denominator $1 - et + t^2$. (Received February 17, 2016)

1120-13-121 **Hop D Nguyen** and **Thanh Vu*** (tvu@unl.edu). *Linearity defects of minors of matrices of linear forms.*

The linearity defect was introduced by Herzog and Iyengar as a measure for the complexity of modules without a linear free resolution. Using the theory of Betti splittings, we compute the linearity defect of the ideals of two minors of certain matrices of linear forms. (Received February 17, 2016)

1120-13-122 **Federico Galetto*** (galettof@math.mcmaster.ca), **Anthony V. Geramita** and **David Wehlau**. *Symmetric complete intersections.* Preliminary report.

Complete intersection ideals in polynomial rings are parametrized by the degrees of their generators. We consider complete intersection ideals that are stable under the action of the symmetric group permuting the variables. These ideals are further parametrized by the representation type of a stable generating subspace. We classify the possible representation types for stable complete intersection ideals and obtain formulas for the graded characters of the corresponding quotient rings. (Received February 17, 2016)

1120-13-124 **Joseph Gubeladze*** (soso@sfsu.edu), Department of Mathematics, San Francisco State University, San Francisco, CA 94132. *Conductor ideals of affine monoids and K-theory.*

A *positive affine monoid* is a finitely generated additive submonoid of $\mathbb{Z}^r$ for some r, containing no nontrivial subgroup. In analogy with commutative rings, the *conductor ideal* of a positive affine monoid M is the set $\mathbf{c}_{\bar{M}/M} = \{m \in \mathbb{Z}^r \ : \ m + \bar{M} \subset M\}$, where $\bar{M}$ is the normaliztion of M in $\mathbb{Z}^r$. It is a non-zero ideal of M. When M is a *numerical monoid*, the ideal $\mathbf{c}_{\bar{M}/M}$ is equivalent to the *Frobenius number* of M. Several people studied conductor ideals of affine monoids in arbitrary dimensions. After a brief survey of such structural results, we will discuss how conductor ideals $\mathbf{c}_{\bar{M}/M}$ appear in the K-theory of monoid rings $R[M]$. The picture is compete for the Grothendieck group K_0 and mostly conjectural for higher groups. (Received February 18, 2016)

1120-13-125 **Tai Ha*** (tha@tulane.edu), Tulane University, Department of Mathematics, 6823 St. Charles Avenue, New Orleans, LA 70002, and **Pham An Vinh**. *Growth of multiplicities of graded families of ideals.*

Let (R, m) be a Noetherian local ring of dimension $d > 0$, and let $\{I_n\}_{n\in\mathbb{N}}$ be a graded family of m-primary ideals in R. We examine how far off from a polynomial can the length function $\ell_R(R/I_n)$ be. In particular, we provide an upper bound for the difference function $\ell_R(R/I_{n+1}) - \ell_R(R/I_n)$. (Received February 18, 2016)

1120-13-127 **Tai Ha*** (tha@tulane.edu). *Symbolic powers of sums of ideals.*

Let k be a field and let $A = k[x_1, \ldots, x_r]$ and $B = k[y_1, \ldots, y_s]$ be polynomial rings over k. Let $I \subseteq A$ and $J \subseteq B$ be proper homogeneous ideals. We investigate the question of how symbolic powers of the sum $I + J \subseteq R = A \otimes_k B$ can be studied via those of I and J. In particular, we give a binomial expansion of $(I + J)^{(n)}$ in terms of symbolic powers of I and J. (Received February 18, 2016)

1120-13-128 **Hema Srinivasan*** (srinivasanh@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *A class of Gorenstein monomial curves.*

This is a joint work with Philippe Gimenez. Let k be an arbitrary field. We strengthen the criterion of Brezinsky for Gorenstein monomial curves and use it to construct a class of monomial Gorenstein curves. In particular, we show that if a sequence of relatively prime positive integers $\mathbf{a} = (a_1, a_2, a_3, a_4)$ defines a Gorenstein non complete intersection monomial curve $\mathcal{C}(\mathbf{a})$ in $\mathbb{A}^4_k$, then there exist two vectors $\mathbf{u}$ and $\mathbf{v}$ such that $\mathcal{C}(\mathbf{a} + t\mathbf{u})$ and $\mathcal{C}(\mathbf{a} + t\mathbf{v})$ are also Gorenstein non complete intersection affine monomial curves for almost all $t \geq 0$. (Received February 18, 2016)

1120-13-141 **Sandra Spiroff*** (spiroff@olemiss.edu), Department of Mathematics, Hume Hall 305, P.O. Box 1848, University, MS 38677-1848, and **Florian Enescu**. *On intersection algebras of polynomial rings.* Preliminary report.

For a polynomial ring R in finitely many variables over a field and principal monomial ideals I and J are, we study $\bigoplus_{r,s\in\mathbb{N}} I^r \cap J^s$, denoted by $\mathcal{B}_R(I,J)$. In particular, we investigate the Hilbert-Samuel and Hilbert-Kunz multplicities, the divisor class group, and the F-signature of $\mathcal{B}$. This continues the research begun by F. Enescu and S. Malec at Georgia State. (Received February 19, 2016)

1120-13-145 **Man Wai Cheung** (mwc31@cam.ak.uk), **Mark Gross** (mg475@dpmms.cam.ac.uk), **Greg Muller** (morilac@umich.edu), **Gregg Musiker*** (musiker@math.umn.edu), **Dylan Rupel** (drupel@nd.edu), **Salvatore Stella** (stella@mat.uniroma1.it) and **Harold Williams** (hwilliams@math.utexas.edu). *The greedy basis equals the theta basis.*

We prove the equality of two canonical bases of a rank 2 cluster algebra, the greedy basis of Lee-Li-Zelevinsky and the theta basis of Gross-Hacking-Keel-Kontsevich. (Received February 19, 2016)

1120-13-152 **Oana Veliche*** (o.veliche@neu.edu), **Lars W. Christensen** and **Jerzy Weyman**. *Intersections and sums of Gorenstein ideals.* Preliminary report.

A complete local ring of embedding codepth 3 has a minimal free resolution of length 3 over a regular local ring. Such resolutions carry a differential graded algebra structure, based on which one can classify local rings of embedding codepth 3. The Gorenstein rings of embedding codepth 3 belong to the class called $\mathbf{G}(r)$, which was conjectured not to contain any non Gorenstein rings. In a previous work with Lars W. Christensen and Jerzy Weyman we gave examples and constructed non Gorenstein rings in $\mathbf{G}(r)$, for any $r \geq 2$. We show now that one can get such rings generically, from intersections of Gorenstein ideals. The class of the rings obtained from sums of such ideals will also be discussed. (Received February 19, 2016)

1120-13-185 **Youngsu Kim*** (youngsu.kim@ucr.edug), 900 Univ. Ave., Surge 253, Riverside, CA 92521, and **Louis J. Ratliff** and **David Rush**. *Itoh (e)-valution rings of an ideal.*

Let R be a Noetherian ring and I an R-ideal. An element x of R is integral over I if there exist $a_i \in I^i$ for $i = 1, \ldots n$ such that $x^n + a_1 x^{n-1} + \cdots + a_n = 0$. The set of elements which are integral over I is the ideal $\overline{I}$ the integral closure of I. For ideal I of positive grade, Rees showed that there exists a unique finite set of Noetherian valuations of R, now called Rees valuations $\mathcal{RV}(I)$, that determines $\overline{I}$, i.e., $x \in \overline{I}$ iff $\nu(x) \geq \nu(I)$ for all $\nu \in \mathcal{RV}(I)$. Write $\mathcal{RV}(I) = \{\nu_1, \ldots, \nu_n\}$, and we call $\nu_1(I), \ldots, \nu_n(I)$ the Rees integers of I.

It is well known that there exists a 1-1 correspondence between $\mathcal{RV}(I)$ and $\mathcal{RV}(t^{-1}R[It, t^{-1}])$, where $R[It, t^{-1}]$ is the extended Rees algebra of I. For any positive multiple e of the Rees integers of I, Itoh showed that there is a 1-1 correspondence between $\mathcal{RV}(t^{-1}R[It, t^{-1}])$ and $\mathcal{RV}(t^{-e}R[It, t^{-e}])$ and that the Rees integers of $t^{-e}(R[It, t^{-e}])$ are all 1. In this talk, we present a generalization of Itoh's statement. In particular, we show an explicit relationship between the associated valuations rings. (Received February 21, 2016)

1120-13-188 **Bill F. Trok*** (william.trok@uky.edu) and **Uwe Nagel**. *The generalized segre bound for arbitrary fat points.* Preliminary report.

Segre established an upper bound for the Castelnuovo-Mumford regularity of a planar scheme of generic fat points. A generalization of this bound has been conjectured to hold for schemes of arbitrary fat points in projective n-space. While in general the conjecture remains open, certain cases are known. In particular, if the points are in linearly general position the bound holds. In this talk, we discuss some partial results on the conjecture, as well as some results on the geometry of small collections of points with applications to this conjecture. (Received February 21, 2016)

1120-13-192 **Javid Validashti***, Cleveland State University, and **Ali Alilooee** and **Ivan Soprunov**. *The j-multiplicity of edge ideals.* Preliminary report.

We explore the connections between the j-multiplicity of edge ideals and the combinatorial properties of underlying graphs. This is a joint work with A. Alilooee and I. Soprunov. (Received February 22, 2016)

1120-13-195 **Elena Guardo*** (guardo@dmi.unict.it), Dipartimento di Matematica e Informatica, Viale Doria 6, 95030 Catania, Sicily, Italy, and **Adam Van Tuyl**, Department of Mathematics and Statistics, McMaster University, Hamilton, Canada. *On the Hilbert Functions of points in $\mathbb{P}^1 \times \mathbb{P}^1 \times \mathbb{P}^1$.*

Let X be a set of points in $\mathbb{P}^1 \times \mathbb{P}^1 \times \mathbb{P}^1$. We describe how geometric information about X is encoded into the Hilbert function H_X. We introduce some new results about the Hilbert functions of points X in $\mathbb{P}^1 \times \mathbb{P}^1 \times \mathbb{P}^1$, which can be scaled to $\mathbb{P}^1 \times \cdots \times \mathbb{P}^1$. (joint paper with A. Van Tuyl) (Received February 22, 2016)

1120-13-200 **Uwe Nagel** and **Alexandra Seceleanu*** (aseceleanu@unl.edu). *Ordinary and symbolic Rees algebras for a class of special point configurations.*

Fermat configurations are planar point configurations that are closely related to the intersection locus of the members of a specific pencil of curves. The ideals defining these sets of projective points have gained recent popularity as counterexamples to some proposed containments between symbolic and ordinary powers. We study the ordinary and the symbolic Rees algebras of Fermat ideals. Although symbolic Rees algebras can in general be badly behaved, we show that in our case of interest the symbolic Rees algebras of Fermat ideals are Noetherian. Along the way, we give formulas for the Castelnuovo-Mumford regularity of powers of Fermat ideals. (Received February 22, 2016)

1120-13-218 **Hailong Dao** and **Jonathan Montaño*** (jmontano@ku.edu). *Local cohomology of powers of ideals.* Preliminary report.

Let $(R, \mathfrak{m})$ be a commutative local ring of dimension d and I an R-ideal. The asymptotic behavior of the sequence $\{\lambda(\mathrm{H}^0_{\mathfrak{m}}(R/I^n))\}_{n\geqslant 0}$ has been studied by several authors. For example, Cutkosky proved that if R is analytically unramified the limit $\lim\limits_{n\to\infty} \dfrac{\lambda(\mathrm{H}^0_{\mathfrak{m}}(R/I^n))}{n^d}$ exists for any I, this results in particular shows that the ε-multiplicity of Ulrich and Validashti exists as a limit. In this work, we focus on the sequence $\{\lambda(\mathrm{H}^i_{\mathfrak{m}}(R/I^n))\}_{n\geqslant 0}$ for $i > 0$. We are able to show that, for large n, this sequence coincides with a quasi-polynomial if I is a monomial ideal. Moreover, for square-free quadratic monomial ideals we show that the limit $\lim\limits_{n\to\infty} \dfrac{\lambda(\mathrm{H}^i_{\mathfrak{m}}(R/I^n))}{n^d}$ exists. (Received February 22, 2016)

1120-13-223 **Dane Wilburne*** (dwilburn@hawk.iit.edu), 3145 South May Street, Chicago, IL 60608. *Combinatorial applications of a randomized algorithm for solving systems of polynomial equations.* Preliminary report.

The theory of violator spaces provides an abstract framework for constructing an algorithm to solve large systems of polynomial equations. This algorithm has expected runtime that is linear in the number of input polynomials. In this talk, I will describe the violator space approach for solving systems of polynomials and explore potential combinatorial applications of this idea. (Received February 22, 2016)

1120-13-229 **Amanda Croll**, **Roger Dellaca**, **Justin Hoffmeier**, **Vivek Mukundan**, **Denise Rangel Tracy*** (detracy@syr.edu), **Liana Sega**, **Gabriel Sosa** and **Peder Thompson**. *Koszul homology and rational Poincaré Series.*

In this talk, we will consider the Koszulness of a local ring. Specially, whether the structure of the homology classes of the Koszul complex can be used to detect if a ring is Koszul. In addition, we will discuss a connection between this and the rationality of Poincaré series of the residue field.
(Received February 22, 2016)

1120-13-230 **Nursel Erey*** (nursel.erey@ndsu.edu), NDSU Dept #2750, PO Box 6050, Fargo, ND 58108-6050, and **Sara Faridi**. *Resolutions of monomial ideals via facet covers.*

In this talk, we will discuss the relationship between facet covers of simplicial complexes and the minimal free resolutions of associated monomial ideals. This talk is based on joint paper with Sara Faridi. (Received February 22, 2016)

1120-13-242 **Solomon Akesseh*** (sakesseh2@math.unl.edu), University of Nebraska Lincoln - Math Dept, 210 Avery Hall, Lincoln, NE 68588-0130. *Ideal containments under flat extensions.*

Let $\varphi : S = k[y_0, ..., y_n] \to R = k[y_0, ..., y_n]$ be given by $y_i \to f_i$ where $f_0, ..., f_n$ is an R-regular sequence of homogeneous elements of the same degree. A recent paper shows for ideals, $I_\Delta \subseteq S$, of matroids, Δ, that $I_\Delta^{(m)} \subseteq I^r$ if and only if $\varphi_*(I_\Delta)^{(m)} \subseteq \varphi_*(I_\Delta)^r$ where $\varphi_*(I_\Delta)$ is the ideal generated in R by $\varphi(I_\Delta)$. We prove this result for saturated homogeneous ideals I of configurations of points in $\mathbb{P}^n$ and use it to obtain new counterexamples to $I^{(3)} \subseteq I^2$ from previously known counterexamples. (Received February 22, 2016)

1120-13-244 **Jennifer Biermann*** (jbierman@mtholyoke.edu), **Augustine O'Keefe** and **Adam Van Tuyl**. *A lower bound on the regularity of toric ideals of graphs.* Preliminary report.

Let G be a finite simple graph. We find a lower bound for the Castelnuovo-Mumford regularity for the toric ideal I_G associated to G in terms of the sizes and number of induced complete bipartite graphs in G. (Received February 22, 2016)

1120-13-245 **Jennifer Biermann**, **Augustine O'Keefe*** (aokeefe@conncoll.edu) and **Adam Van Tuyl**. *An upper bound on the regularity of toric ideals of graphs.* Preliminary report.

Given a finite simple graph G, one can associate a toric ideal which we call I_G. We say that G is a chordal bipartite graph if it has no induced cycles of length six or larger. For such graphs, we find an upper bound on the Castelnuovo-Mumford regularity of I_G in terms of the size of the bipartition of G. (Received February 22, 2016)

1120-13-250 **Eliana M Duarte***, emduart2@illinois.edu, and **Hal Schenck**. *Syzygies and tensor product surfaces.*

The use of syzygies to compute implicit equations of parameterized surfaces has become an important tool for applications in computer graphics. One type of surface that is common in this setting is the closure of the image of a rational map $\phi : \mathbb{P}^1 \times \mathbb{P}^1 - \to \mathbb{P}^3$, also known as a tensor product surface. In the first part of this talk I will explain how the syzygies of the defining polynomials of ϕ determine the implicit equation of the closure of the image. For the second part I will present recent progress on understading the structure of the syzygies that determine the implicit equation for the case that the base locus of ϕ is a generic set of points in $\mathbb{P}^1 \times \mathbb{P}^1$. (Received February 22, 2016)

1120-13-253 **Elizabeth Gross*** (elizabeth.gross@sjsu.edu), San José, CA 95192, and **Nida Obatake** and **Nora Youngs**. *Toric ideals of neural codes.*

A neural code is a collection of codewords (0-1 vectors) of a given length n; it captures the co-firing patterns of a set of neurons. A neural code is convexly realizable if there exist n convex sets in some $\mathbb{R}^d$ so that each codeword in the code corresponds to a unique intersection carved out by the convex sets. There are some methods to determine whether a neural code is convexly realizable, however, these methods do not describe how to draw a realization. In this work, we construct toric ideals from neural codes, and we show how these ideals are related to the theory of piercings in the field of information visualization. (Received February 22, 2016)

1120-13-256 **David Cook II** and **Jessica Striker*** (jessica.striker@ndsu.edu). *Combinatorial dynamics of monomial ideals.* Preliminary report.

We introduce the notion of combinatorial dynamics on algebraic ideals by translating combinatorial results involving rowmotion and other toggle group actions on order ideals of posets to the setting of monomial ideals. (Received February 23, 2016)

1120-13-257 **Nursel Erey*** (nursel.erey@ndsu.edu), NDSU Dept #2750, PO Box 6050, Fargo, ND 58108-6050, and **Sara Faridi**. *Minimal free resolutions of monomial ideals.*

Given a simplicial complex Δ, one can associate a squarefree monomial ideal generated by the facets of Δ. In this talk, we will discuss some algebraic invariants of squarefree monomial ideals in terms of combinatorial properties of their simplicial complexes. This talk is based on joint paper with Sara Faridi. (Received February 23, 2016)

1120-13-265 **Roberto Barrera*** (rbarrera@math.tamu.edu), **Jeffrey Madsen** and **Ashley K. Wheeler**. *A finiteness result for local cohomology modules of Gorenstein Stanley-Reisner rings.* Preliminary report.

Let k be a field, let R be a polynomial ring, and let $\mathcal{D}$ be the ring of k-linear differential operators of R. In 2010, Lyubeznik gave a characteristic free proof that R_f has finite length in the category of $\mathcal{D}$-modules. Using a similar approach, we show an analogous statement for when R is a Gorenstein Stanley-Reisner ring. (Received February 23, 2016)

1120-13-274 **Linquan Ma**, **Janet Page**, **Rebecca R.G.*** (rirg@umich.edu), **William Taylor** and **Wenliang Zhang**. *F-singularities under generic linkage.* Preliminary report.

We prove some results on the singularities of generically linked ideals in characteristic $p > 0$. This is motivated by work of Wenbo Niu in equal characteristic 0. Starting with a complete intersection or almost complete intersection in a polynomial ring, we give conditions for its first generic link to be F-rational. We also show that the F-pure threshold of the first generic link of a complete intersection is greater than or equal to the F-pure threshold of the original ideal. (Received February 23, 2016)

1120-13-276 **Serkan Hosten*** (serkan@sfsu.edu), 1600 Holloway Avenue, San Francisco, CA 94132, and **Winfried Bruns**. *Cohen-Macaulayness of initial ideals of normal toric ideals.* Preliminary report.

Hochster's theorem shows that every normal toric ideal is Cohen-Macaulay. More than fifteen years ago Sturmfels asked whether a normal toric ideal has always a Cohen-Macaulay initial ideal. We will report progress on the road to answering this question. We will show that initial ideals that are associated to what we call normal

liftings are Cohen-Macaulay, and we will provide an effective test whether such a normal lifting exists. We will also provide examples where normal toric ideals without such liftings still can have Cohen-Macaulay initial ideals. (Received February 23, 2016)

14 ► Algebraic geometry

1120-14-36 **Tyler Foster** and **Dhruv Ranganathan***, 10 Hillhouse Avenue, New Haven, CT 06511. *Geometry over higher rank valued fields.*

I will discuss recent joint work with Tyler Foster, in which study the interaction between the polyhedral geometry of multistage degenerations, tropicalization, and the topology of a newly defined space – the Hahn analytification – that generalizes the standard Berkovich analytification. We discuss degenerations of toric varieties over higher rank bases in detail. Furthermore, the Hahn analytification is applied resolve a conjecture of Banerjee on the connectivity of higher rank tropicalizations. (Received January 28, 2016)

1120-14-46 **Jaydeep Chipalkatti*** (jaydeep.chipalkatti@umanitoba.ca). *Poncelet's Theorem over finite fields.*

Suppose that we are given two nonsingular conics A and B in the projective plane. Poncelet's closure theorem says that if there exists a triangle inscribed in A and circumscribed around B, then there exists a continuous family of such triangles. We will say that the conics satisfy the 'Poncelet triangle condition' if such is the case. In this talk, we will calculate the probability that a pair of randomly chosen conics in a finite projective plane satisfies the triangle condition. (Received February 01, 2016)

1120-14-49 **Tassos Vogiannou*** (vogiannou@math.umass.edu), Dept. of Math & Stats, LGRT, University of Massachusetts, 710 N. Pleasant Street, Amherst, MA 01002. *Spherical tropicalization.*

After giving a brief review on spherical varieties, we introduce tropicalization and tropical compactifications in spherical homogeneous spaces in the constant coefficient case. This is a natural extension of tropicalization in tori. We provide some examples and discuss possible applications. (Received February 05, 2016)

1120-14-78 **David Cook**, **Brian Harbourne** and **Juan Migliore*** (migliore.1@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556, and **Uwe Nagel**. *Line arrangements and configurations of points with an unusual geometric property.*

I will give part 2 of a joint talk with Brian Harbourne. We discuss parts of a paper, arXiv:1602.02300, written jointly also with D. Cook and U. Nagel. The well-known SHGH conjecture proposes a solution to the question of how many conditions a general union of fat points imposes on the complete linear system of plane curves of fixed degree d. We propose a new problem, namely to understand the number of conditions imposed by a general union of fat points on the incomplete linear system defined by the condition of passing through a finite set of points, Z (not general). Clearly the geometry of Z has to play a role, but how it manifests itself is slowly emerging. We give a careful analysis of the first interesting case, namely that of just one fat point, having multiplicity $d-1$. After studying the geometry inherent in those Z which admit unexpected curves (i.e. those Z for which a naive dimension count doe not correctly predict the number of conditions imposed on the linear system), we relate our results to properties of the arrangement of lines dual to Z, using work of Di Gennaro-Ilardi-Valles and Faenzi-Valles. We also relate our results to a certain Lefschetz property, leading to a connection to Terao's conjecture on the freeness of line arrangements. (Received February 12, 2016)

1120-14-82 **Grigoriy Blekherman** and **Rainer Sinn*** (sinn@math.gatech.edu), Georgia Institute of Technology, School of Mathematics, 686 Cherry Street NW, Atlanta, GA 30332, and **Mauricio Velasco**. *Matrix completion, free resolutions, and sums of squares.* Preliminary report.

I will discuss a matrix completion problem arising in combinatorial statistics and explain how we can use results in algebraic geometry (or combinatorial commutative algebra) to understand it better. The object linking the two different areas is the cone of sums of squares and its properties as a convex cone. (Received February 13, 2016)

1120-14-84 **David Cook II** and **Brian Harbourne*** (bharbourne1@unl.edu), Math Department, University of Nebraska-Lincoln, Lincoln, NE 68588-0130, and **Juan Migliore** and **Uwe Nagel**. *Line arrangements and configurations of points with an unusual geometric property.*

I will give part 1 of a joint talk with Juan Migliore. We discuss parts of a paper, arXiv:1602.02300, written jointly also with D. Cook and U. Nagel. The well-known SHGH conjecture proposes a solution to the question of how many conditions a general union of fat points imposes on the complete linear system of plane curves of fixed degree d. We propose a new problem, namely to understand the number of conditions imposed by a general union of fat points on the incomplete linear system defined by the condition of passing through a finite set of points, Z (not general). Clearly the geometry of Z has to play a role, but how it manifests itself is slowly emerging. We give a careful analysis of the first interesting case, namely that of just one fat point, having multiplicity $d-1$. After studying the geometry inherent in those Z which admit unexpected curves (i.e. those Z for which a naive dimension count doe not correctly predict the number of conditions imposed on the linear system), we relate our results to properties of the arrangement of lines dual to Z, using work of Di Gennaro-Ilardi-Vallès and Faenzi-Vallès. We also relate our results to a certain Lefschetz property, leading to a connection to Terao's conjecture on the freeness of line arrangements. (Received February 13, 2016)

1120-14-103 **Bruce Reznick*** (reznick@illinois.edu), 1409 W Green St, Urbana, IL 61801. *Sums of powers of binary quadratic forms.* Preliminary report.

Suppose $p \in \mathbb{C}[x,y]$ is a binary form of degree $2d$. We are interested in the minimum number k of quadratic forms q_j so that

$$p = \sum_{j=1}^{k} q_j^d.$$

We show that *every* sextic binary form p can be written a sum of three cubes of binary quadratic forms in infinitely many different ways, and we present an algorithm for finding some (but not all) solutions. This is part of a larger project with Boris Shapiro. (Received February 16, 2016)

1120-14-144 **Amanda Ellis Francis***, 275 TMCB, Brigham Young University, Provo, UT 84602, and **Nathan Priddis** and **Andrew Schaug**. *A Landau Ginzburg mirror theorem inspired by Borcea-Voisin symmetry.* Preliminary report.

Landau-Ginzburg models appear in mirror symmetry and have connections to other important mathematical models, including those in Borcea-Voisin mirror symmetry. In this talk I will briefly review the history and construction of the A- and B-models in Landau-Ginzburg mirror symmetry and then discuss a recent Landau-Ginzburg theorem inspired by Borcea-Voisin mirror pairs (joint work with Nathan Priddis and Andrew Schaug). (Received February 19, 2016)

1120-14-187 **Ursula Whitcher*** (whitchua@uwec.edu). *Arithmetic mirror symmetry and K3 surfaces.*

Mirror symmetry predicts surprising geometric correspondences between distinct families of algebraic varieties. In some cases, these correspondences have arithmetic consequences. For example, we can use mirror symmetry to explore the structure of the zeta function, which encapsulates information about the number of points on a variety over a finite field. We use Berglund-Huebsch-Krawitz mirror symmetry to make and test predictions about the zeta functions of certain K3 surfaces described by quartic polynomials. This talk describes joint work with Charles Doran, Tyler Kelly, Adriana Salerno, Steven Sperber, and John Voight. (Received February 21, 2016)

1120-14-193 **Emma Previato***, Department of Mathematics and Statistics, Boston, MA 02215-2411. *Sato's tau function in Painlevé theory.*

In the 1970s, via probability in random-matrix theory, equations of statistical mechanics were given isomonodromic form and written by tau functions; this powerful method is based on the intrinsic meaning of the tau function as a determinant. One offshoot of the formula is that tau solves ODEs of Painlevé type. The tau function also gives the general solution to "integrable hierarchies" of PDEs, archetypally KP and Toda hierarchy. Independently, self-similar solutions of the hierarchy satisfy Painlevé equations. The relationship of the theories is still a mystery. Notably, Painlevé VI, the most general, was long absent from either model. In 1999, L. Haine and J.-P. Semengue produced Painlevé VI for a random-matrix ensemble whose tau function solves the Toda hierarchy, linking it with the Jacobi polynomials. The goals of this talk include an interpretation of the hierarchy flows in terms of the monodromy variables in random-matrix theory; and a construction of self-similar solutions on the one hand, and a finite-dimensional Hamiltonian system built from the random-matrix data with

deformations those of the hierarchy, on the other hand. We use the work by Haine and Semengues, but revisit the idea of C.A. Tracy and H. Widom to produce the Hamiltonian (1993). (Received February 22, 2016)

1120-14-219 **Rebecca Tramel*** (rtramel@illinois.edu), University of Illinois, Department of Mathematics, 1409 W Green Street, Urbana, IL 61801. *Bridgeland stability conditions on surfaces.*

Abstract: Let X be a smooth projective surface. In 2002, Bridgeland defined a notion of stability for objects in $\mathcal{D}^b(X)$, which can be thought of as a generalization of slope stability for vector bundles on curves. The work of Bayer-Macri and of Toda shows that there are nice connections between deformations in $\mathrm{Stab}(X)$, the space of all Bridgeland stability conditions on X and the birational geometry of X. I will discuss the case in which X contains a smooth projective curve C of negative self-intersection. (Received February 22, 2016)

1120-14-249 **Natalie Hobson*** (nhobson@uga.edu), Boyd Graduate Research Center, 200 DW Brooks Dr., Athens, GA 30602. *Vector bundles of conformal blocks with $\mathfrak{sp}_{2\ell}$ at level one.* Preliminary report.

Given a simple Lie algebra $\mathfrak{g}$, a positive integer ℓ, and an n-tuple $\vec{\lambda}$ of dominant integral weights for $\mathfrak{g}$ at level ℓ, one can define a vector bundle on $\overline{\mathrm{M}}_{g,n}$ known as a vector bundle of conformal blocks. The data defining these vector bundles provide potentially an infinite number of elements in the nef cone of $\overline{\mathrm{M}}_{0,n}$ to analyze; results relating divisors associated to different data is significant in understanding these objects. In this talk, we will relate the divisors of conformal blocks with differing Lie data. Explicitly, we give necessary and sufficient conditions on when the divisors defined with $\mathfrak{sl}_2$ and $\mathfrak{sp}_{2\ell}$ are equivalent. We also explore all bundles defined with $\mathfrak{sp}_{2\ell}$ at level one, we show these divisors become equivalent when the Lie rank is taken large enough. (Received February 22, 2016)

1120-14-285 **Julie Rana*** (jrana@umn.edu), **Jenia Tevelev** and **Giancarlo Urzua**. *The Craighero-Gattazzo surface is simply-connected.* Preliminary report.

We show that the Craighero-Gattazzo surface, the minimal resolution of an explicit complex quintic surface with four elliptic singularities, is simply-connected. This was first conjectured by Dolgachev and Werner. The proof utilizes an interesting technique: to prove a topological fact about a complex surface we use algebraic reduction mod p and deformation theory. (Received February 23, 2016)

1120-14-291 **Dustin Cartwright***, Department of Mathematics, 227 Ayres Hall, Knoxville, TN 37996-1320. *Dual complexes of unirational varieties.*

The dual complex of a semistable degeneration records the combinatorics of the intersections in the special fiber. It is natural to ask for connections between the geometry of an algebraic variety and the combinatorial properties of its dual complex. In this talk, I will explain one such result: The dual complex of an n-dimensional uniruled variety has the homotopy type of an $(n-1)$-dimensional simplicial complex. The key technical tool is a specialization map to dual complexes and a balancing condition for these specialization. (Received February 23, 2016)

1120-14-293 **Anna Kazanova*** (kazanova@uga.edu). *Vector bundles on moduli space of stable curves with marked points.*

Conformal block vector bundles are vector bundles on the moduli space of stable curves with marked points defined using certain Lie theoretic data. Over smooth curves, these vector bundles can be identified with generalized theta functions. In this talk we discuss extension of this identification over the stable curves, and view some applications. (Received February 23, 2016)

15 ► Linear and multilinear algebra; matrix theory

1120-15-51 **Leslie Hogben*** (hogben@aimath.org). *Generalizations of the Strong Arnold Property and the inverse eigenvalue problem of a graph.*

For a given graph G and an associated class of real symmetric matrices whose off-diagonal entries are are nonzero exactly where G has edges, the inverse eigenvalue problem of G is to determine the collection of all possible spectra for such matrices. Inverse eigenvalue problems and the background of this problem will be described, together with techniques such as the fundamental work of Colin de Verdière and the Strong Arnold Property. Two extensions of the Strong Arnold Property that target a better understanding of all possible spectra and their associated multiplicities will be presented, referred to as the Strong Spectral Property and the

Strong Multiplicity Property. Applications of these properties to the inverse eigenvalue problem of a graph will be discussed.

This talk is based on joint work with W. Barrett, S. Fallat, H. T. Hall, J. C.-H. Lin, and B.L. Shader. (Received February 05, 2016)

1120-15-67 **Jianxin Chen**, **Nathaniel Johnston**, **Chi-Kwong Li** and **Sarah Plosker*** (ploskers@brandonu.ca). *Some matrix theory questions arising from quantum coherence.*

The two main concepts that separate quantum information theory from classical information theory are entanglement and superpositions. Both can be used as resources and it is therefore important to measure them. Various measures of quantum entanglement have been investigated for years, but measures of coherence (i.e., "how superpositioned" a quantum state is) have only recently been formally studied. In this talk we will focus on three measures of quantum coherence, using a matrix theory point of view to answer some open questions about them. (Received February 09, 2016)

1120-15-69 **Xavier Martinez-Rivera*** (xaviermr@iastate.edu). *Classification of families of pr- and epr-sequences.*

The *principal minor assignment problem* asks the following question: can we find an $n \times n$ real symmetric matrix having prescribed principal minors. An attempt to simplify this problem led to the introduction of two sequences for a symmetric or (complex Hermitian matrix). The *principal rank characteristic sequence* of an $n \times n$ symmetric matrix B is $r_0]r_1 \cdots r_n$, where, for $k = 1, 2, \ldots, n$, $r_k \in \{0, 1\}$ and $r_k = 1$ if and only if B has a nonzero principal minor of order k, while $r_0 = 1$ if and only if B has a 0 on its main diagonal (otherwise $r_0 = 0$). The *enhanced principal rank characteristic sequence* of an $n \times n$ symmetric matrix B is $\ell_1\ell_2 \cdots \ell_n$, where ℓ_k is A (respectively, N) if all (respectively, none) the principal minors of order k are nonzero; if some but not all are nonzero, then $\ell_k =$ S. Results regarding the attainability of certain classes of sequences are discussed, as well as restrictions for some subsequences to appear in an attainable sequence. (Received February 09, 2016)

1120-15-71 **Colin M Garnett*** (colin.garnett@bhsu.edu), 1200 University St., Unit 9003, Spearfish, SD 57799-9003. *Combinatorial structures that preclude SAP.* Preliminary report.

It is well known that a zero-nonzero pattern cannot be spectrally arbitrary if its digraph doesn't have at least two loops and at least one two cycle. This talk focuses on several other combinatorial conditions on the digraph that preclude it from being spectrally arbitrary. In particular we are sometimes able to reduce the number of unknown entries to be below the threshold of $2n - 1$. We are also able to describe some structures that allow us to conclude that one of the coefficients in the characteristic polynomial is in the ring generated by the other coefficients. (Received February 10, 2016)

1120-15-129 **Jephian C.-H. Lin*** (chlin@iastate.com), Department of Mathematics, Iowa State University, Ames, IA 50011. *Using a new zero forcing process to guarantee the Strong Arnold Property.*

A given symmetric matrix A is said to have the *Strong Arnold Property* (SAP) if the zero matrix is the only symmetric matrix Xthat satisfies $A \circ X = O$, $I \circ X = O$, and $AX = O$. The SAP plays a key role in ensuring the minor-monotonicity of the Colin de Verdière type parameters μ, ν, and ξ. To understand the SAP, the connection between the zero-nonzero pattern of a symmetric matrix and the adjacency of a simple graph provides important information. In this talk, a method of using the graph structure to guarantee the SAP will be introduced, with the help of the zero forcing process. (Received February 18, 2016)

1120-15-149 **Adam H Berliner*** (berliner@stolaf.edu), **Dale Olesky** and **Pauline van den Driessche**. *Refined inertias for zero-nonzero patterns.* Preliminary report.

Let A be any real matrix realization of a given sign pattern $\mathcal{S}$. The refined inertia of $\mathcal{S}$ is the collection of 4-tuples $\{\text{ri}(A) = (n_+, n_-, n_z, 2n_p)\}$, where n_+ and n_- give the number of eigenvalues with positive real part and negative real part (respectively) and n_z and $2n_p$ give the number of zero and purely imaginary eigenvalues (respectively). Recent research has focused on $n \times n$ patterns whose refined inertia contains $\mathbb{H}_n = \{(0, n, 0, 0), (0, n-2, 0, 2), (2, n-2, 0, 0)\}$. In this talk, we extend these notions to zero-nonzero patterns and discuss some results for patterns whose refined inertia contains $\mathbb{H}_n^* = \{(0, n, 0, 0), (0, n-2, 0, 2), (2, n-2, 0, 0), (n, 0, 0, 0), (n-2, 0, 0, 2), (n-2, 2, 0, 0)\}$. (Received February 19, 2016)

1120-15-166 **Steve Kirkland*** (stephen.kirkland@umanitoba.ca), Department of Mathematics, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada. *Kemeny's Constant and an analogue of Braess' Paradox for Markov chains.* Preliminary report.

A square matrix that is entrywise nonnegative and has all row sums equal to 1 is called a stochastic matrix, and such matrices play a central role in the study of Markov chains. Given a stochastic matrix A, Kemeny's constant $K(A)$ measures the expected number of steps required for the Markov chain to transition from a given initial state to a randomly chosen final state.

In this talk, we give a brief introduction to Kemeny's constant. We then explore an analogue of Braess' paradox (wherein adding a road to a network can have the counter-intuitive effect of increasing travel times). Specifically, we will discuss how adding an edge into an undirected graph can increase the value of Kemeny's constant for a certain Markov chain that is naturally associated with the graph. (Received February 20, 2016)

1120-15-180 **In-Jae Kim*** (in-jae.kim@mnsu.edu), 273 Wissink Hall, Mankato, MN 56001. *Matrix theory in data science.*

In this talk we will discuss some examples showing connection between matrix theory and data science. (Received February 21, 2016)

1120-15-181 **Jane Breen*** (breenj3@myumanitoba) and **Steve Kirkland**. *Mean first passage times and load-balancing for Markov chains.* Preliminary report.

For a Markov chain described by an irreducible stochastic matrix T of order n, the mean first passage time $m_{i,j}$ measures the expected time for the Markov chain to reach state j given that the system begins in state i, thus quantifying the short-term behaviour of the chain. In this talk, we give a lower bound for the maximum mean first passage time in terms of the stationary distribution vector of T, and characterise some matrices for which equality is attained. We also discuss the restrictions placed on the directed graph corresponding to the matrix T if equality is to be attained. (Received February 21, 2016)

1120-15-267 **Travis Peters** (tpeters@iastate.edu) and **Michael Young*** (myoung@iastate.edu). *A Linear Algebraic Approach to LIGHTS OUT! on $G\square P_t$.*

The game LIGHTS OUT! is played on a square grid of buttons; each button may be on or off. Pressing a button changes the on/off state of the light of the button pressed and of all its vertical and horizontal neighbors. Given an initial configuration of buttons that are lit, the object of the game is to turn all the lights off. The game can be generalized to arbitrary graphs. We investigate graphs of the form $G\square P_t$. In particular, we extend properties of the Fibonacci polynomials to matrices in order to provide conditions for which $G\square P_t$ is universally solvable. (Received February 23, 2016)

16 ► Associative rings and algebras

1120-16-190 **Alexander Garver*** (alexander.garver@gmail.com), School of Mathematics, 206 Church Street SE, Minneapolis, MN 55455, and **Thomas McConville**. *Noncrossing Tree Partitions and Tiling Algebras.*

We introduce noncrossing tree partitions which are certain noncrossing collections of curves on a tree embedded in a disk. These generalize the classical type A noncrossing partitions, and, as in the classical case, they form a lattice whose partial order is given by refinement. The data of a tree embedded in disk also defines a finite dimensional algebra called a *tiling algebra* by Coelho Simões and Parsons. Examples of such algebras are type A Jacobian algebras and type A m-cluster-tilted algebras, which arise in the context of cluster algebras. Simple-minded collections for finite dimensional algebras are important representation theoretic objects. For example, such objects have been used to construct derived equivalences for symmetric algebras by Rickard. Our main result is a combinatorial classification of 2-term simple-minded collections for tiling algebras in terms of noncrossing tree partitions. This is joint work with Thomas McConville. (Received February 21, 2016)

19 ► K-theory

1120-19-153 **Mahir Bilen Can*** (mcan@tulane.edu), Department of Mathematics, Tulane University, 6823 St. Charles Ave, New Orleans, LA 70118, and **Soumya D Banerjee** and **Michael O Joyce**. *Equivariant K-theory of certain wonderful compactifications and permutohedra.* Preliminary report.

In this talk we present our work on the Stanley-Reisner type presentation of the equivariant K-theory of a smooth projective spherical variety. Our running examples include wonderful compactifications of minimal and non-minimal rank symmetric varieties. (Received February 20, 2016)

20 ► Group theory and generalizations

1120-20-31 **Artem Novozhilov*** (artem.novozhilov@ndsu.edu), NDSU, Department of Mathematics, PO Box 6050, Fargo, ND 58108, and **Yuri Semenov**. *On Eigen's quasispecies model and isometry groups acting on finite metric spaces.*

A nowadays classical Eigen's or quasispecies model of the virus evolution uses as the underlying geometry the N-dimensional hypercube. The distances between the vertices of this hypercube are measured by the number of edges connecting them. While this geometry has a transparent biological interpretation in terms of sequences composed of zeroes and ones, it is a natural generalization to consider an arbitrary isometry group acting on an abstract metric space to move to a next level of abstraction of the quasispecies model. In this talk we introduce an abstract generalization of Eigen's model such that the sequences are identified with the points of a finite metric space X together with a group of isometries acting transitively on X. In particular, a simplicial analogue of the original quasispecies model is discussed. (Received January 26, 2016)

1120-20-108 **Maranda Franke*** (mfranke2@math.unl.edu), 203 Avery Hall, Lincoln, NE 68588. *Geodesic language complexity and group structure.* Preliminary report.

A finitely generated group has solvable word problem if its language of geodesics is computable; the complexity of this language has connections to algebraic and geometric properties of the group. Gilman, Hermiller, Holt and Rees showed that a group is virtually free if and only if there is a finite generating set which produces a locally excluding geodesic language. In this talk, I will discuss existence results that were motivated by the search for a group theoretic characterization of the related language restriction piecewise excluding. (Received February 16, 2016)

1120-20-131 **Benjamin Steinberg*** (bsteinberg@ccny.cuny.edu). *Etale groupoid algebras and inverse semigroups.*

The speaker has associated to any commutative ring with unit $\Bbbk$ and etale groupoid $\mathcal{G}$ with totally disconnected unit space an associative $\Bbbk$-algebra. In the case that the base ring is the field of complex numbers, one obtains a pre-C^*-algebra whose completion is the usual groupoid C^*-algebra of $\mathcal{G}$.

Special cases of this construction include Leavitt path algebras, group algebras, inverse semigroup algebras, commutative algebras generated by idempotents and certain group cross products and partial cross products. Nekrashevych has recently used groupoid algebras to provide a uniform construction of finitely generated simple algebras of quadratic growth over arbitrary base fields.

In this talk, we survey some of the recent developments, focussing on aspects like simplicity, primitivity and semi-primitivity and Mortia equivalence. (Received February 18, 2016)

1120-20-237 **Tim Susse*** (tsusse2@unl.edu), **Susan Hermiller** and **Mark Brittenham**. *Geometry of the word problem in closed 3-manifold groups.* Preliminary report.

Given a finite presentation of a group, the word problem asks whether there is an algorithm that determines whether a given word over the generators is equal to the identity. While not all finitely presented groups have solvable word problems, many classes of groups have uniform algorithms for solving the problem. In this talk we will discuss autostackability, a property which rephrases the word problem in dynamical terms, where paths in the Cayley graph flow towards a unique normal form in a way that is computable by a finite state automaton. Such a structure gives a solution to the word problem. In this talk we will discuss examples of autostackable structures, focusing on hyperbolic and relatively hyperbolic groups. We will also discuss closure properties of the class and prove that every closed 3-manifold group is autostackable. (Received February 22, 2016)

1120-20-254 **Aaron Calderon*** (aaron.calderon256@huskers.unl.edu), 2225 S 86 St, Omaha, NE 68124. *Conjugacy geodesics in Coxeter groups.* Preliminary report.

Coxeter groups are groups generated by reflectional symmetries of mathematical objects. These groups and the spaces on which they act are an important source of examples in group theory and topology and range from tilings of manifolds to homology spheres to CAT(0) cube complexes. In this talk I will discuss results on language theoretic properties of the set of geodesics on the Cayley graphs of Coxeter groups and a generalization (due to Tits) called extended Coxeter groups. These properties are related to many classical problems in geometric group theory, including automaticity, rationality of the group's growth series and the solvability of the word problem. (Received February 22, 2016)

1120-20-302 **Azer Akhmedov** and **Damiano Fulghesu***, fulghesu@mnstate.edu. *Arithmetic sets in groups.*

In this talk, we introduce the notion of arithmetic set for an arbitrary, finitely generated group. Every tile of a group is an arithmetic set, while arithmetic sets form a larger class of subsets. Arithmeticity strongly reflects the geometry of the group. For example, in negatively curved groups, such as free groups of rank at least two, being arithmetic is a loose condition on sets, while in groups at the other extreme, such as cyclic groups, it imposes very strong conditions with number-theoretic flavor. (Received February 23, 2016)

22 ► Topological groups, Lie groups

1120-22-16 **Bradley Currey**, **Hartmut Fuhr** and **Vignon Oussa*** (voussa@bridgew.edu), Dighton, MA 02715. *A classification of irreducible admissible groups in dimension three.* Preliminary report.

The initial constructions of continuous wavelet transforms relied primarily on the similitude group (uniform scaling and rigid motions). However, in the past few years, the focus has shifted towards more diverse choices of matrix groups. An irreducibly admissible matrix group is characterized by the property that its dual action has a single open orbit with associated compact stabilizer. In this presentation, we will give a full list up to conjugacy of these groups acting in dimension three. (Received January 15, 2016)

1120-22-255 **Christopher Caruvana***, christopher.caruvana@unt.edu, and **Robert Kallman**. *The Lie ring of analytic functions on the disk is algebraically determined.* Preliminary report.

We will show that any Lie ring isomorphism between a Polish Lie ring and the Lie ring of analytic functions on the disk is a homeomorphism. (Received February 22, 2016)

1120-22-297 **Azer Akhmedov** and **Michael P Cohen*** (michael.cohen@ndsu.edu). *Existence and genericity of finite topological generating sets for homeomorphism groups.*

We show that the topological groups $\mathrm{Diff}^1_+(I)$ and $\mathrm{Diff}^1_+(\mathbb{S}^1)$ of orientation-preserving C^1-diffeomorphisms of the interval and the circle, respectively, admit finitely generated dense subgroups. We also investigate the question of genericity (in the sense of Baire category) of such finite topological generating sets in related groups. We show that the generic pair of elements in the homeomorphism group $\mathrm{Homeo}_+(I)$ generate a dense subgroup of $\mathrm{Homeo}_+(I)$. By contrast, if M is any compact connected manifold with boundary other than the interval, we observe that an open dense set of pairs from the associated boundary-fixing homeomorphism group $\mathrm{Homeo}(M, \partial M)$ will generate a discrete subgroup. We make similar observations for homeomorphism groups of manifolds without boundary including $\mathbb{S}^1$. (Received February 23, 2016)

30 ► Functions of a complex variable

1120-30-56 **Kyle Kinneberg*** (kk43@rice.edu). *Hölder domains, John domains, and conformal dimension.*

Hölder domains and John domains are two classes of planar sets that have been studied closely in classical potential theory and conformal mapping. They have also arisen naturally in complex dynamics through iteration of polynomials and rational maps. In Rohde and Schramm's foundational work on SLE, they show that the unbounded complementary component of an SLE_κ trace is a Hölder domain, almost surely, if $\kappa \neq 4$. In this talk, I'll discuss a deterministic "converse" relationship, where Hölder domains produce driving terms with regularity similar to that of Brownian motion through the Loewner correspondence. Then, motivated by some questions about the quasiconformal geometry of SLE curves, I'll discuss the conformal dimension problem. As a toy case,

we will see that boundaries of John domains have conformal dimension equal to 1. (Received February 07, 2016)

1120-30-312 **Joan Lind*** (jlind@utk.edu) and **Jessica Robins**. *Loewner deformations driven by the Weierstrass function.*

The Loewner differential equation provides a way of encoding growing families of sets into continuous real-valued functions. Most famously, Schramm-Loewner Evolution (SLE) are the growing random families of sets that are encoded via the Loewner equation by a multiple of Brownian motion. We consider the families of sets encoded by a multiple of the Weierstrass function, which is a deterministic analog of Brownian motion, and prove that there is a phase transition in this setting, just as there is in the SLE setting. (Received February 23, 2016)

33 ► Special functions

1120-33-179 **Diego E. Dominici*** (dominicd@newpaltz.edu), 1 Hawk Dr., New Paltz, NY 12561. *Lax pairs as a bridge between integrable systems and special functions.* Preliminary report.

One of the central ideas in the theory of integrable systems is the fact that each integrable nonlinear problem can be represented as the compatibility condition between two linear equations of a Lax pair.

In this talk, we will present some connections between Lax pairs, the Toda lattice, orthogonal polynomials, and differential-difference equations. (Received February 21, 2016)

1120-33-216 **Thomas Joachim Bothner*** (bothner@umich.edu), 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *Zeros of large degree Vorob'ev-Yablonski polynomials via a Hankel determinant identity.*

It is well known that all rational solutions of the second Painlevé equation and its associated hierarchy can be constructed with the help of Vorob'ev-Yablonski polynomials and generalizations thereof. The zero distribution of the aforementioned polynomials has been analyzed numerically by Clarkson and Mansfield and the authors observed a highly regular and symmetric pattern: for the Vorob'ev polynomials itself the roots form approximately equilateral triangles whereas they take the shape of higher order polygons for the generalizations.

Very recently Buckingham and Miller completely analyzed the zero distribution of large degree Vorob'ev-Yablonski polynomials using a Riemann-Hilbert/nonlinear steepest descent approach to the Jimbo-Miwa Lax representation of PII equation. In our work we rephrase the same problem in the context of orthogonal polynomials on a contour in the complex plane. The polynomials are then analyzed asymptotically and the zeros localized through the vanishing of a theta divisor on an appropriate hyperelliptic curve.

Our approach starts from a new Hankel determinant representation for the square of the Vorob'ev-Yablonski polynomial. This identity is derived using the representation of Vorob'ev polynomials as Schur functions. (Received February 22, 2016)

35 ► Partial differential equations

1120-35-30 **Barbara Prinari***, University of Colorado Colorado Springs, Colorado Springs, CO, **Gino Biondini**, State University of New York at Buffalo, Buffalo, NY, **Daniel Kraus**, State University of New York at Buffalo, Buffalo, NY , and **Federica Vitale**, University of Salento, Lecce, Italy. *Dark-bright soliton solutions with nontrivial polarization interactions for the three-component defocusing nonlinear Schrödinger Equation.*

In this talk we will present novel dark-bright soliton solutions for the three-component defocusing nonlinear Schrödinger equation with nonzero boundary conditions. The solutions are obtained within the framework of a recently developed inverse scattering transform for the underlying nonlinear integrable PDE, and unlike dark-bright solitons in the two component (Manakov) system in the same dispersion regime, their interactions display non-trivial polarization shift for the two bright components. (Received January 26, 2016)

1120-35-85 **Hong-Ming Yin*** (hyin@wsu.edu), Department of Mathematics and Statistics, Washington State University, Pullman, WA 99164, and **Wendy Skulpakdee** (wskulpakdee@math.wsu.edu), Department of Mathematics, Washington State University, Pullman, WA 99164. *Portfolio optimization for security investment.* Preliminary report.

In this talk, I will present a modified Merton's portfolio optimization problem for security investment. Interest rate and consumption rate are assumed to be functions of time variable. We will derive the problem as an

optimization of wealth subject to certain constrain with underlying a nonlocal partial differential equation. (Received February 14, 2016)

1120-35-88 **Steve Zelditch*** (zelditch@math.northwestern.edu). *Level sets of eigenfunctions: number of components.*

There are several recent results proving that the number of nodal domains of almost all eigenfunctions of an ONB ϕ_j tend to infinity with the eigenvalue on surfaces of negative curvature with a special curve C , either the fixed point set of reflection symmetry or the concave boundary of the surface (Ghosh-Reznikov-Sarnak, Jung-Zelditch, Jang-Jung). Quantum ergodic restriction theorems, sup norm estimates and integrals over C play the key role. My talk gives the same kind of results for all level sets, $\phi_j = a$. The proofs are different from the prior ones and are based on the weak convergence in L2 of normalized Cauchy data. They also depend on whether the L1 norm of the normalized Cauchy tends to zero or not. We do not use sup norms, or compare integrals of ϕ and $|\phi|$ as in prior work. (Received February 14, 2016)

1120-35-110 **Mihai Tohaneanu*** (mihai.tohaneanu@uky.edu), Department of Mathematics, 719 Patterson Office, Lexington, KY 40506. *Global existence for quasilinear wave equations close to Schwarzschild.*

We study the quasilinear wave equation $\Box_g u = 0$, where the metric g depends on u and equals the Schwarzschild metric when u is identically 0. Under a couple of extra assumptions on the metric g near the trapped set and the light cone, we prove global existence of solutions. This is joint work with Hans Lindblad. (Received February 17, 2016)

1120-35-158 **Jacob Shapiro*** (jzshapiro@gmail.com). *Semiclassical resolvent bounds in dimension two.*

We study resolvent bounds near the real axis for semiclassical Schrodinger operators in dimension two. We require mild decay conditions on the potential. The resolvent norm grows exponentially in the inverse semiclassical parameter, but near infinity it grows linearly. As an application, we describe progress toward obtaining wave decay rates for wave equations with rough wavespeed. This work builds from the papers of several authors, including Burq, Cardoso, Datchev and Vodev. (Received February 20, 2016)

1120-35-169 **John A Toth*** (jtoth@math.mcgill.ca), Department of Mathematics, McGill University, 805 Sherbrooke Street West, Montreal, Quebec H3A 2K6, Canada. *Restriction bounds for locally QE eigenfunctions.*

I will give an overview of some recent results on L^2 restriction bounds of Laplace eigenfunctions. (Received February 21, 2016)

1120-35-186 **Dylan Muckerman*** (muckerma@live.unc.edu). *Stabilization rates for transport-diffusion equations.* Preliminary report.

We consider a transport-diffusion equation arising in microfluidic mixing devices. Under a geometric control condition, we show that the L^2 norm decays exponentially. Weakening the geometric control condition to allow for transport vanishing near the boundary, as well as diffusion vanishing near the boundary, we show polynomial decay estimates, with an additional assumption on the initial data. (Received February 21, 2016)

1120-35-196 **Dean Baskin*** (dbaskin@math.tamu.edu). *High frequency estimates for the Helmholtz equation with application to boundary integral equations.*

I will discuss joint work with Euan Spence and Jared Wunsch on high frequency estimates for the Helmholtz equation in exterior domains as well as for interior impedance problems. Motivation for these estimates comes from certain problems in numerical analysis. (Received February 22, 2016)

1120-35-239 **Yaiza C Canzani*** (yaizacanzani@gmail.com), 4 Fayette Park, UNIT #1, Cambridge, MA 02139. *On the structure of zero sets of random waves on a manifold.*

There are several questions about the zero set of Laplace eigenfunctions that have proved to be extremely hard to deal with and remain unsolved. Among these are the study of the size of the zero set, the study of the number of connected components, and the study of the topology of such components. A natural approach is to randomize the problem and ask the same questions for the zero sets of random linear combinations of eigenfunctions. In this talk I will present some recent results in this direction. (Received February 22, 2016)

1120-35-243 **Robert Booth*** (rjbooth@live.unc.edu), University of North Carolina at Chapel Hill, Department of Mathematics, Office 416, Phillips Hall CB #3250, Chapel Hill, NC 27514. *Localized energy for wave equations with degenerate trapping.* Preliminary report.

It is well known that locally in space and average in time, solutions to the Schrödinger equation gain one half of derivative of regularity compared to the initial data. This is referred to as a local smoothing estimate. Analogous estimates exist for solutions to the wave equation - except instead of local smoothing, we attain a global integrability estimate (in time and space). When considering the analogues of these estimates for equations on differentiable manifolds, it is known that geodesic trapping necessitates a loss. For non-degenerate hyperbolic trapping, the loss is logarithmic. For elliptic trapping, everything is lost except a logarithm. Recently, Christianson and Wunsch demonstrated an algebraic loss for solutions to the Schrödinger equation on a surface of revolution with degenerate hyperbolic trapping. In this talk, we will review these prior results and consider the analogue for the wave equation on a surface of revolution with degenerate hyperbolic trapping, attaining an algebraic loss. We will use a quasimode construction to show that our estimate is sharp. This is joint work with Hans Christianson, Jason Metcalfe, and Jacob Perry. (Received February 23, 2016)

1120-35-288 **Gino Biondini***, Department of Mathematics, Math Bldg, Putnam Way. *Universal nature of the nonlinear stage of modulational instability.*

After reviewing how how modulational instability (MI) manifests itself within the inverse scattering transform for the focusing nonlinear Schrodinger (NLS) equation, I will characterize the nonlinear stage of MI by computing the long-time asymptotics of solutions of the focusing NLS with initial conditions that are a small perturbation of a constant background. In particular, I will show that such asymptotic behavior is universal. Namely, for generic perturbations, the xt-plane divides into three regions for long times: a left far field and a right far field, in which the solution equals the boundary condition to leading order, and a central region in which the asymptotic behavior is described by a slowly modulated elliptic solution. (Received February 23, 2016)

1120-35-301 **Julia Anderson-Lee*** (juliaal@iastate.edu), 396 Carver Hall, Iowa State University, Ames, IA 50014, and **Scott Hansen**. *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 February 23, 2016)

1120-35-309 **Athanassios S. Fokas**, **A. Alexandrou Himonas** and **Dionyssios Mantzavinos*** (dionyssi@buffalo.edu). *The Korteweg-de Vries equation on the half-line and a new approach for the analysis of initial-boundary value problems.*

Over the past 60 years, numerous results have been established for the initial value problem of nonlinear dispersive PDEs, like the celebrated nonlinear Schrödinger (NLS) and Korteweg-de Vries (KdV) equations, using techniques from integrability, harmonic analysis, geometry and other fields. This is not the case, however, concerning initial-boundary value problems for these PDEs which remain mostly unexplored. In this talk, a new approach for studying the well-posedness in Sobolev spaces of such initial-boundary value problems will be presented. The KdV equation on the half-line will be used as an illustrative example; however, this new approach can be applied to evolution equations of arbitrary spatial order and various nonlinearities. (Received February 23, 2016)

1120-35-310 **Stephen C Anco***, Dept. of Mathematics & Statistics, Brock University, St Catharines, ON , Canada. *Oscillatory solitons of Hirota and Sasa-Satsuma equations.*

The Hirota equation and the Sasa-Satsuma equation are U(1)-invariant integrable generalizations of the modified Korteweg-de Vries equation. In addition to ordinary solitons, these two equations possess oscillatory solitons, which describe harmonically modulated complex solitary waves. In this talk, I will discuss some interesting features of oscillatory solitons and their nonlinear interactions. In particular, unlike ordinary solitons which are uni-directional, the speed of oscillatory solitons can be positive, negative, or zero, depending on their harmonic modulation frequency. This motivates introducing a physical parameterization defined in terms of the speed, modulation frequency, and phase of the soliton. (Received February 23, 2016)

37 ► Dynamical systems and ergodic theory

1120-37-23 **Ali Allahem*** (a.allahem@qu.edu.sa), Qassim Uiversity, Qassim, Buraydah, 81999, Saudi Arabia. *The concept of the dividing surface in collinear Hydrogen exchange reaction.*

Transition state theory (TST) describes the elementary chemical reaction rate. There are three main regions in the reaction: reactant, product and the transition state (TS). The transition state must have two properties to make the transition state theory exact: all reactive trajectories must cross the TS (dividing surface) and the reactive trajectories cross it only once. Dynamical effects recrossing is possible from coupling in kinetic energy where TST provides upper bound of the exact reaction rate. Historically, (Wigner 1938) developed the reaction rate theory and extended the idea from con figuration space to phase space. (Pollak et al 1978) found the structure of the dividing surface in the collinear H2 + H reaction. It is well-known as unstable periodic orbit dividing surface (PODS). We are going to talk about the reactivity on the dividing surface of this reaction. (Received January 20, 2016)

1120-37-45 **Scot Robert Adams*** (adams@math.umn.edu), 206 Church St SE, Vincent Hall, University of Minnesota, Minneapolis, MN 55455. *Freeness of actions in bundles.*

A general Lie group action is not free, but it is often possible to achieve freeness by passing to a well-chosen bundle. Peter Olver has conjectured that, a broad range of situations, working in a specific tower of bundles, freeness can be achieved on a nonempty open set. We investigate that conjecture. (Received February 01, 2016)

1120-37-101 **Jacek Szmigielski*** (szmigiel@math.usask.ca), Department of Mathematics and Statistics, University of Saskatchewan, Saskatoon, SK S7N 5E6, Canada. *Cauchy biorthogonal polynomials: from inverse problems for peakon equations to Cauchy multi-matrix models.*

In this talk I will retrace the history of Cauchy biorthogonal polynomials, starting with the Degasperis-Procesi equation and its inverse problem which motived the theory of Cauchy biorthogonal polynomials, and culminating in the axiomatic theory introduced by M. Bertola, M. Gekhtman and JS. I will describe how this theory fits with the recently studied system of nonlinear partial differential equations introduced by Geng and Xue. In the second half of this talk I will review the Cauchy-Laguerre two-matrix model in order to illustrate the relevance of Cauchy biorthogonal polynomials to the theory of random multi-matrix models. This talk is based on speaker's recent work with H. Lundmark and past work with M. Bertola and M. Gekhtman. (Received February 16, 2016)

1120-37-104 **Semyon Litvinov*** (sbn2@psu.edu), 76 University Drive, Hazleton, PA 18202, and **Vladimir Chilin** (vladimirchil@gmail.com), Vuzgorodok, Tashkent, 700095, Uzbekistan. *Individual Ergodic Theorem in Non-commutative Orlicz Spaces.*

Let (Ω, μ) be a sigma-finite measure space. A classical Orlicz space $L^\Phi = L^\Phi(\Omega, \mu)$ associated with an Orlicz function Φ is a natural generalization of an L^p-space, $1 \leq p < \infty$, for which $\Phi(u) = u^p$, $u \geq 0$. It is known that for a wide class of Orlicz functions Φ and a Dunford-Schwartz operator $T : L^1 + L^\infty \to L^1 + L^\infty$, the inclusion $T(L^\Phi) \subset L^\Phi$ holds, and Dunford-Schwartz individual ergodic theorem follows from its validity for the space $L^1(\Omega, \mu)$. We consider a non-commutative Orlicz space $L^\Phi(\mathcal{M}, \tau)$ associated with a semi-finite von Neumann algebra $\mathcal{M}$, a faithful normal semi-finite trace τ on $\mathcal{M}$ and an Orlicz function Φ satisfying $(\delta_2, \Delta_2)-$condition and establish a non-commutative version of Dunford-Schwartz individual ergodic theorem for $L^\Phi(\mathcal{M}, \tau)$. (Received February 16, 2016)

1120-37-133 **Tamara Kucherenko** (tkucherenko@ccny.cuny.edu), New York, NY 10031, and **Christian Wolf*** (cwolf@ccny.cuny.edu), New York, NY 10031. *Zero temperature measures at the boundary of rotation sets.*

Zero-temperature measures are limits of equilibrium states when the temperature goes to zero. They play a fundamental role in statistical physics. In this paper we consider rotation sets $Rot(\Phi)$ associated with a continuous dynamical system $f : X \to X$ on a compact metric space X and a m-dimensional continuous potential $\Phi = (\phi_1, \cdots, \phi_m) : X \to R^m$. We study the question for which boundary values w of $Rot(\Phi)$ one can realize an entropy maximizing measure in the rotation class of w as a zero-temperature measure associated with a certain linear combination of Φ. We show that at an exposed point $w \in \partial Rot(\Phi)$ there always exists a zero-temperature measure that maximizes entropy in its rotation class. We also construct examples of rotation sets (in any dimension m) that have exposed boundary points with more than one zero-temperature measure in its rotation class. Finally, we consider non-exposed points and show that the following two phenomena

exist: a) boundary points without an associated zero-temperature measure; b) boundary points with a unique zero-temperature measure that is not ergodic. (Received February 18, 2016)

1120-37-135 **Dogan Comez** (dogan.comez@ndsu.edu) and **Mrinal K Roychowdhury*** (mrinal.roychowdhury@utrgv.edu). *Optimal quantization for infinite affine transformations on* $\mathbb{R}^2$.

Quantization of a probability distribution refers to the idea of estimating a given probability by a discrete probability supported by a finite set. In this paper, a probability distribution is considered which is generated by an infinite system of affine transformations S_{ij} on $\mathbb{R}^2$ associated with probabilities p_{ij} such that $p_{ij} > 0$ for all $i, j \in \mathbb{N}$ and $\sum_{i,j=1}^{\infty} p_{ij} = 1$. For such a probability measure P, the optimal sets of n-means and the nth quantization error are calculated for every natural number n. (Received February 18, 2016)

1120-37-148 **Chris Bose*** (cbose@uvic.ca), Department of Mathematics and Statistics, University of Victoria, PO Box 1700 STN CSC, Victoria, BC V8W 2Y2, Canada, and **Wael Bahsoun**. *Limit theorems for random intermittent maps.*

It is well known that non-uniformly expanding, nonsingular maps in one and higher dimensions can exhibit a wide variety of interesting higher-order asymptotics such as sub-exponential rate of correlation decay, central limit theorem, or not, stable laws or not, depending on the strength of the intermittency. We study random maps constructed from a parameterized family of such intermittent maps, drawing two interesting conclusions. 1. Rates of correlation decay are completely determined by the map with the fastest mixing rate, independent of the randomizing process and 2. In cases where correlation decay fails to be square summable, establishing a CLT or stable law (as appropriate) is dependent on both the maps and the randomizing process. We will describe these results and discuss some of the ideas behind the proofs. (Received February 19, 2016)

1120-37-174 **Alessandro Arsie*** (alessandro.arsie@utoledo.edu), The University of Toledo, Department of Mathematics and Statistics, 2801 W Bancroft St. MS 942, Toledo, OH 43606, and **Paolo Lorenzoni** (paolo.lorenzoni@unimib.it), University of Milano-Bicocca, Department of Mathematics and Applications, Via Roberto Cozzi, 55, 20125 Milano, Milano, Italy. *F-manifolds, multi-flat structures and Painlevé transcendents.*

In this talk, we introduce F-manifolds equipped with multiple flat connections (and multiple F-products), that are required to be compatible in a suitable sense. Multi-flat F-manifolds are the analogue for F-manifolds of Frobenius manifolds with multi-Hamiltonian structures. In the semisimple case we show that a necessary condition for the existence of such multiple flat connections can be expressed in terms of the integrability (in the sense of the Frobenius Theorem) of a distribution of vector fields. When the relevant distributions are integrable, coupling the invariants of the foliations they determine with Tsarev's conditions, we construct bi-flat F-manifolds in dimension 2 and 3, and tri-flat F-manifolds in dimensions 3 and 4. We also obtain a parametrization of three-dimensional bi-flat F in terms of a system of six first order ODEs that can be reduced to the full family of P_{VI} equation. In the second part, we extend our analysis to include non-semisimple regular bi-flat and in general multi-flat F-manifolds. We show that in dimension three, regular non-semisimple bi-flat F-manifolds are locally parameterized by solutions of the full P_{IV} and P_{V} equations, according to the Jordan normal form of a distinguished endomorphism. (Received February 21, 2016)

1120-37-184 **Sergey Bezuglyi*** (sergii-bezuglyi@uiowa.edu), University of Iowa, Iowa City, IA 52242, and **Palle E.T. Jorgensen**. *Monopoles, dipoles, and harmonic functions on Bratteli diagrams.*

In our study of electrical networks we develop two themes: finding explicit formulas for special classes of functions defined on the vertices of a transient network, namely monopoles, dipoles, and harmonic functions. Secondly, our interest is focused on the properties of electrical networks supported on Bratteli diagrams. We show that the structure of Bratteli diagrams allows one to describe algorithmically harmonic functions as well as monopoles and dipoles. We also discuss some special classes of Bratteli diagrams (stationary, Pascal, trees), and we give conditions under which the harmonic functions defined on these diagrams have finite energy. (Received February 21, 2016)

1120-37-194 **María J. Carro**, **María Lorente** and **Francisco J. Martín-Reyes*** (martin_reyes@uma.es). *A counting problem in Ergodic Theory and extrapolation for one-sided weights.*

The purpose of this talk is to show that, given a dynamical system $(X, \mathcal{M}, \mu, \tau)$ and $0 < q < 1$, the Lorentz spaces $L^{1,q}(\mu)$ satisfy the so-called Return Times Property for the Tail contrary to what happens in the case $q = 1$. In fact, we consider a more general case than in previous papers since we work with a σ-finite measure

μ and a transformation τ which is only Cesàro bounded. The proof uses the extrapolation theory of Rubio de Francia for one-sided weights. (Received February 22, 2016)

1120-37-201 **Drew D. Ash*** (drew.ash@du.edu), **Lori Alvin** and **Nic Ormes**. *Bounded topological speedups and entropy.*

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 any aperiodic, not necessarily ergodic, measure preserving systems is isomorphic to a speedup of any ergodic measure preserving system. In 2015, the speaker gave necessary and sufficient conditions for a minimal Cantor system to be a topological speedup of another minimal Cantor system. The form of this theorem mirrors that of Giordano, Putnam, and Skau's characterization of orbit equivalence of minimal Cantor systems. In this talk, we will discuss this result and recent joint work with Lori Alvin and Nic Ormes on bounded topological speedups. In particular, we will focus on entropy of speedups, and give a topological analogue of Neveu's entropy result for measure theoretic speedups. (Received February 23, 2016)

1120-37-203 **Leo T Butler*** (leo.butler@ndsu.edu), NDSU Dept #2750, PO Box 6050, Fargo, ND 58108. *Nosé-Thermostatted Mechanical Systems on the n-torus in the High-Temperature Limit.*

Let H be an n-degree of freedom smooth mechanical Hamiltonian on the cotangent bundle of the n-torus. When the metric is sufficiently close to a flat metric, the Nosé-thermostated system associated to H is shown to have invariant tori near the infinite temperature limit. This is shown to be true for all thermostats similar to Nosé's. These results complement the result of Legoll, Luskin and Moeckel who proved the existence of such tori near the decoupling limit. (Received February 22, 2016)

1120-37-204 **Elizabeth Sattler*** (elizabeth.sattler.1@ndsu.edu). *Self-similar measures supported on a subfractal induced by a subshift of finite type.* Preliminary report.

In this talk, we will examine the construction of a self-similar, invariant measure that is supported on a subfractal induced by a subshift of finite type on the underlying symbolic space. We will also discuss a method for calculating the Hausdorff dimension of such a measure. (Received February 22, 2016)

1120-37-217 **James T Campbell*** (jcampbll@memphis.edu), University of Memphis, Department of Mathematical Scien, Dunn Hall 373, Memphis, TN 38152, and **Randall McCutcheon** and **Alistair Windsor**. *A general Alpern tower independent of a given partition.* Preliminary report.

Given a measure-preserving transformation T of a probability space $(X, \mathcal{B}, \mu)$ and a finite measurable partition P of X, we show how to construct a general Alpern tower rep- resented by k towers of heights n_1, n_2, ..., n_k , with prescribed measures, so that the base of the tower is independent of P. (Received February 22, 2016)

1120-37-261 **Jose de Jesus Galarza*** (jose.galarza01@utrgv.edu), 155 Las Villas Ave., Brownsville, TX 78526. *Clustering algorithms and their applications for the quantization of uniform distributions.*

In order to make an optimal quantization of the uniform distribution defined on a set one needs to construct centroidal Voronoi tessellations. First, we explore the k-means method, its motivation and how it is used to approximate the uniform distribution on a square with a measure supported by a set of k points, and obtain the optimal sets of points (k-means) which generate the tessellations. We give numerical results for k$\leq$51 optimal points and explore some applications of the centroidal voronoi tessellations in discrete domain. Then, we discuss Lloyd's algorithm, its motivation, and the latest results by implementing the algorithm with simulations on the quantization of a square. We end by discussing conjectures regarding the tessellations with the Lloyd's algorithm and its future applications.
(Received February 23, 2016)

1120-37-272 **Nikita Barabanov*** (nikita.barabanov@ndsu.edu), Department of Mathematics, 408 Minard Hall, P.O. Box 6050, Fargo, ND 58108. *Absolute stability of infinite dimensional periodic systems with unbounded evolution, input and output operators.* Preliminary report.

We consider a generalization of Pritchard-Salamon systems to the case of periodic operators with mixed continuous/discrete time and nonlinearities satisfying local quadratic constraints. To this end there introduced new left and right admissible evolution, input and output periodic operators, and left and right Pritchard-Salamon systems with hybrid time. The auxiliary results include several sections: linear change of variables, duality, and

stability. In particular, we establish properties of evolution operators of systems closed by linear feedback; definition and properties of the inverse Pritchard-Salamon system; admissibility of input and output operators for closed loop system; stability and exponential stability of dual operators; input-output stability; a generalization of the Redheffer lemma; absolute stability problem; a solution to this problem based on the existence of a special Hermitian periodic operator. (Received February 23, 2016)

1120-37-273 **Tamara Kucherenko***, tkucherenko@ccny.cuny.edu, and **Mrinal Kanti Roychowdhury**. *Asymptotic quantization for condensation systems of infinite self-similar mappings.*

We derive upper and lower bounds for the quantization dimensions of inhomogeneous measures generated by infinite systems of self-similar mappings and probabilistic vectors. We show that the lower bound is the corresponding quantization dimension of the inhomogeneous part of the measure. The upper bound is determined by the zero of the pressure function of the infinite system. (Received February 23, 2016)

1120-37-294 **Isaac Loh** and **Cesar E. Silva*** (csilva@williams.edu), Department of Mathematics, Williams College, Williamstown, MA 01267. *Strict doubly ergodic infinite transformations.*

We give conditions for rank-one infinite measure preserving transformations to be weakly doubly ergodic and for their k-fold cartesian product to be conservative. We give examples of rank-one transformations that are weakly doubly ergodic, rigid (so all their cartesian products are conservative), but their 2-fold cartesian product is not ergodic. We also show that a weakly doubly ergodic nonsingular group action is ergodic with isometric coefficients. (Received February 23, 2016)

41 ► Approximations and expansions

1120-41-55 **Laura De Carli*** (decarlil@fiu.edu), Department of Mathematics, Univ. Park, Miami, FL 33199, and **Pierluigi Vellucci**. *Stability theorems for systems of rect and sinc.* Preliminary report.

We prove stability theorems for Riesz bases of rect (or sinc) functions on subspaces of $L^2(R)$. We apply our results to the zero-order hold (ZOH), a mathematical model of the practical signal reconstruction. This is a joint work with P. Vellucci, from the Univ. Roma "La Sapienza" (Italy) (Received February 06, 2016)

1120-41-70 **Laura De Carli***, Dept. mathematics, Univ. Park, Miami, FL 33199. *Exponential bases on rectangles in R^d.* Preliminary report.

Let Q be the union of N unit cubes in $\mathbb{R}^d$ with vertices in $\mathbb{Z}^d$. We show necessary and sufficient conditions that ensure that a set of exponential $\mathcal{B} = \{e^{2\pi i(\vec{n}+\vec{d}_j)x}\}_{n\in\mathbb{Z}^d, 1\le j\le N}$ is an exponential basis on Q. In the process, we also show that $\mathcal{B}$ is a Riesz basis if and only if it is a frame and if and only if it is a Riesz sequence. We also prove a new stability theorem for $\mathcal{B}$. The proof of our main result relies on the semigroup properties and precise norm estimates of a remarkable family of linear operators on $\ell^2(Z^d)$. (Received February 10, 2016)

1120-41-113 **Dan Freeman** and **Darrin Speegle*** (speegled@slu.edu). *Sampling from a continuous frame to obtain a frame.* Preliminary report.

We prove that every continuous frame can be sampled in such a way as to produce a frame. Our technique involves reducing the problem that is very similar to known equivalences of the Marcus-Spielman-Srivastava Theorem, and proving that it indeed follows from MSS. (Received February 17, 2016)

1120-41-155 **Shidong Li*** (shidong2000@yahoo.com), Department of Mathematics, San Francisco State University, San Francisco, CA 94132, and **Tiebin Mi**. *Sparsity-inducing dual frames and sparse signal recovery with coherent frames.* Preliminary report.

When signals are sparse with respect to a coherent frame D, the associated compressed sensing problem becomes more complicated. A notion of *sparsity-inducing dual frames* (SIDF) is introduced aiming at an efficient recovery of x where $f = Dx$ and x is sparse. SIDFs are special/optimal dual frames that induces sparse coefficients x for a sparse signal (or a set of signals) $f = Dx$. As a result, SIDFs are signal dependent. But they are locally stable. This stability will be discussed. A SIDF-based ℓ_1-analysis approach for the sparse signal recovery and its performance analysis will be presented. Examples will be provided. (Received February 20, 2016)

1120-41-268 **Radu Balan** (rvbalan@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742, and **Dongmian Zou*** (zou@math.umd.edu), AMSC Program, University of Maryland, College Park, MD 20742. *Lipschitz properties for deep networks.* Preliminary report.

In this talk we review stability properties of deep neural networks. In particular we look possibility of using families of nonlinear functions, and their analytic properties. (Received February 23, 2016)

42 ► Fourier analysis

1120-42-14 **Marcin Bownik***, Department of Mathematics, University of Oregon, Eugene, OR 97403, and **Pete Casazza**, **Adam Marcus** and **Darrin Speegle**. *Improved bounds in Weaver and Feichtinger Conjectures.*

In this talk we present some results related to the recent solution of the Kadison-Singer problem by Marcus, Spielman, and Srivastava. We sharpen the constant in the KS_2 conjecture of Weaver that plays a key role in this solution. We then apply this result to prove optimal asymptotic bounds on the size of partitions in the Feichtinger conjecture. The talk is based on a joint work with Casazza, Marcus, and Speegle. (Received January 12, 2016)

1120-42-20 **Joseph W. Iverson***, Department of Mathematics & Statistics, Air Force Institute of Technology, 2950 Hobson Way, Bldg 641, Wright Patterson AFB, OH 45433. *Group frames with several generators.*

When a compact group acts on a Hilbert space irreducibly, the orbit of any single nonzero vector forms a tight frame. When the action is not irreducible, the situation is considerably more complicated. This is especially true if one wants to use multiple generating vectors and make a frame from the disjoint union of their orbits. We tackle both generalizations at once, and give a neat duality result that captures the result for irreducible representations under the same umbrella as the familiar duality of frames and Riesz sequences. (Received January 18, 2016)

1120-42-25 **Alex Iosevich*** (iosevich@math.rochester.edu), 145 Dunrovin Lane, Rochester, NY 14618. *On the Fuglede Conjecture.*

We are going to discuss the Fuglede Conjecture in the context of vector spaces over finite fields. (Received January 20, 2016)

1120-42-26 **Bin Han*** (bhan@ualberta.ca), Dept of Mathematical and Statistical Sciences, University of Alberta, Edmonton, Alberta T6G 2G1, Canada. *Tight framelets and refinable structure.* Preliminary report.

It is widely known that refinable (vector) functions play a central role in wavelet theory for constructing various wavelets or framelets. A natural question is: where are the refinable functions from? In this talk, we study nonhomogeneous tight framelets and we shall completely characterize nonhomogeneous tight framelets in terms of their refinable structures and filter banks. We shall see that refinable (vector) functions, filter banks and (generalized) multiresolution analysis naturally appear in the study of nonhomogeneous tight framelets. The relations among multiresolution analysis, refinable structure, and wavelet functions will also be discussed. As a byproduct, we answered a question asked by Baggett, Jorgensen, Merrill and Packer in 2005. (Received January 21, 2016)

1120-42-27 **Christopher Heil*** (heil@math.gatech.edu), School of Mathematics, Georgia Tech, Atlanta, GA 30032-0160, and **Darrin Speegle** (speegled@yahoo.com), Department of Mathematics, Saint Louis University, Saint Louis, MO 63103. *HRT versus the Zero Divisor Conjecture.*

The Linear Independence of Time-Frequency Translates Conjecture, also known as the HRT conjecture, states that any finite set of time-frequency translates of a given L^2 function must be linearly independent. This conjecture, which was first stated in print in 1996, remains open today. We will discuss this conjecture, its relation to the Zero Divisor Conjecture in abstract algebra, and the (frustratingly few) partial results that are currently available. (Received January 21, 2016)

1120-42-44 **Peter G Casazza**, **Daniel Freeman** and **Richard G Lynch*** (rglz82@mail.missouri.edu). *Weaving Schauder Frames.*

We extend the concept of weaving Hilbert space frames to the Banach space setting. Similar to frames in a Hilbert space, for any two approximate Schauder frames for a Banach space, every weaving is an approximate Schauder frame if and only if there is a uniform constant $C \geq 1$ such that every weaving is a C-approximate

Schauder frame. We also consider weaving Schauder bases, where it is necessary to introduce two notions of weaving. On one hand, we can ask if two Schauder bases are woven when considered as Schauder frames with their biorthogonal functionals, and alternatively, we can ask if each weaving of two Schauder bases remains a Schauder basis. We will see that these two notions coincide when all weavings are unconditional, but otherwise they can be different. Lastly, we provide two perturbation theorems for approximate Schauder frames. (Received February 01, 2016)

1120-42-47 **Chun-Kit Lai*** (cklai@sfsu.edu), Department of Mathematics, 1600 Holloway Ave., San Francisco, CA 94132, and **Yang Wang**. *Non-spectral fractal measures with Fourier frames.*

Constructing Fourier frames on fractal measures has been a challenging problem. In this talk, we demonstrate the first singular fractal measure which has only finitely many mutually orthogonal exponentials and hence it does not admit any exponential orthonormal bases, but it still admits some Fourier frames. (Received February 03, 2016)

1120-42-48 **Dorin Ervin Dutkay*** (ddutkay@gmail.com) and **Chun Kit Lai**. *Fourier series on self-affine measures.*

We show how orthonormal bases of exponential functions (Fourier series) can be constructed for some invariant measures of affine iterated function systems associated to Hadamard pairs. (Received February 04, 2016)

1120-42-87 **Kasso Okoudjou*** (kasso@math.umd.edu), Department of Math, Math Blg, College Park, MD 20742. *A new proof of the three-point HRT conjecture.* Preliminary report.

In this talk we introduce an extension principle to investigate the Heil-Ramanathan-Topiwala (HRT) conjecture. More specifically, knowing that the Conjecture holds for a given function $g \in L^2(\mathbb{R})$ and a given set $\Lambda = \{(a_k, b_k)\}_{k=1}^N \subset \mathbb{R}^2$, we seek the set of all (new) points $(a, b) \in \mathbb{R}^2 \setminus \Lambda$ such that the conjecture remains true for the same function g and the new set $\Lambda' = \Lambda \cup \{(a, b)\}$. We demonstrate the merit of this approach by giving a new proof of the HRT conjecture for 3 points. (Received February 14, 2016)

1120-42-90 **Gabriel Picioroaga***, gabriel.picioroaga@usd.edu, and **Eric Weber**, esweber@iastate.edu. *Fourier frames for the Cantor-4 set.*

The measure supported on the Cantor-4 set constructed by Jorgensen-Pedersen is known to have a Fourier basis, i.e. that it possess a sequence of exponentials which form an orthonormal basis. We construct Fourier frames for this measure via a dilation theory type construction. We expand the Cantor-4 set to a 2 dimensional fractal which admits a representation of a Cuntz algebra. Using the action of this algebra, an orthonormal set is generated on the larger fractal, which is then projected onto the Cantor-4 set to produce a Fourier frame. (Received February 15, 2016)

1120-42-99 **Matthew Fickus*** (matthew.fickus@afit.edu), Department of Mathematics and Statistics, Air Force Institute of Technology, 2950 Hobson Way, Wright-Patterson AFB, OH 45433, and **Dustin G. Mixon** and **John Jasper**. *Equiangular tight frames from hyperovals.*

An equiangular tight frame (ETF) is a set of equal norm vectors in a Euclidean space whose coherence is as small as possible, equaling the Welch bound. Such frames arise in various applications, such as waveform design, quantum information theory, compressed sensing and algebraic coding theory. ETFs seem to be rare, and only a few methods of constructing them are known. We present a new infinite family of complex ETFs that arises from hyperovals in finite projective planes. In particular, we give the first ever construction of a complex ETF of 76 vectors in a space of dimension 19. Recently, a computer-assisted approach was used to show that real ETFs of this size do not exist, resolving a longstanding open problem in this field. Our approach modifies the way Steiner ETFs are constructed from balanced incomplete block designs. (Received February 16, 2016)

1120-42-120 **John Herr*** (jherr@iastate.edu) and **Eric Weber** (esweber@iastate.edu). *Fourier series for singular measures.*

Using the Kaczmarz algorithm, we prove that for any singular Borel probability measure μ on $[0, 1)$, every $f \in L^2(\mu)$ possesses a Fourier series of the form $f(x) = \sum_{n=0}^{\infty} c_n e^{2\pi i n x}$. We show that the coefficients c_n can be computed in terms of the quantities $\widehat{f}(n) = \int_0^1 f(x) e^{-2\pi i n x}\, d\mu(x)$. We also demonstrate a Shannon-type sampling theorem for functions that are in a sense μ-bandlimited. (Received February 17, 2016)

1120-42-137 **John Isaac Haas*** (haasji@missouri.edu). *Tight orthoplectic Grassmannian frames.*

A (complex) Grassmannian frame is a spanning set of N unit vectors for $\mathbb{C}^M$ whose maximal magnitude among pairwise inner products is minimal. Grassmannian frames are useful in many applications, but few methods for

constructing them are known. Moreover, most known constructions produce equiangular tight frames (ETFs). While ETFs are arguably the most important class of Grassmannian frames, their minimizing property corresponds to saturation of the Welch bound, which is only feasible when $N \leq M^2$.

In this talk, we turn our attention to the case $N > M^2$, where the lesser known orthoplex bound is stronger than the Welch bound. By generalizing a known construction of ETFs based on Singer sets, we develop families of complex Grassmannian frames whose maximal magnitude among pairwise inner products equals the orthoplex bound, which we call orthoplectic Grassmannian frames (OGFs). In particular, whenever $M-1$ is a prime power, we obtain tight OGFs of $N = M^2+1$ vectors and whenever M is a prime power, we obtain tight OGFs of $N = M^2+M-1$ vectors. Furthermore, along with ETFs and mutually unbiased bases, we show that OGFs form weighted complex projective 2-designs and are thus useful additions to quantum state tomography. (Received February 18, 2016)

1120-42-143 **Roza Aceska*** (raceska@bsu.edu), Muncie, IN 47304, and **Jean Luc Bouchot** and **Shidong Li**. *Local sparsity and fusion frames.*

We analyze the problem of recovering signals from low quality sensing devices, and implement a combination of compressed sensing and distributed sensing to model so-called fusion frames structured signals.

Within our framework, it is possible to recover signals with high accuracy by increasing the number of measurements. We show that, under suitable constraints, nonsparse signals can be recovered with high probability. Moreover, we show that, with the use of a few linear measurements, cheap sensors are sufficient when combined with the fusion frame methodology. (Received February 19, 2016)

1120-42-205 **David R Larson** and **Sam L Scholze*** (scholzes@math.tamu.edu), Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77840-3368. *Bridging frame erasures.*

In this talk, I will discuss a method of reconstruction from frame coefficient erasures which is more efficient than older methods. While older methods require an $n \times n$ matrix inversion, where n is the dimension of the underlying Hilbert space, the new method, called Nilpotent bridging, requires only an $L \times L$ matrix inversion, where L is the size of the set of erased frame coefficients. To recover from erasures indexed by Λ, the method of Nilpotent bridging uses frame coefficient information from a subset, Ω of the non-erased coefficients satisfying $|\Lambda| = |\Omega|$. I will discuss this method in detail. I will also discuss the skew-spark property and why most frames satisfy this property. The full skew-spark property guarantees that any bridge set we choose of the same size as the erasure set will work for Nilpotent bridging. This is joint work with David Larson. (Received February 22, 2016)

1120-42-222 **Azita Mayeli*** (amayeli@gc.cuny.edu), NY, **Bradley Currey**, MO , and **Vignon Oussa**, RI. *Sampling and interpolation on certain nilpotent lie groups.* Preliminary report.

Let G be a two step nilpotent Lie group of certain property. In this talk we show a characterization of left-invariant subspaces of $L^2(G)$ which are sampling and have the interpolation property with respect to a class of discrete subsets of G. (Received February 22, 2016)

1120-42-226 **Jameson Cahill**, **Xuemei Chen*** (xchen@nmsu.edu) and **Rongrong Wang**. *The gap between NSP and RIP.*

The null space property (NSP) and the restricted isometry property (RIP) are two properties which have received considerable attention in the compressed sensing literature. As the name suggests, NSP is a property that depends solely on the null space of the measurement procedure and as such, any two matrices which have the same null space will have NSP if either one of them does. On the other hand, RIP is a property of the measurement procedure itself, and given an RIP matrix it is straightforward to construct another matrix with the same null space that is not RIP. We say a matrix is RIP-NSP if it has the same null space as an RIP matrix. We show that such matrices can provide robust recovery of compressible signals under Basis pursuit which in many applicable settings is comparable to the guarantee that RIP provides. More importantly, we constructively show that the RIP-NSP is stronger than NSP with the aid of this robust recovery result, which shows that RIP is fundamentally stronger than NSP. (Received February 22, 2016)

1120-42-241 **Keith F Taylor*** (keith.taylor@dal.ca), Dept. of Math & Stats, Dalhousie University, Halifax, Nova Scoti B3H 4R2, Canada. *Admissible Groups in Three Dimensions.*

We explore the abelian closed subgroups of $\mathrm{Gl}_3(\mathbb{R})$ that are admissible in the sense that their action admits a wavelet for a continuous wavelet transform. (Received February 22, 2016)

1120-42-251 **Jean-Pierre Gabardo*** (gabardo@mcmaster.ca). *Beurling density in weighted Fourier spaces.*

The concepts of upper and lower Beurling density play an important role in sampling theory for the space of square-integrable functions on $\mathbb{R}^n$ with spectrum contained in a bounded set. In this talk, we will consider the problem of defining appropriate notions of density for Hilbert spaces whose norm are defined by the integral of the square of the Fourier transform multiplied by a certain weight. Examples of such spaces are the standard Sobolev spaces $H^s(\mathbb{R}^n)$, $s \in \mathbb{R}$. We will use the theory of frames to extend some density results valid for the usual L^2-norm to this more general setting. (Received February 22, 2016)

1120-42-266 **Azita Mayeli*** (amayeli@gc.cuny.edu). *Tiling and spectral sets in $\mathbb{Z}_p \times \mathbb{Z}_p$.* Preliminary report.

The equivalence relation between tiling and spectral property of a set has its root in the Fuglede Conjecture a.k.a Spectral Set Conjecture in $\mathbb{R}^d$, $d \geq 1$. In 1974, Fuglede stated that a Lebesgue measurable set $\Omega \subset \mathbb{R}^d$, with positive and finite measure, tiles $\mathbb{R}^d$ by its translations if and only if $L^2(\Omega)$ possesses an orthogonal basis of exponentials. A variety of results were proved for establishing connection between tiling and spectral property for some special cases of Ω. However, the conjecture is false in general for dimensions 3 and higher, and it is still open in $\mathbb{R}$ and $\mathbb{R}^2$.

In this talk, we will define the tiling and spectral sets in $\mathbb{Z}_p \times \mathbb{Z}_p$, p prime, and show that these two properties are equivalent for such sets. In other words, we prove that Fuglede's conjecture holds for $\mathbb{Z}_p \times \mathbb{Z}_p$. This is a joint work with Alex Iosevich and Jonathan Pakianathan. (Received February 23, 2016)

1120-42-269 **Radu Balan*** (rvbalan@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742. *The Iterative and Regularized Least Squares (IRLS) algorithm for phase retrieval.* Preliminary report.

In this talk we present the motivation and convergence analysis of the Iterative Regularized Least Squares (IRLS) algorithm for the phase retrieval problem. We also look at simulations and numerical results. This is a joint work with Naveed Haghani (UMD). (Received February 23, 2016)

1120-42-290 **Matthew Fickus** (matthew.fickus@gmail.com), **Dustin G Mixon** (dustin.mixon@gmail.com), **John Jasper*** (john.jasper@uc.edu) and **Jesse Peterson** (peterson.jesse.d@gmail.com). *Tremain equiangular tight frames and strongly regular graphs.*

An equiangular tight frame (ETF) is a set of unit vectors whose coherence achieves the Welch bound, and thus is as incoherent as possible. Such frames arise in various applications such as waveform design, quantum information theory, compressed sensing and algebraic coding theory. Unfortunately, ETFs seem to be quite rare, and only a few methods for constructing them are known. In this talk we present a construction of a new class of ETFs, which we call Tremain ETFs. These new ETFs can be constructed to be real infinitely often. We use these real Tremain ETFs to obtain new results on some well-studied problems in graph theory. (Received February 23, 2016)

43 ► Abstract harmonic analysis

1120-43-198 **Dustin G. Mixon*** (dustin.mixon@gmail.com), 2950 Hobson Way, Wright-Patterson AFB, OH 45433. *The Voronoi Means Conjecture.*

We recently developed a relax-and-round algorithm for k-means clustering. When applied to balanced spherical Gaussian mixtures of unit entrywise variance, this algorithm clusters most points according to Gaussian component provided the minimum distance between component centers is at least some polynomial in k. This talk introduces a new conjecture called the Voronoi Means Conjecture, which implies that this distance for successful clustering must exhibit k-dependence as an artifact of k-means. The conjecture is a statement about highly symmetric collections of vectors, and I will announce a prize for its resolution. (This is joint work with Soledad Villar and Rachel Ward at the University of Texas at Austin.) (Received February 22, 2016)

1120-43-213 **Calvin F. Hotchkiss*** (hotchkis@iastate.edu) and **Eric S. Weber**. *A fast Fourier transform for fractal approximations.*

We consider finite approximations of a fractal generated by an iterated function system of affine transformations on $\mathbb{R}^d$ as a discrete set of data points. Considering a signal supported on this finite approximation, we propose a Fast (Fractal) Fourier Transform by choosing appropriately a second iterated function system to generate a set of frequencies for a collection of exponential functions supported on this finite approximation. Since both

the data points of the fractal approximation and the frequencies of the exponential functions are generated by iterated function systems, the matrix representing the Discrete Fourier Transform (DFT) satisfies certain recursion relations, which we describe in terms of Diţă's construction for large Hadamard matrices. These recursion relations allow for the DFT matrix calculation to be reduced in complexity to $O(n \log n)$, as in the case of the classical FFT. (Received February 22, 2016)

46 ► Functional analysis

1120-46-17 **Jameson Cahill** (jameson.cahill@gmail.com), Department of Mathematical Sciences, New Mexico State University, 1290 Frenger Mall, Las Cruces, NM 88003, **Peter G Casazza*** (casazzap@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211, and **Ingrid Daubechies** (ingrid.daubechies@duke.edu), Mathematics Department, Duke University, Box90320, Durham, NC 27708. *Infinite dimensional phase retrieval.*

Phase retrieval just celebrated its 100th anniversary. It has broad application to x-ray crystallography, electron microscopy, astronomical imaging, optics, and much more. We will see that some fundamental results in phase retrieval extend to the infinite dimensional case while other fundamental results fail. In particular, we will see that phase retrieval in infinite dimensional Hilbert spaces is never uniformly stable. We will also give sufficient conditions for phase retrieval in infinite dimensions and give a number of examples. (Received January 16, 2016)

1120-46-18 **Peter G Casazza*** (casazzap@missouri.edu), Department of Mathematical Sciences, University of Missouri, Columbia, MO 65211, and **Xuemei Chen** (anotherdai@gmail.com), Department of Mathematics, New Mexico State University, 1290 Frenger Mall, Las Cruces, 88003. *Frame scalings a condition number approach.*

Scaling frame vectors is a simple and noninvasive way to construct tight frames. However, not all frames can be modifed to tight frames in this fashion, so in this case we explore the problem of finding the best conditioned frame by scaling, which is crucial for applications like signal processing. We conclude that this problem is equivalent to solving a convex optimization problem involving the operator norm, which is unconventional since this problem was only studied in the perspective of Frobenious norm before. We also further study the Frobenious norm case in relation to the condition number of the frame operator, and the convexity of optimal scalings. (Received January 16, 2016)

1120-46-39 **Ionut Chifan*** (ionut-chifan@uiowa.edu), 14 MacLean Hall, Iowa City, IA 52242, **Rolando de Santiago** (rolando-desantiago@uiowa.edu), 14 Maclean Hall, Iowa City, IA 52242, and **Thomas Sinclair** (tsincla@purdue.edu), 150 North Unvesity Street, West Lafayette, IN 47907. *Product rigidity for von Neumann algebras arising from hyperbolic groups.*

Two groups Γ and Λ are called W^*-equivalent if they give rise to isomorphic von Neumann algebras. I will show that whenever $\Gamma_1, \Gamma_2, ..., \Gamma_n$ are icc hyperbolic groups and Λ is an arbitrary group such that $\Gamma_1 \times \Gamma_2 \times \cdots \times \Gamma_n$ is W^*-equivalent to Λ it follows that $\Lambda = \Lambda_1 \times \Lambda_2 \times \cdots \times \Lambda_n$ and, up to amplifications, Γ_i is W^*-equivalent to Λ_i, for all i. This strengthens some results of N. Ozawa and S. Popa from 2003. The talk based on a joint work with Rolando de Santiago and Thomas Sinclair. (Received January 29, 2016)

1120-46-50 **Benton L Duncan*** (benton.duncan@ndsu.edu). *Amalgamated universal free products of finite dimensional C^*-algebras.*

We consider free products of finite dimensional C^*-algebras with amalgamations over certain diagonal subalgebras. In this context we investigate exactness/nuclearity of the associated universal free products. This has uses in studying free products of graph C^*-algebras. (Received February 05, 2016)

1120-46-53 **Armenak Petrosyan*** (armenak.petrosyan@vanderbilt.edu), 1906 Chet Atkins Place, Apt 601, Nashville, TN 37212, and **Akram Aldroubi** (akram.aldroubi@vanderbilt.edu), 1520 Stevenson Center, Vanderbilt University, Nashville, TN 37240. *Frames and Bessel systems generated by the iterative actions of normal operators.*

We consider systems of vectors of a form

$$\{A^n g_i : \ i \in I, n \geq 0\}$$

where $\{g_i\}_{i\in I}$ is a countable (finite or infinite) subset of a separable Hilbert space $\mathcal{H}$ and $A \in B(\mathcal{H})$ is a normal operator. We show that a system of that form can never be complete and minimal and find conditions that the operator A needs to satisfy for the system to be complete and Bessel.

We also investigate systems of a form

$$\{\pi(\gamma)g_i : \ i \in I\},$$

where π is a unitary representation on $\mathcal{H}$ of the discrete group Γ and extract information about the spectrum of the operators in the group when the system is minimal or complete and Bessel. (Received February 06, 2016)

1120-46-59 **Palle E. T. Jorgensen*** (palle-jorgensen@uiowa.edu), Dept Math MLH, University of Iowa, Iowa City, IA 52242. *Probability theory of infinite iterated function systems.*

Abstract: The study of spectral duality for singular measures started long ago with a joint paper, Jorgensen-Pedersen. Subsequently the theme of Fourier bases and fractals was followed up by many researchers,... Dorin Dutkay and more; and by now the subject has branched off in a variety of new directions, some motivated by applications. In the case of affine IFS measures mu, when an associated complex Hadamard matrix is further assumed to satisfy an additional symmetry condition; then the $L^2(mu)$ Hilbert space will have an orthogonal Fourier basis; in other words we get an associated fractal Fourier transform. In order to appreciate the nature of the spectral duality, note that spectral duality holds for the middle-1/4 Cantor measure, but not for its middle-1/3 cousin. Typically the distribution of the associated Fourier frequencies satisfies very definite lacunary properties, in the form of geometric almost-gap distributions; the size of the gaps grows exponentially, with sparsity between partitions. The probabilistic significance will be explored. Use will be made of reproducing kernel Hilbert spaces of analytic functions. (Received February 08, 2016)

1120-46-62 **S Kaliszewski*** (kaliszewski@asu.edu), PO Box 871804, Tempe, AZ 85287-1804, and **Magnus B Landstad** and **John Quigg**. *A survey of exotic crossed products.*

When a locally compact group G acts on a C^*-algebra, we have both full and reduced crossed products, each carries a dual coaction of G, and each has its own version of crossed-product duality. Inspired by work of Brown and Guentner on new C^*-completions of group algebras, we have begun to understand what we call "exotic" crossed products — C^*-algebras that lie between the familiar full and reduced crossed products — and more generally, "exotic coactions." Some of these satisfy a corresponding exotic crossed product duality, intermediate between full and reduced duality; they are also related to the crossed-product functors used recently by Baum, Guentner, and Willett in a new approach to the Baum-Connes conjecture. (Received February 08, 2016)

1120-46-72 **S. Kaliszewski**, **Tron Omland** and **John Quigg*** (quigg@asu.edu), School of Math and Stat Sciences, Arizona State University, PO Box 871804, Tempe, AZ 85287-1804. *Generalized fixed-point algebras and a theorem of Pedersen.*

If an abelian locally compact group G acts on a C^*-algebra, an old theorem of Landstad shows how to recover the action up to isomorphism from the crossed product, using a generalized fixed-point algebra determined by the dual action (of the dual group $\widehat{G}$) and an equivariant embedding of $C_0(\widehat{G})$. Pedersen showed how, forgetting about $C_0(\widehat{G})$, one recovers the original action up to outer conjugacy. We parlay this into an equivalence between two equivariant categories of C^*-algebras, where the isomorphisms in one are given by outer conjugacies of actions of G, and in the other by generalized fixed-point algebras of actions of $\widehat{G}$. Somehow irritating, it seems difficult to find examples with different generalized fixed-point algebras (and consequently non-exterior equivalent actions of G), and we discuss various approaches to this problem. All of the preceding makes sense, and some of it has been proven, for nonabelian G, but we eschew opening that particular can of worms in this talk. (Received February 10, 2016)

1120-46-178 **Beatrice-Helen Vritsiou*** (vritsiou@umich.edu), Department of Mathematics, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109-1043. *On the thin-shell conjecture for the Schatten classes.*

The thin-shell conjecture is a question from the theory of isotropic convex bodies which asks whether the variance of the Euclidean norm, with respect to the uniform measure on an isotropic convex body, can be bounded from above by an absolute constant (that is, independent of the dimension of the body) times the mean of the Euclidean norm (if the answer to this is affirmative, then we have as a consequence that most of the mass of the isotropic convex body is concentrated in an annulus with very small width, a "thin shell"). So far all the general bounds we know depend on the dimension of the bodies, however for certain families of convex bodies, like the ℓ_p balls, the conjecture has been resolved optimally.

In this talk we will discuss some results concerning the conjecture on another special family of bodies, the unit balls of the Schatten classes, which are spaces of square matrices equipped with the ℓ_p-norm of their singular values. One of the results is the proof of the conjecture for the operator norm (case of $p = \infty$).

Includes joint work with Jordan Radke (Received February 21, 2016)

1120-46-202 **Vrej Zarikian*** (zarikian@usna.edu), USNA Department of Mathematics, 572C Holloway Road, Annapolis, MD 21402. *Unique pseudo-expectations for C^*-inclusions.*

A pseudo-expectation for a C^*-inclusion $D \subset C$ is a generalization of a conditional expectation. Precisely it is a ucp map $\Phi : C \to I(D)$ such that $\Phi|_D = id$. (Here $I(D)$ is the injective envelope of D.) Whereas a C^*-inclusion may not admit any conditional expectations, it must have at least one pseudo-expectation, by injectivity. In this talk, based on recent joint work with David Pitts, we investigate the relationship between a C^*-inclusion and its pseudo-expectation space, in particular how the existence of a unique pseudo-expectation relates to structural properties of the inclusion. First we consider examples, emphasizing the cases of abelian inclusions and W^*-inclusions. Then we state some general results, the strongest of which hold when D is abelian. In that case there is a Krein-Milman theorem for the pseudo-expectation space, and an order-theoretic characterization of the unique pseudo-expectation property. Finally, as applications, we explore the connection between the unique pseudo-expectation property and norming (in the sense of Pop, Sinclair, and Smith), as well as its impact on C^*-envelope calculations. (Received February 22, 2016)

1120-46-225 **Judith A. Packer*** (packer@colorado.edu), Department of Mathematics, Ubniversity of Colorado, Boulder, CB 395, Boulder, CO 80309-0395. *Wavelets and frames associated to representations of higher-rank graph algebras.* Preliminary report.

Here we discuss notions of wavelets and frames defined on L^2-spaces for fractal-like sets associated to certain representations of higher-rank graph C^*-algebras, where the graphs in question are finite and strongly connected. We generalize work of M. Marcolli and A. Paolucci for Cuntz-Krieger C^*-algebras and obtain the wavelets and frames using the isometries and partial isometries that generate the C^*-algebras in question. This work is joint with C. Farsi, E. Gillaspy, and S. Kang. (Received February 22, 2016)

1120-46-233 **Allan Donsig*** (adonsig@unl.edu), **Adam Fuller** and **David Pitts**. *von Neumann Algebras and inverse semigroups (part I).*

Recently, Adam Fuller, David Pitts, and I developed a reformulation of Feldman-Moore's classification of von Neumann algebras containing Cartan MASAs in terms of certain extensions of inverse semigroups. Here, we show the classification extends to von Neumann algebras containing a regular abelian subalgebra with a conditional expectation onto the commutant of the subalgebra. (Received February 22, 2016)

1120-46-236 **Nina Zorboska*** (zorbosk@cc.umanitoba.ca), University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada. *Uniform local univalence and composition operators on Bloch spaces.*

The properties of a composition operator acting on specific space of analytic functions depend on the geometric properties of the inducing function. We will discuss the connections between the boundedness from below of a composition operator on a Bloch space and uniform local univalence of the inducing self-map of the unit disk. (Received February 22, 2016)

1120-46-275 **Ben Li*** (bxl292@case.edu), 12000 Fairhill Road. Apt 710, Cleveland, OH 44120, and **Elisabeth Werner**. *Affine invariant points for functions.*

Gruenbaum introduced affine invariant points and mappings for convex bodies and Meyer Schuett and Werner carried out an extensive study of these notions.

We introduce them for log-concave and s-concave functions. We give new examples of affine invariant points and mappings for functions, e.g., the John function, the Loewner function and the floating function. (Received February 23, 2016)

1120-46-278 **Ross Stokke*** (r.stokke@uwinnipeg.ca). *Module actions and isometric representations of Arens product algebras.*

Let A be a Banach algebra, X a Banach A-module. I will introduce two associated subspaces of A^* – where A^* is the Banach space dual of A – the Fourier space $\mathcal{F}(A^*)$ and the Eberlein space $\mathcal{E}(A^*)$, and will observe that with respect to an Arens product, their dual spaces $\mathcal{F}(A^*)^*$ and $\mathcal{E}(A^*)^*$ are Banach algebras in which A embeds homomorphically. I will discuss properties of these algebras and, by considering specific examples of module actions – often associated with representations on Hilbert spaces – will recover several classical (and some new) objects and theorems from abstract harmonic analysis. In particular, I will show that $\mathcal{F}(A^*)^*$ always has a

weak*-continuous (completely) isometric representation mapping onto a closed subalgebra of operators on X^*, and will thereby recover several representation theorems from abstract harmonic analysis. (Received February 23, 2016)

1120-46-279 **Marius V Ionescu*** (ionescu@usna.edu), **Alex Kumjian**, **Aidan Sims** and **Dana P Williams**. *A stabilization theorem for Fell bundles over groupoids and applications.*

We show that the C^*-algebra of a second countable saturated upper-semicontinuous Fell bundle $p : \mathcal{B} \to G$ over a second countable Hausdorff locally compact groupoid is Morita equivalent to the C^*-algebra of a groupoid dynamical system that the Fell bundle determines. 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 G on the primitive ideal space of the C^*-algebra A over $G^{(0)}$. Time permiting, I will present applications to twisted groupoid C^*-algebras. This talk is based on joint work with Alex Kumjian, Aidan Sims, and Dana P. Williams. (Received February 23, 2016)

1120-46-300 **Jonathan H Brown**, **Gabriel Nagy**, **Sarah A Reznikoff*** (sarahrez@ksu.edu), **Aidan Sims** and **Dana Williams**. *Combinatorially-defined C*-algebras and their special subalgebras.*

Uniqueness theorems for combinatorially defined C*-algebras provide conditions under which a representation of the (universal) C*-algebra associated to combinatorial data—from a directed graph, for example—is faithful. We will identify a subalgebra from which injectivity of a representation always lifts. We further discuss the properties of this subalgebra and how they are reflected in the underlying combinatorial object.

This is joint work with Jonathan Brown, Gabriel Nagy, Aidan Sims, and Dana Williams. (Received February 23, 2016)

1120-46-315 **Grigoris Paouris** (griogorios.paouris@gmail.com), College Station, TX 77843, and **Petros Valettas*** (valettasp@missouri.edu), Columbia, MO 65211. *Dvoretzky's theorem for subspaces of L_p.*

We are going to discuss the dependence on ε (and on the dimension) in Dvoretzky's theorem for finite-dimensional subspaces of L_p. We will focus in the case $p > 2$. (Received February 23, 2016)

47 ► Operator theory

1120-47-13 **Timothy Rainone** (trainone@uwaterloo.ca), Pure Mathematics, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada, and **Christopher Schafhauser*** (cschafha@uwaterloo.ca), Pure Mathematics, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada. *Crossed products of nuclear C*-algebras by free groups.*

Following the work of N. Brown, we define the notion of an MF trace on a C*-algebra in terms of approximately trace-prerving representations on finite dimensional matrix algebras. We have shown that if A is an A$\mathbb{T}$-algebra of real rank zero and F is a free group acting on A, then every trace on $A \rtimes_r F$ is MF. Combining this with recent results in classification, yields some structural results for free group actions on many simple, nuclear C*-algebras. In particular, we characterize when the crossed products formed by these actions are MF in the sense of Blackadar and Kirchberg.

As a consequence, if G is a semi-direct product of an amenable group by a free group, then the group C*-algebra $C_r^*(G)$ is MF and the group von Neumann algebra $L(G)$ satisfies Connes's Embedding Problem. (Received January 12, 2016)

1120-47-29 **Cyrus P Aryana*** (aryana@svsu.edu), Department of Mathematical Sciences, Saginaw Valley State University, University Center, MI 48710. *Self-adjoint Toeplitz operators associated with representing measures on doubly connected planar regions and their eigenvalues.*

An analysis is made of the eigenvalues of Self-adjoint Toeplitz operators defined on Hardy spaces associated with non-negative representing measures on multiply connected planar regions. The presence of eigenvalues of these operators acting on Hardy spaces associated with 2-holed connected planer regions is revealed in the case where there exists a bounded component in the complement of the essential range of the symbol ϕ of the operators.

The analysis uses the zeros of translations of theta functions restricted to $\mathbb{R}^2$ in $\mathbb{C}^2$. (Received January 24, 2016)

1120-47-37 **Scott M LaLonde** (slalonde@uttyler.edu) and **David Milan*** (dmilan@uttyler.edu). *Amenability and uniqueness for groupoids associated with inverse semigroups.* Preliminary report.

We investigate recent uniqueness theorems for reduced C^*-algebras of Hausdorff étale groupoids in the context of inverse semigroups. In many cases the distinguished subalgebra is closely related to the algebraic structure of the inverse semigroup. In order to apply our results to full C^*-algebras we also inverstigate amenability. (Received January 28, 2016)

1120-47-60 **Dilian Yang*** (dyang@uwindsor.ca), Department of Mathematics & Statistics, University of Windsor, Windsor, ON N9B 3P4, Canada. *The Yang-Baxter Equation and affine actions on groups.*

Our motivation of studying the Yang-Baxter equation is from higher rank graphs. In this talk, we will show how to classify solutions of the Yang-Baxter equation using affine actions on groups. Also, we will give a connection with C*-dynamical systems. (Received February 08, 2016)

1120-47-63 **Douglas Farenick**, **Samuel Jaques** and **Mizanur Rahaman*** (mizanur1@gmail.com). *Fidelity preservation in C^* algebras.* Preliminary report.

Fidelity provides a measure of distance between quantum states, where a quantum state is understood to be a density operator acting on a finite-dimensional Hilbert space. In quantum information theory, one is interested in the structure of positive trace-preserving linear maps that preserve fidelity for all pairs of states. In this lecture I will consider fidelity in a C*-algebra A and describe the structure of positive trace-preserving linear maps on A that preserve fidelity. (Received February 08, 2016)

1120-47-74 **Aamena Rasim Al-Qabani*** (rn030601@reading.ac.uk), University of Reading/ Whiteknights, PO Box 2, Reading, RG6 6AX, United Kingdom, **Titus Willem Hilberdink** (t.w.hilberdink@reading.ac.uk), University of Reading/ Whiteknights, PO Box 2, Reading, RG6 6AX, United Kingdom, and **Jani A. Virtanen** (j.a.virtanen@reading.ac.uk), University of Reading/ Whiteknights, PO Box 2, Reading, RG6 6AX, United Kingdom. *Fredholm properties of block Toeplitz operators on vector valued Fock spaces $(F^p_\alpha)_N$.*

Let F^2 be the standard Fock space. *The vector valued space* $(F^p_\alpha)_N$, is defined by

$$(F^p_\alpha)_N = \{\mathcal{F} = (f_1, f_2, \cdots, f_n) : f_k \in F^p_\alpha for\ all\ 1 \le k \le n\},$$

it is a subspace of L^p_N. Let $\mathcal{A} \in L^\infty_{N\times N}(\mathbb{C})$ is a matrix valued function and let $M_\mathcal{A} : L^p_N \to L^p_N$ is the multiplication operator

The block Toeplitz operator $T_\mathcal{A}$ on $(F^p_\alpha)_N$ defined by

$$T_\mathcal{A}(f) = \left(\sum_{i=1}^N T(a_{ki})f_i\right)_{k=1}^N = \left(\sum_{i=1}^N P(a_{ki}f_i)\right)_{k=1}^N,$$

where, P is the orthogonal projection from $L^p(\mathbb{C}, d\lambda_\alpha)$ onto F^p_α, and $f \in (F^p_\alpha)_N$.

We study the boundedness, compactness and the Fredholm properties of $T_\mathcal{A}$ on $(F^p_\alpha)_N$ with $\mathcal{A}$ in $(L^\infty(\mathcal{C}) \cap VO)_{N\times N}$ and $(L^\infty(\mathcal{C}) \cap VMO)_{N\times N}$. The main result establishes a criterion for the Fredholmness and the index of $T_\mathcal{A}$ on $(F^p_\alpha)_N$. (Received February 11, 2016)

1120-47-75 **Raphael Clouatre*** (raphael.clouatre@umanitoba.ca) and **Kenneth R. Davidson** (krdavids@uwaterloo.ca). *Absolute continuity for commuting row contractions.*

Absolutely continuous Hilbert space contractions admit a functional calculus which is weak-$*$ continuous. Over the years, this finer continuity property has been exploited with great success to tackle a variety of important problems. At the root of this success is the fact that absolutely continuous contractions can be understood through the dual space of the disc algebra $A(\mathbb{D})$.

Turning to the topic of multivariate operator theory, we investigate the analogous notion of absolutely continuous commuting row contractions, and provide a complete characterization for it in measure theoretic terms. On the surface, the statements of our results are reminiscent of the corresponding classical single variable theorems. However, the underlying operator algebra $\mathcal{A}_d$ consists of multipliers on the Drury-Arveson space, and thus is vastly different from $A(\mathbb{D})$. In particular, it is not a uniform algebra. We highlight the new tools that must be used to circumvent this difficulty. (joint work with Ken Davidson) (Received February 11, 2016)

1120-47-83 **Justin R. Peters*** (peters@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011, and **Preechaya Sanyatit**. *A class of commutative operator algebras.* Preliminary report.

Let α be a positive irrational number, and let $\mathcal{A}_\alpha$ be the set of continuous functions on the 2-torus $\mathbb{T}^2$ satisfying $\hat{f}(m,n) = 0$ whenever $m + \alpha n < 0$. These algebras and other subalgebras of continuous functions on compact groups were studied by Wermer, Gleason, Gamelin and others in the 1950's and 60's. These algebras $\mathcal{A}_\alpha$ are Dirichlet algebras, they are maximal subalgebras of $C(\mathbb{T}^2)$, and have various properties related to analyticity. None of the properties they studied, however, distinguished between $\mathcal{A}_\alpha$ and $\mathcal{A}_\beta$ if α and β are two positive irrationals. From the operator algebra viewpoint it is natural to ask: Are these algebras in fact indistinguishable?

We can also describe the automorphism group of the $\mathcal{A}_\alpha$. (Received February 13, 2016)

1120-47-94 **S. Molahajloo**, Department of Mathematics, IASBS, 4513879368 Gava zang, Zanjan, Iran, **Kasso Okoudjou*** (kasso@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742, and **G. Pfander**, School of Science and Engineering, Jacobs University, 28759 Bremen, Germany. *On the boundedness of the bilinear Hilbert transform on modulation spaces.*

In this talk, we present new boundedness results for multilinear pseudodifferential operators on products of modulation spaces. These results are derived by relying on ordered integrability conditions on the short-time Fourier transform of the operators' symbols. The flexibility and strength of the introduced methods are demonstrated by their applications to the bilinear and trilinear Hilbert transform. The talk is based on a joint work with S. Molahajloo, and G. Pfander (Received February 15, 2016)

1120-47-105 **Ilya A Krishtal*** (ikrishtal@niu.edu), Northern Illinois University, Department of Mathematical Sciences, Watson Hall 320, DeKalb, IL 60115. *On the spectral theory of operator polynomials with coefficients in a Banach algebra.*

We use the techniques of abstract harmonic analysis to study the spectral properties of a polynomial of a closed linear operator with coefficients in some Banach algebra of bounded linear operators. For example, we show that if the closed operator generates a bounded C_0-group and the Banach algebra satisfies some mild conditions then the spectrum of the operator polynomial in the algebra of all bounded linear operators coincides with its spectrum in the algebra of coefficients. The talk is based on joint work with A. Baskakov. (Received February 16, 2016)

1120-47-130 **Sivaram K Narayan*** (sivaram.narayan@cmich.edu), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859, and **Daniel Sievewright** and **Derek Thompson**. *Complex symmetric composition operators on H^2.*

We say that a bounded operator T on a complex Hilbert space H is *complex symmetric* if there exists a *conjugation* (i.e., a conjugate linear, isometric involution) J such that $T = JT^*J$. In this talk, we will discuss the complex symmetry of composition operators $C_\varphi f = f \circ \varphi$ induced on the Hardy space H^2 by analytic self-maps φ of the open unit disk $\mathbb{D}$. We show that there are complex symmetric composition operators on H^2 induced by φ that are linear-fractional but not automorphisms. In doing so, we answer a recent question of Noor, and partially answer the original problem posed by Garcia and Hammond. (Received February 18, 2016)

1120-47-139 **Elias G. Katsoulis*** (katsoulise@ecu.edu), Department of Mathematics, East Carolina University, Greenville, NC 27858. *Crossed products of operator algebras.*

In this talk I will be defining the crossed product of an approximately unital operator algebra by a locally compact group of completely isometric automorphisms. I will explain how to make sense of iterated crossed products and then present a version of Takai duality. Applications will be given to the study of semisimplicity for operator algebras. (Joint work with Chris Ramsey.) (Received February 19, 2016)

1120-47-167 **Talat Nazir*** (talat.nazir@mdh.se), Malardalen University Vasteras, 72123 Vasteras, Sweden. *Fixed point results of block operator matrix and its applications.*

In this paper, we study the existence of solutions of operator equations employing the block operator matrix. We present some examples in the support of our results. An application is also obtained for solutions of a coupled system of differential equations under abstract boundary conditions of Rotenberg's model type. Our results unify, extend and generalize various results in existing literature. (Received February 21, 2016)

1120-47-211 **Douglas Farenick**, **Mitja Mastnak** and **Alexey Popov*** (alexey.popov@uleth.ca), C526 University Hall, 4401 University Drive, Lethbridge, Alberta T1K 3M4, Canada. *Isometries of the Toeplitz Matrix Algebra.*

We study the structure of isometries defined on the algebra $\mathcal{A}$ 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 $\mathcal{A}$ 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 $\mathcal{A} \to M_n(C)$ is necessarily an algebra homomorphism. (Received February 22, 2016)

1120-47-224 **Travis B Russell*** (trussell8@huskers.unl.edu). *Characterizations of ordered self-adjoint operator spaces.*

Abstract characterizations have played an important role in the study of operator spaces (subspaces of $B(H)$) and operator systems (unital self-adjoint subspaces of $B(H)$), as they allow us to study these objects without directly considering their actions on a particular Hilbert space. While abstract characterizations for operator systems and operator spaces have been well known for several decades, corresponding characterizations for self-adjoint subspaces of $B(H)$ which may not posses a unit have not been considered until very recently.

In this talk, we will consider a new abstract characterization for self-adjoint subspaces of $B(H)$ which may be non-unital. This characterization accounts for both the sequence of norms and the sequence of partial orderings inherited by such subspaces, generalizing the work of Werner. Time permitting, we will examine some applications, including extension problems and quotients. (Received February 22, 2016)

1120-47-232 **Allan P. Donsig**, **Adam H. Fuller*** (fuller.ah@gmail.com) and **David R. Pitts**. *von Neumann Algebras and inverse semigroups (part II).*

In recent work with Allan Donsig and David Pitts, we associate Cartan masas in von Neumann algebras to extensions of inverse semigroups. In this talk we will discuss how this discussion allows us to classify (Bures-closed) bimodules of the Cartan masa. These bimodule include sub-von Neumann algebras and maximal triangular algebras which contain the Cartan masa. (Received February 22, 2016)

1120-47-263 **Ian Charlesworth*** (ilc@math.ucla.edu), **David Penneys** and **Emily Peters**. *Standard invariants of amalgamated Bisch-Haagerup subfactors.* Preliminary report.

Given countable groups H, K with common finite-index subgroup L and an outer action of $\langle H, K\rangle$ on the hyperfinite II_1 factor R, we take N a downwards basic construction $N \subset R \rtimes L \subset R \rtimes H$, and consider the subfactor $N \subset R \rtimes K$. We show that the standard invariant of $N \subset R \rtimes K$ is the same as the subfactor $R \rtimes H \subseteq R \rtimes \mathcal{G}$ with $\mathcal{G}$ a particular groupoid with zero. In fact, every element of the Jones tower of this subfactor is a crossed product of R by a groupoid with zero. We go on to describe the associated standard invariant. (Received February 23, 2016)

52 ► Convex and discrete geometry

1120-52-9 **Alexander Koldobsky*** (koldobskiya@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *The slicing problem for sections of proportional dimensions.*

We consider the following problem. Does there exist an absolute constant C such that for every $n \in N$, every integer $1 \le k < n$, every origin-symmetric convex body L in R^n, and every measure μ with non-negative even continuous density in R^n,

$$\mu(L) \ \le \ C^k \max_{H \in Gr_{n-k}} \mu(L \cap H) \ |L|^{k/n},$$

where Gr_{n-k} is the Grassmanian of $(n-k)$-dimensional subspaces of R^n, and $|L|$ stands for volume? This question is an extension to arbitrary measures (in place of volume) and to sections of arbitrary codimension k of the hyperplane conjecture of Bourgain, a major open problem in convex geometry.

We show that the inequality holds for arbitrary origin-symmetric convex bodies, all k and all μ with $C \sim \sqrt{n}$, and with an absolute constant C for some special classes of bodies. We also prove that for every $\lambda \in (0, 1)$ there exists a constant $C = C(\lambda)$ so that the inequality holds for every $n \in N$, every origin-symmetric convex body L in R^n, every measure μ with continuous density and the codimension of sections $k \ge \lambda n$. (Received December 19, 2015)

1120-52-107 **Sergii Myroshnychenko***, Kent State University, Department of Mathematical Sciences, Summit street, Kent, OH 44242. *On a functional equation related to a pair of hedgehogs with congruent projections.*

Hedgehogs are geometrical objects that describe the Minkowski differences of arbitrary convex bodies in Euclidean space. We prove that two hedgehogs in the three dimensional Euclidean space coincide up to translation and reflection in the origin, provided that their projections onto any plane are directly congruent and have no direct rigid motion symmetries. Our result is a consequence of a more general analytic statement about the solutions of a functional equation in which the support functions of hedgehogs are replaced with two arbitrary continuous functions on the unit sphere. (Received February 16, 2016)

1120-52-112 **Elisabeth M Werner*** (elisabeth.werner@case.edu), **Steven Hoehner** and **Carsten Schuett**. *Approximation of convex bodies by polytopes.*

How well can a convex body be approximated by a polytope? This is a fundamental question in convex geometry, also in view of applications in many other areas of mathematics and related fields. It often involves side conditions like a prescribed number of vertices, or, more generally, k-dimensional faces and a requirement that the body contains the polytope or vice versa. Accuracy of approximation is measured using various metrics. We will present recent results, together with Steven Hoehner and Carsten Schuett, on these issues. (Received February 17, 2016)

1120-52-123 **Alexandru Chirvasitu***, University of Washington, Department of Mathematics, Box 354350, Seattle, WA 98195-4350. *Parkable convex sets and finite-dimensional Hilbert spaces.*

A convex subset C of a convex set $B \ni 0$ in a Euclidean space is said to be parkable in B if the latter contains a translate of C containing 0.

We give a characterization of ellipsoids in $\mathbb{R}^n$ in terms of the parkability of their convex subsets, proving a conjecture of G. Bergman.

The proof relies on the realization of centrally symmetric convex bodies as unit balls of Banach spaces, together with characterization due to Kakutani of Hilbert spaces as Banach spaces admitting an involution on their lattice of closed subspaces. (Received February 17, 2016)

1120-52-168 **Dmitry Ryabogin**, **Vladyslav Yaskin*** (yaskin@ualberta.ca) and **Ning Zhang**. *Unique determination of convex lattice sets.*

Let K and L be origin-symmetric convex lattice sets in $\mathbb{Z}^n$. We study a discrete analogue of the Aleksandrov theorem for the surface areas of projections. If for every $u \in \mathbb{Z}^n$, the sets $(K|u^\perp) \cap \partial(\mathrm{conv}(K)|u^\perp)$ and $(L|u^\perp) \cap \partial(\mathrm{conv}(L)|u^\perp)$ have the same number of points, is then necessarily $K = L$? We give a positive answer to this question in $\mathbb{Z}^3$. In higher dimensions, we obtain an analogous result when $\mathrm{conv}(K)$ and $\mathrm{conv}(L)$ are zonotopes. (Received February 21, 2016)

1120-52-172 **Christos Saroglou** and **Ivan Soprunov*** (i.soprunov@csuohio.edu), 2121 Euclid Ave, Cleveland, OH 44115, and **Artem Zvavitch**. *Bezout inequality for mixed volumes.*

The classical Bezout inequality in algebraic geometry relates the degrees of hypersurfaces to the degree of their intersection. For generic hypersurfaces with fixed Newton polytopes the degree can be computed as the mixed volume according to the Bernstein–Kushnirenko theorem. Thus the Bezout inequality can be interpreted as an inequality for mixed volumes of lattice polytopes. Indeed, for $2 \le r \le n$ hypersurfaces with Newton polytopes $P_1, \dots, P_r$ in $\mathbb{R}^n$ the Bezout inequality becomes

$$V(P_1, \dots, P_r, \Delta^{n-r}) V_n(\Delta)^{r-1} \le \prod_{i=1}^{r} V(P_i, \Delta^{n-1}), \tag{1}$$

where Δ is the standard n-simplex $\Delta = \mathrm{conv}\{0, e_1, \dots, e_n\}$ and Δ^k indicates that Δ is repeated k times in the expression of the mixed volume. This turns out to be a general inequality which holds for arbitrary convex bodies P_i and arbitrary n-simplex Δ. The main question we will discuss is whether the Bezout inequality characterizes simplices, that is, if Δ is a convex body which satisfies (1) for all convex bodies $P_1, \dots, P_r$ does it imply that Δ is an n-simplex? (Received February 21, 2016)

1120-52-175 **Florian Besau*** (florian.besau@case.edu) and **Elisabeth M. Werner**. *The floating body in real space forms.*

We carry out a systematic investigation of floating bodies in real space forms. A new unifying approach not only allows us to treat the important classic case of Euclidean space as well as the recent extension to the Euclidean unit sphere, but also the new extension of floating bodies to hyperbolic space.

In our main result we establish a relation between the derivative of the volume of the floating body and a certain surface area measure, which is called the floating area. In the Euclidean setting the floating area coincides with the well known affine surface area, a powerful tool in the affine geometry of convex bodies. (Received February 21, 2016)

1120-52-238 **Christos Saroglou*** (christos.saroglou@gmail.com), 233 MSB, 1300 Lefton Esplanade, Kent, OH 44242. *On the equivalence between two problems of asymmetry on convex bodies.*

The simplex was conjectured to be the extremal convex body for the two following "problems of asymmetry":
P1) What is the minimal possible value of the quantity $\max_{K'} |K'|/|K|$? Here, K' ranges over all symmetric convex bodies contained in K.
P2) What is the maximal possible volume of the Blaschke-body of a convex body of volume 1?
Our main result states that (P1) and (P2) admit precisely the same solutions. This complements a result from [K. Böröczky, I. Bárány, E. Makai Jr. and J. Pach, (Received February 22, 2016)

1120-52-277 **Jaegil Kim** (jaegil@ualberta.ca), Department of Mathematical and Statistical Sc, University of Alberta, Edmonton, Albrta T6G 2G1, Canada, **Vladyslav Yaskin** (vladyaskin@math.ualberta.ca), Department of Mathematical and Statistical Sc, University of Alberta, Edmonton, Alberta T6G 2G1, Canada, and **Artem Zvavitch*** (zvavitch@math.kent.edu), The Department of Mathematical Sciences, Kent State University, kent, OH 44202. *Distribution functions of sections and projections of convex bodies.*

Typically, when we are given the section (or projection) function of a convex body, it means that in each direction we know the size of the central section (or projection) perpendicular to this direction. Suppose now that we can only get the information about the sizes of sections (or projections), and not about the corresponding directions. In this talk we will discussto what extent the distribution function of the areas of central sections (or projections) of a convex body can be used to derive some information about the body, its volume, etc. (Received February 23, 2016)

1120-52-298 **Karoly Bezdek*** (bezdek@math.ucalgay.ca), University of Calgary, Calgary, Canada. *On minimizing the volume of self-polar convex bodies in spherical d-space.*

I call a spherical convex polytope a spherical Reuleaux polytope if it is of constant spherical width of $\pi/2$. The talk will discuss a number of properties of spherical Reuleaux polytopes in connection with a generalization of the Blaschke-Leichtweiss theorem. (Received February 23, 2016)

53 ► Differential geometry

1120-53-12 **Tian-Jun Li** and **Cheuk Yu Mak*** (makxx041@umm.edu). *Symplectic log Calabi Yau surfaces.*

We show that symplectic log Calabi Yau surfaces are uniquely determined by the homological data of the boundary divisors up to symplectic deformation equivalence. (Received January 10, 2016)

1120-53-80 **Jeff A Viaclovsky*** (jeffv@math.wisc.edu), Department of Mathematics, University of Wisconsin, Madison, WI 53706. *Moduli spaces and gluing.*

Geometers are interested in the problem of finding a "best" metric on a manifold. In dimension 2, the best metric is usually one which possesses the most symmetries, such as the round metric on a sphere, or a flat metric on a torus. In higher dimensions, there are many classes of geometrically interesting "best" metrics, such as Einstein metrics, metrics with special holonomy, and extremal Kähler metrics, to name a few. One technique for finding new examples of such metrics is a procedure called "gluing", in which one takes known solutions on two different manifolds, attaches them together using some kind of surgery to obtain an "approximate" solution on a new manifold, and then attempts to perturb to an exact solution of the equations on the new manifold. There are obstructions to carrying this out in practice, which can be understood using a fancy version of the implicit function theorem. Gluing techniques are a valuable tool in studying moduli spaces of solutions, because they give an understanding of how solutions can degenerate. I will describe some well-known examples of moduli spaces and gluing techniques, and then discuss some of my work in this area regarding critical metrics on four-manifolds. (Received February 12, 2016)

1120-53-147 **Richard Hind***, Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Optimal embeddings of Lagrangian tori.*

We investigate when there exists a Hamiltonian diffeomorphism of $\mathbb{R}^4$ taking a given Lagrangian torus into a ball.

To be precise, we define the product torus

$$L(a,b) = \{\pi(x_1^2 + y_1^2) = a, \pi(x_2^2 + y_2^2) = b\}$$

and compute the infimum of $R > 0$ such that there exists a Hamiltonian diffeomorphism mapping $L(a,b)$ into a ball of capacity R.

This is joint work with Emmanuel Opshtein, and our analysis relies on a classification result of Georgios Dimitroglou Rizell. (Received February 19, 2016)

1120-53-154 **Michael Usher*** (usher@uga.edu). *The Calabi homomorphism and generating functions.*

The Calabi homomorphism is an $\mathbb{R}$-valued homomorphism on the Hamiltonian diffeomorphism group Ham of an exact symplectic manifold, and is essentially unique in the sense that all other non-injective homomorphisms from Ham factor through it. Oh has conjectured that the Calabi homomorphism extends continuously to the group of Hamiltonian homeomorphisms, and has observed that his conjecture (in the case of the 2-disk) would imply a negative solution to the longstanding question of whether the compactly-supported area-preserving homeomorphism group of the 2-disk is simple. The basic problem in trying to prove the conjecture is to understand the behavior of the Calabi homomorphism on sequences of Hamiltonian diffeomorphisms which C^0-converge to the identity and have some control on their associated Hamiltonians. I will discuss a partial result covering sequences that satisfy an additional hypothesis, which arises from a reformulation of Oh's conjecture in terms of generating functions. (Received February 20, 2016)

1120-53-208 **Susan Tolman** and **Jordan Watts*** (jordan.watts@colorado.edu), Department of Mathematics, Campus Box 395, Boulder, CO 80309. *Tame circle actions.*

A famous question of Dusa McDuff, the so-called "McDuff Conjecture", asks whether there exists a non-Hamiltonian symplectic circle action with isolated fixed points on a compact symplectic manifold. Susan Tolman recently answered this question in the affirmative, constructing a 6-dimensional such space with exactly 32 fixed points. A crucial ingredient to this construction involves Hamiltonian circle actions on complex manifolds and orbifolds in which the interaction between the complex structure and the symplectic form is fairly weak. Specifically, versions of the holomorphic slice theorem, the birational equivalence theorem, as well as reduction, cutting, and blow-up (all of which work in the Kaehler world) are required in this weaker setting.

All of these theorems and constructions are extended to this weaker setting in joint work by Tolman and myself. By weak, we mean a positivity condition involving the infinitesimal circle action, the symplectic form and the complex structure on the complement of the fixed point set. This condition is sufficient for almost all of the theorems and constructions above. In this talk, I will focus on a few of the constructions that appear in the joint paper. (Received February 22, 2016)

1120-53-220 **Heidi M. Andersen*** (and02626@umn.edu). *Symplectic birational cobordism and the Hard Lefschetz Property.* Preliminary report.

A study of compact symplectic manifolds which are symplectic birationally cobordant to Hard Lefschetz or Kähler manifolds. (Received February 22, 2016)

54 ► General topology

1120-54-10 **Sümeyra Sakallı*** (sakal008@umn.edu), 127 Vincent Hall, 206 Church St. SE, Minneapolis, MN 55455. *On the geography of simply connected, nonspin, symplectic 4-manifolds withe nonnegative signature.*

We will construct infinitely many irreducible symplectic and non-symplectic 4-manifolds that are homeomorphic but not diffeomorphic to $(2n-1)\mathbb{CP}^2\#(2n-1)\overline{\mathbb{CP}^2}$ for each integer $n \geq 12$, and the families of simply connected irreducible nonspin symplectic 4-manifolds that have the smallest Euler characteristics among the all known simply connected 4-manifolds with positive signature and with more than one smooth structure. Our construction uses the complex surfaces of Hirzebruch and Bauer-Catanese on Bogomolov-Miyaoka-Yau line with $c_1^2 = 9\chi_h = 45$. This is a joint work with A. Akhmedov. (Received December 31, 2015)

55 ► Algebraic topology

1120-55-170 **M. Naeem Ahmad*** (ahmadn@smcsc.edu). *Complex N-Spin bordism and elliptic genera.*
We give a complete bordism analysis of rational bordism groups of semifree circle actions on complex N-Spin manifolds. Moreover, we introduce the notion of a complex N-Spin^{c,t} manifold and give a characterization of cobordism groups of such manifolds which we use to compute the rational bordism groups of free circle actions of type t on complex N-Spin manifolds. Furthermore, we exploit this bordism analysis to furnish a mechanism with which we investigate a description, in terms of kernels of complex elliptic genera, of the ideal $I_*^{N,t}$, generated by bordism classes of connected complex N-Spin manifolds admitting an effective circle action of type t, in the rational complex N-Spin cobordism ring $\Omega_*^{U,N} \otimes \mathbb{Q}$. This work is part of a paper to appear in Homology, Homotopy and Applications. (Received February 21, 2016)

1120-55-258 **Adam Clay*** (adam.clay@umanitoba.ca). *Orderability and Dehn fillings of knot complements.*
Recent years have seen an ongoing investigation into left-orderability of fundamental groups of 3-manifolds, motivated by conjectured connections with Heegaard-Floer homology and foliations. In this talk, I will discuss the behaviour of left-orderability of fundamental groups with respect to the operation of Dehn filling along a knot in S^3. Specifically, I'll explain what is conjectured to be true in the context of Dehn fillings, what has already been proved, and current directions of research. (Received February 23, 2016)

57 ► Manifolds and cell complexes

1120-57-28 **Naoyuki Monden*** (monden@isc.osakac.ac.jp), Department of Engineering Science, Osaka Electro-Communication University, 18-8, Hatsu-cho, Neyagawa, Osaka 572-8530, Japan. *Stable commutator length of Dehn twists and the signatures of surface bundles.*
It is well-known that the signature of surface bundles over surfaces is $4n$ for an integer n. Especially, the signature vanishes if the base genus is 0 or 1. In this talk, for any integer n, we construct surface bundles of fiber genus at least $39|n|$ over the surface of genus 2 with signature $4n$. Such examples are constructed using mapping class group arguments. Moreover, by applying the construction techniques, we give factorizations of powers of Dehn twists as products of commutators. As a corollary, we obtain new upper bounds for stable commutator lengths of Dehn twists. (Received January 23, 2016)

1120-57-64 **Nur Saglam*** (sagla004@umn.edu). *Strongly fillable but not Stein fillable contact structures on 3-manifolds $-\Sigma(2, 2g+1, 2(2g+1)-1)$.* Preliminary report.
In this talk, we will show that the 3-manifold $-\Sigma(2, 2g+1, 2(2g+1)-1)$ admits a contact structure μ_0 which is strongly fillable but not Stein fillable. We will explain how to produce $(-\Sigma(2, 2g+1, 2(2g+1)-1), \mu_0)$ and show that μ_0 is strongly symplectically filllable. If time permit, we will prove the non-Stein fillability of μ_0 using the contact invariants in Heegaard-Floer theory. (Received February 13, 2016)

1120-57-111 **Tian-Jun Li*** (lixxx248@umn.edu) and **Chung-I Ho**. *Non-orientable Lag surfaces in symplectic 4-manifolds.*
We study the existence of non-orientable Lag surfaces in symplectic 4-manifolds, especially in rational 4-manifolds. (Received February 17, 2016)

1120-57-140 **Nicholas J Owad*** (nowad2@math.unl.edu). *Recent results in bridge spectra.*
The bridge spectrum is a generalization of the bridge number of a knot to higher genus Heegaard decompositions. It is necessarily a decreasing sequence, and it has been proven that certain knots obtain a stair-step bridge spectrum, which decreases by one with each step. We will cover recent progress in computing the bridge spectra of Montesinos knots and cables of 2-bridge knots. (Received February 19, 2016)

1120-57-142 **Derek Davies** and **Alexander Zupan*** (zupan@unl.edu). *The trunk of a knot and connected sums.*
Loosely, the trunk of a knot K in 3-space is the greatest number of intersections of K with any plane parallel to the xy-plane, minimized over all embeddings isotopic to K. If K and J are two distinct knots, it is straightforward to obtain an upper bound for the trunk of their connected sum simply by stacking embeddings with minimal trunk on top of each other; the trunk of the resulting embedding is the maximum of the trunks of K and J. We prove that this upper bound is sharp, so that the trunk of the connected sum of two knots is the maximum of the trunks of its summands, resolving an open question of Makoto Ozawa. (Received February 19, 2016)

1120-57-177 **Luke Morgan Williams*** (lukewilliams@math.ksu.edu). *On non-Stein rational balls.* Preliminary report.

The existence of a Stein structure on a smooth 4-manifold provides powerful constraints on it's (smooth) topology. These constraints can be leveraged to obstruct a given 4-manifold from being Stein. Unfortunately, many of these obstructions break down in the case of rational balls. I will describe methods that can overcome this breakdown and allow the construction of infinite families of rational balls that cannot be Stein. (Received February 21, 2016)

1120-57-191 **Jun Li*** (lixx1727@umn.edu), 206 church street S.E., Room127, Minneapolis, MN 55455, **Tian-Jun Li** (lixxx248@umn.edu), 206 church street S.E., Room 127, Minneapolis, MN 55455, and **Weiwei Wu**. *A generalized Alexander duality, -2 spheres and symplectomorphism groups of rational 4-manifolds.*

We study the space of tamed almost complex structure for symplectic 4 manifold using a generalized Alexander duality for ∞-dimensional stratification. Consequently, we relate the number of generators of the fundamental group of symplecotomorphism group for $S^2 \times S^2$ or $S^2 \times S^2 \# n\overline{\mathbb{C}P^2}$ when $n = 0, 1, 2, 3$ with the number of -2 symplectic spheres. Further, we find a new family of symplectic form on $\mathbb{C}P^2 \# 5\overline{\mathbb{C}P^2}$ such that the symplecotomorphism group has disconnected Torelli part. (Received February 22, 2016)

1120-57-235 **Azer Akhmedov** and **Cody Martin*** (cody.martin@ndsu.edu), 514 29th Ave N, Apt 23, Fargo, ND 58102. *The Non-bi-orderability of* 6_2 *and* 7_6.

A group G is said to be left-orderable if there exists a total order on G that is invariant under left multiplication. A bi-order on a group G is left order which is also invariant under right multiplication.

Given a knot K, we define the knot group to be $\pi_1(\mathbb{S}^3 \backslash K)$. It can be shown that every knot group is left-orderable; however, not every knot group is bi-orderable (e.g. the trefoil). Other than the knots 6_2 and 7_6, the bi-orderability of all knots up to seven crossings was known. Using tools such as HNN extensions and the subgroup of infinitesimals, we show 6_2 and 7_6 are not bi-orderable. This is a joint work with Azer Akhmedov. (Received February 22, 2016)

60 ► Probability theory and stochastic processes

1120-60-5 **Anatoliy Swishchuk*** (aswish@ucalgary.ca), 2500 University Drive NW, Calgary, AB T2N1N4, Canada. *A semi-Markovian modeling of limit order markets.*

R. Cont and A. de Larrard (SIAM J. Finan. Math., 2013) introduced a tractable stochastic model for the dynamics of a limit order book, computing various quantities of interest such as the probability of a price increase or the diffusion limit of the price process. As suggested by empirical observations, we extend their framework to 1) arbitrary distributions for book events inter-arrival times (possibly non-exponential) and 2) both the nature of a new book event and its corresponding inter-arrival time depend on the nature of the previous book event. We do so by resorting to Markov renewal processes to model the dynamics of the bid and ask queues. We keep analytical tractability via explicit expressions for the Laplace transforms of various quantities of interest. We justify and illustrate our approach by calibrating our model to the five stocks Amazon, Apple, Google, Intel and Microsoft on June 21st 2012. As in Cont and Larrard (SIAM J. Finan. Math., 2013), the bid-ask spread remains constant equal to one tick, only the bid and ask queues are modeled (they are independent from each other and get reinitialized after a price change), and all orders have the same size. (Received November 12, 2015)

1120-60-21 **Xiaoshan Chen**, **Yu-Jui Huang**, **Qingshuo Song** and **Chao Zhu*** (zhu@uwm.edu), Department of Mathematical Sciences, University of Wisconsin-Milwaukee, Milwaukee, WI 53201. *The stochastic solution to a cauchy problem for degenerate parabolic equations.*

This paper studies the stochastic solution to a Cauchy problem for degenerate parabolic equations in unbounded domains arising from option pricing. We first prove that "martingality of the underlying price process" is equivalent to "uniqueness of local stochastic solutions," which in particular yields a non-standard Feynman-Kac formula. The stochastic solution, which represents the price of a European option, is shown to be a classical solution to the Cauchy problem, as long as the diffusion coefficient is locally Hölder continuous with exponent $\delta \in (0, 1]$. This improves the standard condition $\delta \geq 1/2$. A comparison theorem is also derived, without the usual linear growth condition on the diffusion coefficient. When the stochastic solution is not smooth, it is characterized as the limit of an approximating smooth stochastic solutions. Also noteworthy is that this paper presents a new proof for an equivalent condition for martingality of a one-dimensional diffusion process in natural scale. (Received January 18, 2016)

1120-60-22 **Sebastian Jaimungal*** (sebastian.jaimungal@utoronto.ca), University of Toronto, Sidney Smith Hall, 100 St. George St., Toronto, Ontario M5S 3G3, Canada, and **Luhui Gan** and **Álvaro Cartea**. *Option pricing and hedging with limit and market orders.*

Traditionally, option valuation is carried out using continuous time models for the underlier which are based on diffusive models, sometimes augmented with jump processes. However, if one's aim is to hedge options intraday, such models are far from the reality. For example, stock prices are inherently discrete, and there is a bid-ask spread. The spread acts as cost when trading with market orders while it is a source of income when trading with limit orders. In this paper, we introduce a class of pure jump models, in continuous time, that reflect a number of features seen in real intraday markets (such as volatility clustering and adverse selection), develop a statistically sound calibration methodology, and demonstrate how to simultaneously value and hedge an option using an optimal mix of limit and market orders. Finally, we investigate some of the qualitative features of the strategies, and demonstrate how they differ from the naïve ones resulting from ignoring the bid-ask spread and optimal mix of limit and market orders. (Received January 19, 2016)

1120-60-33 **Gregory F Lawler*** (lawler@math.uchicago.edu), Department of Mathematics, University of Chicago, 5734 University Ave., Chicago, IL 60637-1546. *Convergence of loop-erased random walk to the Schramm-Loewner evolution in the natural parametrization.*

I will discuss recent work with Fredrik Viklund showing that the loop-erased random walk (LERW) on a fine lattice in bounded domain parametrized by number of steps, appropriately normalized, converges to the Schramm-Loewner evolution of parameter 2 (SLE_2) in the natural parametrization. The new part is to show that the number of steps in the walk converges to the 5/4-dimensional Minkowski content of the SLE_2 path. The proof uses the fact that the Minkowski content for SLE_2 exists and is nontrivial (work with M. Rezaei) and precise asymptotics for the LERW Green's function (work with Viklund and C. Benes). (Received January 27, 2016)

1120-60-41 **Nguyet Nguyen*** (ntnguyen01@ysu.edu), 1 University Plaza, Youngstown, OH 44555. *Stock price prediction using Hidden Markov Model.*

In this talk, I will introduce the Hidden Markov Model (HMM) and use it to predict the prices of three stocks: Apple, Google and Facebook. The prediction procedure consists of several steps. Firstly, the Akaike information criterion (AIC) and Bayesian information criterion (BIC) were used to test the performances of HMM with different numbers of states. Then, predicted stock prices were compared with the market prices to see if the AIC or BIC test result for HMM is consistent with the prediction results. (Received January 29, 2016)

1120-60-42 **Leonid Petrov*** (petrov@virginia.edu), Department of Mathematics, University of Virginia, 141 Cabell Drive, Kerchof Hall, Charlottesville, VA 22904. *Inhomogeneous exponential jump model: a KPZ particle system with new unusual phase transitions.* Preliminary report.

I will talk about a stochastic interacting particle system on the continuous real line equipped with a function $\xi(x)$ determining the speed of jumping particles at each location $x \in \mathbb{R}$. The waiting times and jump lengths of particles are exponentially distributed, and the behavior of the system is somewhat similar to a queuing model. By relating this system to the inhomogeneous stochastic higher spin six vertex model, it can be shown that the exponential jump model is exactly solvable for an arbitrary speed function $\xi(x)$. In particular, q-moments of the height function admit explicit multiple contour integral expressions. I will discuss the asymptotic behavior of the system (as time and the number of particles grows), which leads to limit shapes with new unusual phase transitions. The fluctuations of the random height function around the limit shape are governed by the GUE Tracy–Widom distribution. (Received January 31, 2016)

1120-60-43 **John C Wierman*** (wierman@jhu.edu), Dept. of Applied Mathematics and Statistics, Johns Hopkins University, Baltimore, MD 21218. *Bounds for bond percolation thresholds of two three-dimensional lattices.* Preliminary report.

A percolation model is an infinite random graph model for phase transitions and critical phenomena. The percolation threshold corresponds to a phase transition point, such as a melting or freezing temperature. The exact value of the percolation threshold is not known for any three-dimensional percolation models, which are important for physical applications. Furthermore, rigorous bounds for the percolation thresholds of three-dimensional models are quite poor. We derive bounds for the bond percolation thresholds of two three dimensional lattices, the cubic lattice and a type of face-centered cubic lattice. We use the substitution method, which is based on stochastic ordering of probability measures on partition lattices. Upper bounds for the cubic lattice threshold are obtained by comparisons with two-dimensional subgraphs. Bounds for the cubic lattice are translated into bounds for the face-centered cubic. In addition, the approach provides a lower bound for the difference between

the bond percolation thresholds of the two lattices, without knowing very accurate bounds for either individual lattice. A growth process approach in development may also be discussed. (Received January 31, 2016)

1120-60-79 **Aziz Issaka***, Department of Mathematics, NDSU Dept # 2750, Minard Hall 406, Fargo, ND 58108-6050, and **Indranil SenGupta**. *Feynman path integrals for transition probability densities of some financial markets.*

In this paper we implement the method of Feynman path integral for the analysis of option pricing for certain Lévy process driven financial markets. For such markets, we find closed form solutions of transition probability density functions of option pricing in terms of various special functions. Asymptotic analysis of transition probability density functions is provided. We also find expressions for transition probability density functions in terms of various special functions for certain Lévy process driven market where the interest rate is stochastic. (Received February 12, 2016)

1120-60-91 **Rodrigo Banuelos*** (banuelos@math.purdue.edu), Department of Mathematics, Purdue University, West Lafayette, IN 47907. *Lévy processes, nonlocal operators, and spectral/heat asymptotics.*

Hermann Weyl's 1911 celebrated result, commonly referred to as *Weyl's Law*, asserts that if $N_D(\lambda)$ is the number of eigenvalues of the Dirichlet Laplacian not exceeding λ in a planar region Ω of area $|\Omega|$, then $N_D(\lambda) = \frac{|\Omega|}{4\pi}\lambda + o(\lambda)$, as $\lambda \to \infty$. Weyl's theorem has been extended and refined in many directions with connections to many areas of pure and applied mathematics. In this talk we first give an overview of some of the classical results on spectral and heat asymptotics motivated by Weyl's law and discuss the elegant connections to Brownian motion first explored by Mark Kac and others in the 1950s and 1960s. We then consider problems that arise when Brownian motion, which "goes" with the Laplacian, is replaced by other stochastic processes that share several basic properties with Brownian motion. These processes, called Lévy processes after Paul Lévy who introduced them in the 1920s, give rise to a rich collection of nonlocal operators that generalize, in a probabilistically natural way, the Laplacian. While many questions on spectral and heat asymptotics remain quite open in this setting, there is some progress to report. We shall do this maintaining technicalities at a minimum. (Received February 15, 2016)

1120-60-95 **Michael Damron***, Georgia Institute of Technology, School of Mathematics, 686 Cherry St., Atlanta, GA 30332, and **Xuan Wang** and **Wai-Kit Lam**. *Asymptotics for 2D critical first-passage percolation.*

In first-passage percolation, we consider the integer lattice $\mathbb{Z}^d$ with nonnegative, i.i.d. edge-weights (t_e), and study the induced weighted graph metric T. As long as $\alpha := \mathbb{P}(t_e = 0)$ is small, the quantity $T(0, x)$ grows linearly as $x \to \infty$. If α is too large, then $T(0, x)$ remains bounded stochastically. In the so-called critical case between these two regimes, the behavior of $T(0, x)$ is unknown. I will report on work with Xuan Wang and Wai-Kit Lam where, in two dimensions, we can exactly quantify the growth of $T(0, x)$ (and derive limiting laws) in this critical case, in terms of the distribution of t_e, answering questions of Zhang and Kesten-Zhang from the '90s. (Received February 15, 2016)

1120-60-115 **Dapeng Zhan*** (zhan@math.msu.edu), Department of Mathematics, Wells Hall, Michigan State University, East Lansing, MI 48824. *Decomposition of Schramm-Loewner evolution along its curve.*

We show that, for $\kappa \in (0, 8)$, the integral of the laws of two-sided radial SLE_κ curves through different interior points against a measure with SLE_κ Green function density is the law of a chordal SLE_κ curve, biased by the path's natural length. We also show that, for $\kappa > 0$, the integral of the laws of extended $\mathrm{SLE}_\kappa(-8)$ curves through different interior points against a measure with a closed formula density restricted in a bounded set is the law of a chordal SLE_κ curve, biased by the path's capacity length restricted in that set. Another result is that, for $\kappa \in (4, 8)$, if one integrates the laws of two-sided chordal SLE_κ curves through different force points on $\mathbb{R}$ against a measure with density on $\mathbb{R}$, then one also gets a law that is absolutely continuous w.r.t. that of a chordal SLE_κ curve. To obtain these results, we develop a framework to study stochastic processes with random lifetime, and improve the traditional Girsanov's Theorem. (Received February 17, 2016)

1120-60-118 **Alexander E Fribergh*** (fribergh@dms.umontreal.ca), , Canada. *The ant in a labyrinth.* Preliminary report.

One of the most famous open problem in random walks in random environments is to understand the behavior of a simple random walk on a critical percolation cluster, a model known as the ant in the labyrinth. I will present new results on the scaling limit for the simple random walk on the critical branching random walk in high dimension. In the light of lace expansion, we believe that the limiting behavior of this model should be

universal for simple random walks on critical structures in high dimensions. This is a joint work with G. Ben Arous and M. Cabezas. (Received February 17, 2016)

1120-60-126 **Mohammad A Rezaei*** (a.rezaei65@gmail.com), Department of Mathematics, Michigan State Uni, 619 Red Cedar Road, East Lansing, MI 48824, and **Dapeng Zhan** (zhan@math.msu.edu). *Existence and Lower bound for Multi-point Green's function of SLE curves.* Preliminary report.

In this work we show that multi-point Green's function for SLE curve exists. The method is generalization of the method for 2-point Green's function by Lawler and Werness. We also provide a lower bound which is sharp up-to constant. (Received February 18, 2016)

1120-60-132 **Mustazee Rahman*** (mustazee@mit.edu). *Factor of IID percolation on trees.*

It is well known that Bernoulli percolation on the d-regular tree has finite clusters so long as the density is at most $1/(d-1)$. Now consider a natural generalizing: an invariant percolation process on the d-regular tree that is a factor of an IID process such that the factor map commutes with automorphisms of the tree. What is the largest density of such a percolation if its clusters are finite?

A simple greedy algorithm provides a lower bound of $(\log d)/d$ for large d. This bound also turns out to be asymptotically optimal in d. We will explain this result and illustrate some ideas behind the proof. (Received February 18, 2016)

1120-60-134 **Sylvain Corlay*** (scorlay@bloomberg.net). *Branching diffusions for stochastic control.*

Most numerical approaches used to solve the nonlinear PDEs arising in mathematical finance require the computation of conditional expectations, which are approximated with regression methods. In high dimensions, the choice and the fine-tuning of the regression method becomes the crux of the problem. The recently introduced branching diffusion methods provide a completely different approach to the resolution of nonlinear PDEs which does not involve the estimation of conditional expectations or dynamic programming. They are applicable to a large class of nonlinear problems including the computation of Credit Value Adjustment. (Received February 18, 2016)

1120-60-151 **Janosch Ortmann*** (janosch.ortmann@gmail.com). *Tracy-Widom asymptotics for a random polymer model with gamma-distributed weights.*

We establish Tracy-Widom asymptotics for the partition function of a random polymer model with gamma-distributed weights recently introduced by Seppäläinen. We show that the partition function of this random polymer can be represented within the framework of the geometric RSK correspondence and consequently its law can be expressed in terms of Whittaker functions.

This leads to a representation of the law of the partition function which is amenable to asymptotic analysis. In this model, the partition function plays a role analogous to the smallest eigenvalue in the Laguerre unitary ensemble of random matrix theory.

Joint work with Neil O'Connell. (Received February 19, 2016)

1120-60-159 **Huy V Tran*** (tvhuy@math.ucla.edu) and **Mario Bonk**. *The topology of continuum random trees.*

Trees are objects that appear in many areas of mathematics. In this talk we will explain how a question about random trees in probability motivates questions about Julia sets in complex dynamics. In particular, we will answer a recent question by Nicolas Curien about the topologies of independent samples of the Continuum Random Tree. Then we will address similar questions about Julia sets. This is joint work with Mario Bonk. (Received February 20, 2016)

1120-60-171 **Tom Alberts*** (alberts@math.utah.edu). *Ideas from KPZ in Directed Polymer Models.* Preliminary report.

I will discuss how ideas from the Duplantier-Sheffield approach to the KPZ equation can be carried over to the world of directed polymers. The latter does not involve complex analysis but many similar relations nonetheless seem to hold. (Received February 21, 2016)

1120-60-173 **Christian Benes*** (cbenes@brooklyn.cuny.edu), **Gregory F. Lawler** and **Fredrik Viklund**. *The scaling limit of the loop-erased random walk Green's function.*

We show that the probability that a planar loop-erased random walk passes through a given edge in the interior of a lattice approximation of a simply connected domain converges, as the lattice spacing goes to zero, to a multiple of the SLE(2) Green's function. (Received February 21, 2016)

1120-60-182 **Jonathan Chavez-Casillas*** (jonathan.chavezcasil@ucalgary.ca), Mathematical Sciences, University of Calgary, 2500 University Dr. NW, Calgary, T2N 1N4, Canada, and **Anatoliy Swishchuk**. *A Level-1 Limit order book with time dependent rates.*

In this talk, we will present a model for a level-1 Limit Order book, similar to the model presented by Cont and de Larrard (2012), but as empirical evidence shows, the distribution of the inter arrival times between orders seems to be different from a constant exponential distribution. Therefore, the given assumption of homogeneous Poisson arrivals is relaxed to consider non-homogeneous Poisson arrivals. Under the relaxed assumptions, the mid-price diffusive behaviour is presented. (Received February 21, 2016)

1120-60-197 **Wei-Kuo Chen*** (wkchen@umn.edu), 235 Vincent Hall 206 Church St. SE, Minneapolis, MN 55414, and **Arnab Sen**. *Parisi formula, disorder chaos and fluctuation for the ground state energy in the spherical mixed p-spin models.*

Spin glasses are disordered spin systems originated from the desire of understanding the strange magnetic behaviors of certain alloys in physics. As mathematical objects, they are often cited as examples of complex systems and have provided several fascinating structures and conjectures. In this talk, we will focus on the spherical mixed p-spin mean-field spin glass model. We will present the Parisi formula and some fluctuation properties for the maximum energy. In addition, we will discuss results concerning the chaotic nature of the location of the maximum energy under small perturbations to the disorder. This talk is based on a joint work with Arnab Sen. (Received February 22, 2016)

1120-60-206 **Jack Hanson*** (jhanson@ccny.cuny.edu). *Chemical distance in critical percolation.*

In critical two-dimensional Bernoulli percolation, fraction 1/2 of the edges of the graph $\mathbb{Z}^2$ are erased independently. The resulting graph has connected components and "holes" appearing on all scales. As a result, the chemical (graph) distance inside large connected components is conjectured to grow superlinearly in the Euclidean distance according to a chemical distance exponent, and some results in this direction are known. For instance, the shortest crossing of the box $[-n, n]^2$ has length $S_n > n^{1+\epsilon}$ with high probability, and is no longer than the unique lowest crossing, whose length L_n is known to scale as $n^{4/3}$. Kesten and Zhang asked whether $S_n = o(L_n)$; we will discuss recent work which gives an affirmative answer to this question, as well as some results on point-to-point and point-to-box distances.

Joint work with M. Damron and P. Sosoe. (Received February 22, 2016)

1120-60-212 **Elnur Emrah*** (elnuremrah@gmail.com), 2924 Harvey St, Apt 5G, Madison, WI 53705, and **Chris Janjigian**. *Large deviations for some corner growth models with inhomogeneity.*

We consider certain corner growth models with inhomogeneous exponential and geometric weights. We present recent work on the large deviation properties of the last-passage times. This is a joint work with Chris Janjigian. (Received February 22, 2016)

1120-60-248 **David Sivakoff*** (dsivakoff@stat.osu.edu), 1958 Neil Ave., 440N Cockins Hall, Columbus, OH 43210. *Bootstrap percolation on products of complete graphs and lattices.*

We study threshold θ bootstrap percolation on graphs of the form $\mathbb{Z}_m^{d_1} \times K_n^{d_2}$ starting from initial occupation density p. Our primary interest is in classifying the location and nature of phase transitions in the probability of the event Span, that all vertices eventually become occupied, as $m, n \to \infty$ and $p \to 0$, with d_1, d_2, θ fixed. We find that when $d_1 = 1$ and $d_2 = 2$, the phase transition may be sharp or gradual depending on the relative scaling of m and n. When $d_1 = 2$, we find interesting connections between this model and a bootstrap process with heterogeneous activation thresholds, which allows us to locate a sharp phase transition in the probability of Span. Based on joint works with Janko Gravner. (Received February 22, 2016)

1120-60-252 **Anirban Basak***, anirbanb@math.duke.edu. *Mean-field Ising models.*

We consider the asymptotics of the log-partition function of an Ising model on a sequence of growing graphs. We show that under a fairly general condition the mean-field prediction to the log partition function is asymptotically tight. This covers many naturally occurring graph ensembles such as regular graphs with degree going to infinity, graphs converging in cut-metric sense, bi-partite bi-regular graphs. This is joint work with Sumit Mukherjee. (Received February 22, 2016)

1120-60-260 **Brent Morehouse Werness*** (bwerness@math.washington.edu). *Convergence of discrete holomorphic functions on non-uniform lattices.*

The theory of discrete holomorphic functions has been studied by researchers from a diverse set of fields from classical complex analysts to applied computer scientists. In the field of conformally invariant random processes, discrete analyticity has found a particularly central role as the convergence of discrete analytic functions to their

continuum counterparts is the key step in the showing convergence of discrete random processes to Schramm–Loewner Evolutions. In this talk, we will discuss recent work that proves that discrete analytic functions converge to their continuum counterparts on lattices with only local control on the geometry and its potential applications of this result to the study conformally invariant random processes on random surface models. (Received February 23, 2016)

1120-60-264 **Wai-Tong Fan*** (ariesfanhk@gmail.com), 926 Eagle Heights C, Madison, WI 53705.
Genealogies for the biased voter model.

I will present rigorous results for the behavior of genealogies in a one-dimensional long range biased voter model introduced by Hallatschek and Nelson. The fi rst step, which is easily accomplished using results of Mueller and Tribe, is to show that when space and time are rescaled correctly, our biased voter model converges to a Wright-Fisher SPDE. A simple extension of a result of Durrett and Restrepo then shows that the dual branching coalescing random walk converges to a branching Brownian motion in which particles coalesce after an exponentially distributed amount of intersection local time. Our main result concerns "tracer dynamics" in which some of the initial particles in the biased voter model are labeled. We show that the joint distribution of the labeled and unlabeled particles converges to the solution of a system of SPDEs. A new duality equation is the key to the proof of that result. Joint work with Rick Durrett. (Received February 23, 2016)

1120-60-287 **Alan A. Sola*** (sola@usf.edu), Department of Mathematics and Statistics, Tampa, FL 33620, and **Amanda Turner**, Lancaster University, Lancaster, United Kingdom.
Conformal aggregation with strong feedback. Preliminary report.

I will report on work in progress with A. Turner (Lancaster) on scaling limits in variants of the Hastings-Levitov conformal aggregation process in which feedback results in growth at tips being favored. (Received February 23, 2016)

62 ► Statistics

1120-62-15 **Tatjana Miljkovic***, 319 Upham Hall, and **Bettina Gruen** (bettina.gruen@jku.at), Linz, Austria.
Finite mixture modeling of univariate data with Non-Gaussian component distributions. Preliminary report.

An alternative approach for flexible modeling of multimodal, heavy tailed insurance loss data is proposed based on finite mixture models of univariate distributions. The components distributions from six non-Gaussian parametric families which were previously used in actuarial modeling are considered with all components assumed to be from the same parametric family. Estimation of the models with a fixed number of components K is proposed based on the expectation-maximization (EM) algorithm using three different initialization strategies and model selection can be performed using information criteria such as the BIC. Risk measures, such as value-at-risk and tail-value-at-risk, can easily be computed for these mixture models. The results of the mixture models are compared to the composite Weibull models considered in recent literature as the best models for modeling heavy tail distributions. This modeling approach is demonstrated on a real insurance data set. (Received January 15, 2016)

82 ► Statistical mechanics, structure of matter

1120-82-150 **Tayyab Nawaz*** (tnawaz2@illinois.edu), Room 250, 1409 W. Green Street, Urbana, IL 61801, and **Kay Kirkpatrick**.
Non-normal asymptotics of the mean-field O(N)-models.

I will discuss the mean-field classical N-vector models, for even integers $N \geq 2$. I will discuss current work with Kay Kirkpatrick on non-normal behavior in case of even dimensions at the phase transition. We used large deviations and Stein's method to study the typical behavior of asymptotics of physical quantities such as magnetization.Some of the important special cases for these N-vector models are XY model ($N = 2$) and Toy model ($N = 4$), both of which have importance in statistical physics. (Received February 19, 2016)

90 ► Operations research, mathematical programming

1120-90-89 **Christoph Frei*** (cfrei@ualberta.ca), University of Alberta, and **Nicholas Westray**, Imperial College London. *Optimal execution in Hong Kong given a market-on-close benchmark.*

For stocks traded on the Hong Kong Exchange, the median of five prices taken over the last minute of trading is currently chosen as the closing price. We introduce a stochastic control formulation to target such a median benchmark in an empirically justified model which takes the key microstructural features into account. We solve this problem by providing an explicit and efficient algorithm which even has applications beyond this talk as it can be used for the dynamic linear approximation of any square-integrable random variable. Implementing the algorithm on the stocks of the Hang Seng Index, we find an average improvement of around 6% in standard deviation of slippage compared to an average trader's execution. (Received February 15, 2016)

1120-90-176 **Elaheh Gorgin*** (elaheh.gorgin@minotstateu.edu), 311 Model Hall, 500 University Avenue West, Minot, ND 58707. *A new parameter choice approach for Tikhonov Regularization Method- finite dimensional linear inverse problems.* Preliminary report.

Inverse problems arise in many branches of science and engineering. Tikhonov regularization is one of the most convenient regularization methods for dealing with linear inverse problems. This method needs a regularization parameter and the quality of the computed solution depends on how good the regularization parameter is. In this work, we introduce a new parameter selection method for Tikhonov regularization method, present some initial results and compare the performance of this method with the previous convenient parameter choice strategies. (Received February 21, 2016)

91 ► Game theory, economics, social and behavioral sciences

1120-91-11 **Runhuan Feng***, Department of Mathematics, 1409 W Green St., Urbana, IL 61801, and **Hans W Volkmer**, 3200 N Cramer St, Milwaukee, WI 53211. *Conditional Asian options.*

Conditional Asian options are recent market innovations, which offer cheaper and long-dated alternatives to regular Asian options. In contrast with payoffs from regular Asian options which are based on average asset prices, the payoffs from conditional Asian options are determined only by average prices above certain threshold. Due to the limited inclusion of prices, conditional Asian options further reduce the volatility in the payoffs than their regular counterparts and have been promoted in the market as viable hedging and risk management instruments for equity-linked life insurance products. There has been no previous academic literature on this subject and practitioners have only been known to price these products by simulations. We propose the first analytical approach to computing prices and deltas of conditional Asian options in comparison with regular Asian options. In the numerical examples, we put to the test some cost-benefit claims by practitioners. As a by-product, the work also presents some distributional properties of the occupation time and the time-integral of geometric Brownian motion during the occupation time. (Received January 04, 2016)

1120-91-57 **Tomoyuki Ichiba*** (ichiba@pstat.ucsb.edu), 5508 South Hall, University of California, Santa Barbara, CA 93106. *Portfolios in an abstract equity market with transitory volatility.*

It is often observed in financial equity markets that volatility increases temporarily by external economic shocks and then dissipates gradually. On a filtered probability space we shall construct and examine an abstract equity market model with such transitory volatility by which stocks with smaller values are influenced more, in addition to intrinsic volatility structure. We evaluate the effect of additional volatility structure from a view point of enhancing new information in the market, and compare several portfolios which include functionally generated portfolios and ones with short-term strong relative arbitrage property over the market. (Received February 07, 2016)

1120-91-61 **Xikui Wang*** (xikui.wang@umanitoba.ca), Department of Statistics, University of Manitoba, Winnipeg, Manitoba R3T 2N2, Canada, and **You Liang**. *Dynamic risk measures.* Preliminary report.

After a brief review of risk and Markov decision processes, we discuss how Markov decision processes are used to characterize and derive dynamic risk measures. (Received February 08, 2016)

94 ► Information and communication, circuits

1120-94-292 **Sui Tang*** (rosier1989@gmail.com), 1326 Stevenson center, Vanderbilt University, Nashville, TN 37240. *Dynamical sampling.*

Let $f \in \ell^2(\mathbb{I})$ be a signal at time $t = 0$ of an evolution process controlled by a bounded linear operator A that produces the signals $Af, A^2f, \cdots$ at times $t = 1, 2, \cdots$. Let $Y = \{f(i), Af(i), \cdots, A^{l_i}f(i) : i \in \Omega \subset \mathbb{I}\}$ be the spatiotemporal samples taken at various time levels. The problem under consideration is to find necessary and sufficient conditions on A, Ω, l_i in order to recover any $f \in \ell^2(\mathbb{I})$ from the measurements Y. This is so called Dynamical Sampling Problem in which we seek to recover a signal f by combining coarse samples of f and its futures states $A^l f$. In this talk, we will study the problem and show some recent results. (Received February 23, 2016)

97 ► Mathematics education

1120-97-210 **Sara L. Solhjem*** (sara.solhjem@ndsu.edu). *Math anxiety and its relationship to gender and genetics.*

How many times have you heard someone say, "Well my dad is bad at math, and so am I". Or "I hate math"? Have you thought about why there are a lot more males in engineering math classes than in basic math classes? This talk will explore math anxiety and if there is a relationship to gender or genetics or is it all environmental. We will explore the data collected from a small sample set to see if there is a potential for any case. My research also looked at the area of gender bias to see if there is some environmental connection along with a possible genetic connection. (Received February 22, 2016)

1120-97-234 **Aziz Issaka*** (aziz.issaka@ndsu.edu), Department of Mathematics-NDSU, Minard 406. 1210 Albrecht Boulevard, Fargo, ND 58102, and **Abraham Ayebo** (abraham.ayebo@ndsu.edu), Department of Mathematics-NDSU, Minard 406. 1210 Albrecht Boulevard, Fargo, ND 58102. *Undergraduate students' perceptions of mathematical proofs.* Preliminary report.

Although proving is an indispensable activity in mathematics, there are serious difficulties encountered by mathematics undergraduates in engaging with proof in the right way. In this talk, we will present an initial analysis of a sample of mathematics undergraduate students which will describe their declared perceptions about proof. We would also describe a qualitative study of a sub sample of these students which will analyze their actual perceptions of proof as well as their proof practices. We would then compare their self-declared perceptions of proof with their personal inclinations in proving. (Received February 22, 2016)

1120-97-240 **Caleb B. Larson*** (caleb.b.larson@ndsu.edu). *Gender equity in mathematics.* Preliminary report.

The situation is arising where it is socially acceptable to be deficient in the area of mathematics, a situation that needs addressing by those who work in the field of math. In order to understand the roots of this problem, we must address individual issues as related to society's disposition towards mathematics. One such issue is that of gender equity. Equity is the concept of fair and impartial treatment towards individuals. Literature and personal evidence suggest that there is a bias held among members of academia that math is a male domain, a bias that must be eliminated if we hope to achieve gender equity in mathematics and give all students of math an equal opportunity to succeed. For a beginning to the study, literature has been reviewed to determine the factual existence of this problem and to consult prior studies on the results found in this area. Results discussed surround: beliefs of students, teachers, and parents, statistical effects of gender on achievement scores, and statistical effects of gender on pursuit of further education in math. To further understand the problem, primary sources in the form of interviews with men and women in the mathematical community will be summarized and survey results from North Dakota high schoolers will be presented. (Received February 22, 2016)

1120-97-286 **Carol A Okigbo** (okigbo@mnstate.edu), Department of Mathematics, Minnesota State University Moorhead, 1104 7th Ave South, Moorhead, MN 56563, and **Abraham Ayebo*** (abraham.ayebo@ndsu.edu), Department of Mathematics - #2750, 406F Minard Hall, North Dakota State University, Fargo, ND 58108. *Contemporary issues in mathematics education: emerging trends, challenges and research in the teaching of mathematics.*

Contemporary Mathematics Education faces many challenges that include (1) interference of government policies' such as No Child Left Behind, Common Core State Standard, that places accountability on teachers and encourages teaching-to-test approaches, (2) lack of motivated and committed elementary school mathematics

teachers who can provide solid foundation that children need to succeed in Mathematics; (3) elementary school teachers' reliance on textbooks for day-to-day activities in Mathematics classrooms; and (4) ever increasing diversity of learners in all the levels of Mathematics classrooms, but particularly at the pre-K and elementary school level. This presentation is designed to examine each of these challenges, but particularly the diversity challenge from the perspective of Preparing Future Mathematics Teachers for Primary Schools. The data are based on the experiences of primary school Mathematics teachers, university teachers of Mathematics Education students, and the self-reports of undergraduate Mathematics Education students. Recommendations will be offered for improvements in how we prepare Mathematics Education teachers for the inevitably more diverse Mathematics classes of the future, especially with regard to English Language Learners. (Received February 23, 2016)

1120-97-303 **Maxx Kureczko** (maxx.kureczko@ndsu.edu), Department of Mathematics, North Dakota State University, FARGO, ND 58108, and **Abraham Ayebo*** (abraham.ayebo@ndsu.edu), Department of Mathematics, North Dakota State University, Fargo, ND 58078. *Flipping a college algebra class.* Preliminary report.

Recent technological advancements have unlocked an entirely new direction for education research. The flipped classroom is a new pedagogical method which employs asynchronous video lectures and practice problems as homework, and active, group-based problem solving activities in the classroom. It has become an increasingly popular pedagogical approach to teaching and learning. In this talk, we report on how a College Algebra class was taught in the Flipped Classroom format. Students' performance were compared with those of a similar class taught in the traditional format. This talk will also focus on the challenges of teaching in the flipped classroom format and implications for mathematics teaching and learning. (Received February 23, 2016)

1120-97-307 **William O Martin*** (william.martin@ndsu.edu), NDSU School of Education, Dept 2625, PO Box 6050, Fargo, ND 58108-6050. *Assessing undergraduate student comprehension of mathematical proofs.* Preliminary report.

We describe a project designed to improve undergraduate student reasoning and comprehension of mathematical proofs, a central component of all mathematics programs. We draw on mathematics education research to collaborate with research mathematicians who teach upper level proof based courses. Our strategy is to initiate change in the teaching and learning of proof by working with mathematics faculty to learn about, understand, develop and implement research-based assessments of proof. We propose a cyclic, iterative assessment model to provide detailed information about undergraduates' abilities to read, interpret, critique and write proofs. Information gained from this proof assessment model will be used to collaboratively develop, implement and revise pedagogy and curricula. The proposed iterative assessment cycle will provide formative and summative evidence of the impact of these course changes on student learning. (Received February 23, 2016)

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
53 Differential geometry
54 General topology
55 Algebraic topology
57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
65 Numerical analysis
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
85 Astronomy and astrophysics
86 Geophysics
90 Operations research, mathematical programming
91 Game theory, economics, social and behavioral sciences
92 Biology and other natural sciences
93 Systems theory; control
94 Information and communication, circuits
97 Mathematics education

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