ABSTRACTS

of Papers Presented to the American Mathematical Society

Volume 37, Number 3, Issue 185 Summer 2016

Abstracts for

ISSN 0192-5857 Pages 795–920

AMS

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Abstracts of Papers Presented to the American Mathematical Society (ISSN 0192-5857) is published four times a year by the American Mathematical Society at 201 Charles Street, Providence, RI 02904-2294. The subscription price for Volume 37 (2016) is US$180.00 list, US$144.00 institutional member, US$108.00 individual member. Please add US$5 for delivery within the United States; US$11 for delivery outside the United States. Subscription renewals are subject to late fees. See `www.ams.org/customers/macs-faq.html#journal` for more information. Periodicals postage paid at Providence, RI. POSTMASTER: Send address change notices to Abstracts of Papers Presented to the American Mathematical Society, 201 Charles Street, Providence, RI 02904-2294 USA.

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PAPERS PRESENTED AT MEETINGS

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

MEETING #	DATE	PLACE	ABSTRACT DEADLINE	ABSTRACT ISSUE
1123	October 28–30, 2016	Minneapolis, MN	EXPIRED	Vol 37, No. 4
1124	November 12–13, 2016	Raleigh, NC	EXPIRED	Vol 37, No. 4
1125	January 4–7, 2017	Atlanta, GA	EXPIRED	Vol 38, No. 1
1126	March 10–12, 2017	Charleston, SC	January 17	TBA
1127	April 1–2, 2017	Bloomington, IN	February 7	Vol 38, No. 2
1128	April 22–23, 2017	Pullman, WA	February 28	Vol 38, No. 2
1129	May 6–7, 2017	New York, NY	March 14	Vol 38, No. 2
1130	July 24–28, 2017	Montréal, Canada	TBA	TBA
1131	September 9–10, 2017	Denton, TX	July 18	Vol 38, No. 3
1132	September 16–17, 2017	Buffalo, NY	July 25	Vol 38, No. 3
1133	September 23–24, 2017	Orlando, FL	August 1	Vol 38, No. 4
1134	November 4–5, 2017	Riverside, CA	September 12	Vol 38, No. 4
1135	January 10–13, 2018	San Diego, CA	TBA	TBA

BRUNSWICK, ME, September 24–25, 2016

Abstracts of the 1121st Meeting.

00 ► General

1121-00-56 **Jeong-Mi Yoon*** (yoonj@uhd.edu), One Main St., Houston, TX 77002. *The Undergraduate Research Experience in Financial Mathematics.* Preliminary report.

I design an undergraduate research program in financial mathematics as a consecutive two-semester courses. At the first semester, a student registers in the undergraduate research course which introduces the background of basic finance, statistics and probabilities with weekly-based reading assignments and discussion sessions. At the second semester, he/she registers in the senior project course which provides step-by-step guidance and discussions to achieve the final goal of the research. He/she gives an oral presentation and submits his/her paper until the end of the second semester. The first project was titled in *The Analytic and Numerical Approached to Black Sholes Partial Differential Equations*. The ongoing two projects are titled in *Greeks and Hedging of European Option Pricing* and *Dynamics of Social Security Dependence on Age-Structured Population*. Based on my experiences in this field as a faculty advisor I could generate two continuing education courses which could support many students who plan to take the Actuary Exam. I would like to share my experience and extend my realm of the undergraduate research through this meeting. (Received July 07, 2016)

1121-00-205 **Sarah Tymochko*** (sjtymo17@g.holycross.edu), **Derek Hoare** (hoared@kenyon.edu) and **Brandon Sit** (sit18@up.edu). *Spanning Tree Modulus and Homogeneity of Undirected Graphs.* Preliminary report.

The p-modulus of a family of objects on a discrete graph provides a method for quantifying the "richness" of the family. When applied to the family of spanning trees of a simple, undirected graph, modulus has a particularly interesting probabilistic interpretation. Among all possible probability mass functions (pmfs) on the set of spanning trees, modulus selects those that most evenly distribute the usage of graph edges. If a graph admits a pmf such that all edges are equally likely to appear in a random spanning tree, the graph is called homogeneous. If the uniform distribution on spanning trees is optimal, the graph is called uniform.

We present a necessary and sufficient condition for a graph to be both uniform and homogeneous. Numerical experiments suggest large, well-connected, non-homogeneous graphs are rare. We present a sufficient condition for

the homogeneity of d-regular, connected graphs. This condition suggests that as d gets large, d-regular graphs are almost surely homogeneous. Since any graph can be decomposed into homogeneous components using a process called deflation, understanding homogeneous graphs is the primary focus of this project. (Received July 18, 2016)

1121-00-233 **Juergen Desmond Kritschgau*** (jkritsch@bates.edu), 15448 Village Drive, Lake Oswego, OR 97034. *Origami Constructions of Algebraic Integer Rings.*

In origami, the artist uses a set of reference points to guide his or her folds of the paper. The intersections of folds result in new reference points. We can abstract away from the physical art form of origami to get a mathematical notion of origami construction. That is, we can consider our paper to be the complex plane, and use a set of reference points and lines at allowable angles to create new reference points at intersections. It is know that if the initial set of reference points is $S = \{0, 1\}$ and the set of allowable angles forms a group in $T/\{1, -1\}$, the unit semi-circle, then the set of points closed under the origami construction forms a ring. I provide a construction for the ring of algebraic integers in all imaginary quadratic subfields of the complex plane. (Received July 19, 2016)

01 ► History and biography

1121-01-248 **Gordon A. Swain*** (gswain@ashland.edu), Ashland University, 401 College Avenue, Ashland, OH 44805. *Thabit ibn Qurra, Archimedes, and the Parabola.* Preliminary report.

The 9th century Arabic mathematician Thabit ibn Qurra proved that the area of any segment of the parabola is equal to two-thirds of the area of the parallelogram with the same base and equal height as the segment. This result had already been established by Archimedes, but Thabit's proof uses a very different approach. We will discuss and contrast both proofs and show how the later proof reflects an increasing comfort with algebra. (Received July 19, 2016)

05 ► Combinatorics

1121-05-11 **Olivier E. Bernardi*** (bernardi@brandeis.edu), Bradeis University, 415 South Street, Waltham, MA 02453. *Bijections for the deformations of the braid arrangement.*

We consider real hyperplane arrangements such that all the hyperplanes are of the form $x_i - x_j = s$ for some integer s. Classical examples include the braid, Catalan, Shi, semiorder and Linial arrangements, as well as graphical arrangements.

In this talk we will present enumerative results and bijections for the regions of such arrangements. (Received June 15, 2016)

1121-05-17 **Ethan Rarity*** (erarity@masonlive.gmu.edu), **Steven Schluchter** and **Justin Scoroeder**, Kej Bratsvo Edinstvo 45, 1230 Gostivar, Rep of Macedonia. *Self-dual embeddings of small simple graphs in pseudosurfaces.*

A proper embedding of a connected graph G in a pseudosurface P is an embedding that maps vertices of G to pinchpoints of P and induces a cellular decomposition of P. The dual graph of a proper embedding $G \to P$ captures the incidence of faces and edges of $G \to P$, and we say that $G \to P$ is self dual if the dual graph is isomorphic to G. Using elementary argumentation, we will show that a simple connected graph must have at least 13 edges in order to be self-dual embeddable in a pseudosurface with at least one pinchpoint. With some combinatorial insight and with the aid of a computer, we will show how we can determine the self-dual embeddability of a graph in a pseudosurface, and we will state our results concerning the self-dual embeddability of all connected 13-edge simple graphs in all pseudosurfaces. (Received June 21, 2016)

1121-05-24 **Pete L. Clark** (plclark@gmail.com), **Aden Forrow** (aforrow@math.mit.edu) and **John R. Schmitt*** (jschmitt@middlebury.edu). *Chevalley-Warning Meets Hypergraphs: Counting Sub-hypergraphs with Union Cardinality* 0 *Modulo* q.

Let q be a prime power and let $\mathcal{F} = \{F_1, \ldots, F_n\}$ be a hypergraph (i.e. $\mathcal{F}$ is a finite collection of finite subsets of some fixed set) with maximal degree d. We show that the number of non-trivial sub-hypergraphs $\mathcal{F}_0$ with $|\cup_{F\in\mathcal{F}_0} F| \equiv 0 \pmod{q}$ is either 0 or exponentially many. To do this we use **the polynomial method** and an extension of a classical number-theoretic result of Ewald Warning. As a result, we recover a theorem of Alon, Kleitman, Lipton, Meshulam, Rabin and Spencer that computes the minimal value of n for which we are guaranteed to have a non-trivial sub-hypergraph meeting the condition. (Received June 29, 2016)

1121-05-33 **Cristina M Ballantine*** (cballant@holycross.edu), College of the Holy Cross, 1 College Street, Worcester, MA 01610, and **William T Hallahan**. *Stability of coefficients in the Kronecker product of a hook and a rectangle.*

We use Blasiak's combinatorial rule for Kronecker coefficients for one hook shape to prove a stability result for the coefficients in the Kronecker product of two Schur functions: one indexed by a hook partition and one indexed by a rectangle partition. We also give sharp bounds for the size of the partition starting with which the Kronecker coefficients are stable. Our study of this particular case of the Kronecker product is motivated by its usefulness for the understanding of the quantum Hall effect. (Received July 02, 2016)

1121-05-36 **Francois Bergeron*** (bergeron.francois@uqam.ca), Departement de Mathematiques, Universite du Quebec a Montreal, Cp. 8888, Succ Centre-Ville, Montreal, Quebec H2L2N2, Canada. *A q-analog of Foulkes conjecture.* Preliminary report.

We will discuss new q-analogs of classical plethystic conjectures due to Foulkes. In our conjectures, divided differences of plethysms of Hall-Littlewood polynomials replace analogous differences of plethysms of Schur functions. At q=0, we get back the original conjectures, and we show that our new ones holds at q=1. We discuss further supporting evidence of various kind, links with representation theory, Schur-Weyl duality, combinatorics, as well as various interesting new generalizations of the classical setup. (Received July 03, 2016)

1121-05-38 **Satoshi Murai**, Department of Pure and Applied Mathematics, Osaka University, Suita, Osaka, 565-0871, Japan, and **Isabella Novik*** (novik@math.washington.edu), Department of Mathematics, University of Washington, Seattle, WA 98195-4350. *Face numbers and the fundamental group.*

A conjecture of Kalai posits a lower bound on the number of edges of a $(d-1)$-dimensional triangulated manifold Δ in terms of d, the minimum number of generators of the fundamental group of Δ, and the number of vertices of Δ. We will discuss the proof of this conjecture and several related results. Our proofs rely on the μ-numbers introduced by Bagchi and Datta and on their algebraic and topological interpretations. (Received July 04, 2016)

1121-05-42 **Rosa C Orellana*** (rosa.c.orellana@dartmouth.edu), Mathematics Department, 6188 Kemeny Hall, Hanover, NH 03755, and **Mike Zabrocki** (zabrocki@mathstat.yorku.ca), Toronto, Canada. *Symmetric group characters as symmetric functions.*

The characters of the general linear group are symmetric functions. The irreducible characters of the general linear group 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 July 05, 2016)

1121-05-50 **Cristian Lenart**, **Kirill Zainoulline** and **Changlong Zhong*** (czhong@albany.edu), albany, NY 12222. *Hyperbolic formal group law and parabolic Kazhdan-Lusztig basis.*

In this talk I will introduce the Hecke-type algebra associated to hyperbolic formal group law. The dual of this algebra gives the T-equivariant elliptic cohomology of flag varieties $h_T(G/B)$. Using this algebra, we give a new definition of Deodhar's parabolic Kazhdan-Lusztig basis inside $h_T(G/B)$, called the KL-Schubert class. It is conjectured by Lenart and Zainoulline that if the Schubert variety corresponding to w is smooth, then the KL-Schubert class coincides with the Schubert class. In this talk I will talk about some evidence of this conjecture. (Received July 06, 2016)

1121-05-59 **ASAF FERBER*** (ferberasaf@gmail.com), 41 Loomis, Cambridge, MA 02138, and **Eoin Long** and **Benny Sudakov**. *On two problems related to Hamilton cycles in oriented graphs.*

In this talk we present a relatively simple approach for packing directed Hamilton cycles in "nice" oriented graphs. In particular, we provide a short proof for an approximate version of the so-called Kelly's Conjecture (recently solved by Kuhn and Osthus), extend it to a more general setting, and suggest some new interesting problems. Moreover, based on the impressive work of Kuhn and Osthus, using our technique, we give an approximate formula for the number of Hamilton decompositions in a regular "robust expander" oriented graph.

Joint work with Eoin Long and Benny Sudakov. (Received July 08, 2016)

1121-05-60 **Michael Barrus*** (barrus@uri.edu). *Realization graphs of degree sequences.*

Given the degree sequence d of a simple graph, the realization graph of d is the graph having as its vertices the labeled realizations of d, with two vertices adjacent if one realization may be obtained from the other via an edge-switching operation. After a brief survey of known results on realization graphs, we describe a connection between Cartesian products in realization graphs and a degree sequence decomposition introduced by Tyshkevich. We also present results on the connectivity and induced subgraphs of realization graphs, in particular characterizing the degree sequences whose realization graphs are triangle-free graphs or hypercubes. (Received July 08, 2016)

1121-05-61 **Benny Sudakov**, 8050 Zurich, Switzerland, and **Jan Volec*** (jan@ucw.cz), 8050 Zurich, Switzerland. *Properly colored and rainbow copies of graphs with few cherries.*

Let G be an n-vertex graph that contains r cherries, i.e., paths on three vertices, and let c be a coloring of the edges of K_n such that at each vertex every color appears only constantly many times. In 1979, Shearer conjectured that if $r = O(n)$, then such a coloring c must contain a properly colored copy of G. We confirm this conjecture and show that the same is true even for graphs G with $r = O(n^{4/3})$ cherries. This bound is up to a constant factor best possible.

We also show that an analogous result holds for colorings of $E(K_n)$ where for each color the total number of appearances is bounded, and then the aim is to find a rainbow copy of G.

This is a joint work with Benny Sudakov. (Received July 08, 2016)

1121-05-63 **Sam Hopkins*** (shopkins@mit.edu). *The coincidental down-degree expectations (CDE) property for posets.*

Reiner, Tenner, and Yong recently introduced the coincidental down-degree expectations (CDE) property for posets. A poset P is CDE if the expected down-degree is the same for the uniform distribution on P and for the distribution on P that weights each element proportional to the number of maximal chains passing through that element. Reiner, Tenner, and Yong showed that many posets familiar to algebraic combinatorialists, such as certain intervals of the weak Bruhat order, are CDE. In earlier independent work with Chan, Haddadan, and Moci (which was motivated by some surprising combinational results arising from a new approach to Brill-Noether theory) we found a large family of CDE intervals of Young's lattice. In this more recent work I extend these results to the shifted setting. These shifted results complete the case-by-case proof that all minuscule lattices are CDE, as was conjectured by Reiner-Tenner-Yong. Time permitting I will explain some applications of the study of CDE posets: product formulas for certain kinds of set-valued tableaux (i.e., product formulas for certain square-free coefficients of stable Grothendieck polynomials), and homomesy results (in the sense of Propp and Roby) for rowmotion and gyration acting on sets of order ideals. (Received July 09, 2016)

1121-05-67 **Sergi Elizalde*** (sergi.elizalde@dartmouth.edu), Department of Mathematics, Dartmouth College, 6188 Kemeny Hall, Hanover, NH 03755, and **Yuval Roichman**. *Schur-positive grid classes.*

To each set of permutations one can associate a quasisymmetric function in a natural way, by adding the fundamental quasisymmetric functions indexed by the descent sets of the permutations in the set. A long-standing problem in algebraic combinatorics is to characterize sets of permutations whose associated quasisymmetric function is symmetric and Schur-positive.

After discussing some known examples of such Schur-positive sets, we give a general method to construct new Schur-positive sets and multisets of permutations. The method is based on the product operation, and on sets of pattern-avoiding permutations called geometric grid classes. (Received July 10, 2016)

1121-05-72 **Ryan R. Martin*** (rymartin@iastate.edu), Department of Mathematics, 396 Carver Hall, Iowa State University, Ames, IA 50010, and **Richard Mycroft** and **Jozef Skokan**. *An asymptotic multipartite Kühn-Osthus theorem.*

An h-vertex graph H is said to perfectly tile an n-vertex graph G if there is a subgraph of G consisting of n/h vertex-disjoint copies of H. Kühn and Osthus showed that n sufficiently large, $h \mid n$, and $\delta(G) \geq \left(1 - \frac{1}{\chi^*(H)}\right) n + C$ is sufficient for a perfect H-tiling. Here, $\chi^*(H)$ is a parameter related to Komlós' critical chromatic number and C is a constant depending only on H. This generalizes classical results by Hajnal and Szemerédi, among others.

When the underlying graph is a balanced multipartite graph, the picture changes and seems even more difficult. We prove an asymptotic multipartite version of the Kühn-Osthus result. For an r-partite graph G, the relevant parameter is denoted $\delta^*(G)$, the minimum number of neighbors a vertex in G has in any of the other $r-1$ vertex classes. We show that if H is an h-vertex, r-colorable graph, $\alpha > 0$ is fixed, n is sufficiently large, and $h \mid n$, then any balanced r-partite graph G on rn vertices with $\delta^*(G) \geq \left(1 - \frac{1}{\chi^*(H)}\right) n + \alpha n$, then G

has a perfect H tiling. Moreover, this cannot be improved, apart from replacing the αn term by a constant C. (Received July 11, 2016)

1121-05-75 **Jose Alejandro Samper*** (jasamper88@gmail.com), 121 South Main Street, 11th Floor, Providence, RI 02903. *Matroid polytopes and shifted simplicial complexes.*

Matroid independence complexes and pure shifted simplicial complexes are two remarkable classes of simplicial complexes with similar structural properties. However, there is no common explanation for those remarkable similarities. The goal of this talk is to propose a way to study both classes from a geometric perspective that tries to unify them: the facet polytopes. We will see that shifted complexes almost satisfy various matroid defining axioms and explain how the geometry of the polytopes see these phenomena. We then explain how to use this as a tool in matroid theory. (Received July 11, 2016)

1121-05-76 **Florian Frick*** (ff238@cornell.edu). *Intersection Patterns of Finite Sets and of Convex Sets.*

The combinatorics of missing faces of a simplicial complex give nontrivial information about whether it is embeddable into d-space, and more generally whether every continuous map to d-space exhibits a point of r-fold intersection. This can be used to relate intersection patterns of finite sets as in Kneser's conjecture to intersection patterns of convex sets as in Tverberg's theorem and its continuous generalizations. We will present a theorem that is a common generalization of results from Tverberg-type theory and lower bounds for chromatic numbers of uniform intersection hypergraphs, extending work of Sarkaria. (Received July 11, 2016)

1121-05-77 **Simona Settepanella*** (s.settepanella@math.sci.hokudai.ac.jp), Sapporo, Japan, and **Anatoly Libgober**. *STRATA OF DISCRIMINANTAL ARRANGEMENTS.*

We give explicit description of the multiplicities of codimension two strata of discriminantal arrangements of Manin and Schechtman. As applications we discuss the study of the fundamental groups of the complements to discriminantal arrangements and study of the space of generic arrangements of lines in projective plane. (Received July 11, 2016)

1121-05-79 **Yinghui Wang*** (yinghui@mit.edu), Massachusetts Institute of Technology, Department of Mathematics, 77 Massachusetts Avenue, Cambridge, MA 02139, and **Richard P. Stanley** (rstan@math.mit.edu), Massachusetts Institute of Technology, Department of Mathematics, 77 Massachusetts Avenue, Cambridge, MA 02139. *The Smith normal form distribution of a random integer matrix.*

We show that the density μ of the Smith normal form (SNF) of a random integer matrix exists and equals a product of densities μ_{p^s} of SNF over $\mathbb{Z}/p^s\mathbb{Z}$ with p a prime and s some positive integer. Our approach is to connect the SNF of a matrix with the greatest common divisors (gcds) of certain polynomials of matrix entries, and develop the theory of multi-gcd distribution of polynomial values at a random integer vector. We also derive a formula for μ_{p^s} and compute the density μ for several interesting types of sets. Finally, we determine the maximum and minimum of μ_{p^s} and establish its monotonicity properties and limiting behaviors. (Received July 12, 2016)

1121-05-85 **Richard P. Stanley*** (rstan@math.mit.edu). *A survey of plethysm and Kronecker products.* Preliminary report.

We will give a survey of the history of plethysm and Kronecker products, including some more recent work. The talk is aimed at those who have basic knowledge of symmetric functions and the representation theory of the symmetric group $\mathfrak{S}_n$ and the general linear group $\mathrm{GL}(n,\mathbb{C})$, but who are not specialists in plethysm and Kronecker products. (Received July 12, 2016)

1121-05-86 **Richard P. Stanley*** (rstan@math.mit.edu) and **Yinghui Wang**, Department of Mathematics, M.I.T., Cambridge, MA 02139. *Some aspects of (r,k)-parking functions.*

An (r,k)-*parking function* of length n may be defined as a sequence $(a_1,\dots,a_n)$ of positive integers whose increasing rearrangement $b_1 \le \cdots \le b_n$ satisfies $b_i \le k+(i-1)r$. The case $r=k=1$ corresponds to ordinary parking functions. If $F_n^{(r,k)}$ denotes the Frobenius characteristic of the action of the symmetric group $\mathfrak{S}_n$ on the set of all (r,k)-parking functions of length n, then we find a combinatorial interpretation of the coefficients of the power series $\left(\sum_{n\ge 0} F_n^{(r,1)} t^n\right)^k$ for any $k\in\mathbb{Z}$. For fixed r, we can use the symmetric functions $F_n^{(r,1)}$ to define a multiplicative basis for the ring Λ of symmetric functions. We also discuss some of the properties of this basis. (Received July 12, 2016)

1121-05-94 **B. Kaskosz** and **L. Thoma*** (thoma@math.uri.edu). *Sidorenko type inequalities.*
We present new results on integral inequalities with integrands containing products of functions over edges of a bipartite graph. (Received July 13, 2016)

1121-05-101 **Mingxian Zhong*** (mz2325@columbia.edu), 528 Riverside Drive, Apt 4A, New York, NY 10027. *Recent progress on three-coloring graphs without long induced paths.*
We present a polynomial time algorithm that determines if an input graph containing no induced seven-vertex path is 3-colorable. This affirmatively answers a question posed by Randerath, Schiermeyer and Tewes in 2002. Our algorithm also solves the list-coloring version of the 3-coloring problem, where every vertex is assigned a list of colors that is a subset of $\{1, 2, 3\}$, and gives an explicit coloring if one exists.

Our second result is an algorithm that approximately color a 3-colorable graph that does not contain an induced path on t vertices, for an arbitrary but fixed t. Specifically, we propose an algorithm that, given a 3-colorable graph without an induced path on t vertices, computes a coloring with $\max\{5, 2\lceil\frac{t-1}{2}\rceil - 2\}$ many colors. (Received July 13, 2016)

1121-05-106 **Zachary Hamaker**, **Rebecca Patrias*** (patri080@umn.edu), **Oliver Pechenik** and **Nathan Williams**. *Doppelgängers: Bijections of Plane Partitions.*
For Y of type B_n, H_3, or $I_2(m)$, there exists a minuscule poset that is a "doppelgänger" of the positive root poset of Y–the two posets have the same number of linear extensions and the same number of plane partitions of each height k. Furthermore, for each such Y, there is a second minuscule poset whose upper half is the positive root poset of Y. Remarkably, these two facts are related.

In this talk, we synthesize a remark of R. Proctor, M. Haiman's rectification bijection, and minuscule K-theoretic Schubert calculus techniques of H. Thomas and A. Yong to give a uniform framework for combinatorial proofs of these poset coincidences. As a special case, we provide the first bijective proof of a 1983 theorem of R. Proctor–that plane partitions of height k in a rectangle are equinumerous with plane partitions of height k in a trapezoid. (Received July 14, 2016)

1121-05-110 **Laura Escobar** and **Oliver Pechenik***, Department of Mathematics, Rutgers University, 110 Frelinghuysen Rd., Piscataway, NJ 08854, and **Bridget Eileen Tenner** and **Alexander Yong**. *Rhombic tilings and Bott-Samelson varieties.*
S. Elnitsky (1997) gave an elegant bijection between rhombic tilings of $2n$-gons and commutation classes of reduced words in the symmetric group on n letters. P. Magyar (1998) found an important construction of the Bott-Samelson varieties introduced by H.C. Hansen (1973) and M. Demazure (1974). We explain a natural connection between S. Elnitsky's and P. Magyar's results. This suggests using tilings to encapsulate Bott-Samelson data and indicates a geometric perspective on S. Elnitsky's combinatorics. We also extend this construction by assigning desingularizations to the zonotopal tilings considered by B. Tenner (2006). (Received July 14, 2016)

1121-05-112 **Kevin Dilks** and **Oliver Pechenik***, Department of Mathematics, Rutgers University, 110 Frelinghuysen Rd., Piscataway, NJ 08854, and **Jessica Striker**. *Taking the long way home: Orbits of plane partitions.*
Plane partitions are piles of cubes stacked in the corner of a room. P. Cameron and D. Fon-der-Flaass (1995) studied a simple action on such piles, whose dynamics are nonetheless quite mysterious. In particular, repeating this action will always eventually return the original pile, but sometimes the voyage is much longer than expected. To understand the Grothendieck rings of algebraic vector bundles over Grassmannians and other spaces, H. Thomas and A. Yong (2009) introduced a suite of combinatorial algorithms on certain grids of numbers. In particular, there is an attractive K-theoretic promotion operator, which again has some mysteriously large orbits. We'll see how these two mysteries are in fact the same mystery, and use this relation to explain special cases of both actions. (Received July 14, 2016)

1121-05-113 **Patricia Hersh*** (plhersh@ncsu.edu) and **Cristian Lenart**. *From the weak Bruhat order to crystal graphs as posets.*
Crystal graphs give a combinatorial approach to studying the representation theory of Kac-Moody algebras. These graphs are partially ordered sets in many important cases, for instance the case of crystals representing the highest weight representations in finite type. We prove that fundamental properties of the weak Bruhat order transfer to lower intervals in these crystal posets, but that even in type A these properties do not always hold for arbitrary intervals. For lower intervals we prove a crystal theoretic analogue of the statement that any two reduced expressions for the same Coxeter group element are connected by a series of braid moves, and we prove that the Moebius function only takes the values 0,1,-1. Our negative results for arbitrary intervals imply that there are relations of arbitrarily high degree amongst the crystal operators that are not implied by any lower

degree relations. We will also discuss the role of the key of a crystal, a generalization of the key polynomials which arose in work of Lascoux and Schutzenberger on Schubert polynomials, in this story. We will not assume previous familiarity with crystals or crystal operators in this talk. (Received July 14, 2016)

1121-05-115 **M 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 July 14, 2016)

1121-05-131 **Anna Weigandt*** (weigndt2@illinois.edu), 1409 W. Green St, Urbana, IL 61801. *Prism tableaux for alternating sign matrix varieties.* Preliminary report.

Alternating sign matrices (ASMs) form the MacNeille completion of the strong Bruhat order on the symmetric group. To an ASM A, we associate the ASM variety X_A, a subvariety of the space of square matrices. X_A is defined by imposing rank conditions determined by the corner sum matrix of A. In the case where A is a permutation matrix, X_A is a matrix Schubert variety. We give a formula for the T-equivariant cohomology class of X_A as a generating series over prism tableaux, extending joint work with A. Yong. (Received July 16, 2016)

1121-05-134 **Aba Mbirika*** (mbirika@uwec.edu), University of Wisconsin-Eau Claire, and **Julianna Tymoczko**. *Combinatorial questions related to the representation stability of the cohomology of Springer varieties.* Preliminary report.

The Springer variety $\mathfrak{S}_X$ is the set of flags stabilized by a nilpotent operator $X \in Mat_n(\mathbb{C})$. Each nilpotent operator corresponds to a partition μ_n of n via decomposition of X into Jordan canonical blocks. The Springer representation arises when the symmetric group S_n acts on the cohomology ring of this family of varieties. Constructed by Springer in 1976, this ring $H^*(\mathfrak{S}_X)$ was later given a simplified presentation by Concini and Procesi, then refined by Tanisaki who simplified the Concini-Procesi ideals, and finally Garsia and Procesi who gave a basis for $H^*(\mathfrak{S}_X)$ as a quotient $R(n)/I_{\mu_n}$ where $R(n) = \mathbb{C}[x_1, \ldots, x_n]$ and the I_{μ_n} are the Tanisaki ideals.

We present some combinatorial aspects that arise in the representation stability of the sequence $\{H^*(R(n)/I_{\mu_n})\}_{n=1}^{\infty}$. In joint work with Tymoczko, we describe the co-FI-module structure (in the sense of Church, Ellenberg, and Farb) of this sequence. A surprising feature of the proof is that this structure exists for every possible sequence $\mu_1 \subseteq \mu_2 \subseteq \cdots$ of Young diagrams. We explore some combinatorial questions related to this representation stability of the Springer representation. (Received July 16, 2016)

1121-05-137 **Emily Barnard*** (esbarnar@ncsu.edu), 728 A Grove Ave, Raleigh, NC 27606. *The canonical join complex.* Preliminary report.

Suppose that L is a lattice and $x \in L$. The canonical join representation of x, when it exists, is a certain minimal factorization of x in terms of the join operation, analogous to the prime factorization of an integer. In this case, the join-irreducible elements of L, Irr(L), play the role of prime numbers. We study the the complex of subsets $A \subset$ Irr(L) such that $\bigvee A$ is a canonical join representation, and answer the question: When is this complex flag? (Received July 16, 2016)

1121-05-138 **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 a new basis for the polynomial ring called the fundamental slide polynomials. Our aim is to better understand the geometrically-motivated basis of Schubert polynomials, whose structure constants count intersection points of triples of Schubert subvarieties of the complete flag variety. As is the case for the Schubert

basis, the structure constants of the fundamental slide basis are nonnegative integers, and we give a nonnegative combinatorial rule for these numbers in terms of shuffles. Moreover, Schubert polynomials expand positively in the fundamental slide basis; we give a combinatorial rule for this expansion. We use these rules to obtain a more compact formula for the product of two Schubert polynomials, and to gain a refined understanding of stability of Schubert polynomials. (Received July 16, 2016)

1121-05-148 **Endre Csoka**, **Oleg Pikhurko** and **Gabor Lippner*** (g.lippner@neu.edu). *Measurable Graph Theory.*

"Graphings" are a natural generalization of finite graphs on probability measure spaces. These objects arise naturally as limits of finite graphs, as well as from the study of invariant random processes on discrete groups.

Measurable graph theory studies graphings from the perspective of classical graph theory. It lies at the crossroads of ergodic theory and discrete mathematics. I will explain how to generalize standard notions (matchings, chromatic number, expansion, etc) to graphings and survey recent results on the surprising behavior of these notions in the measurable setting. (Received July 17, 2016)

1121-05-150 **Rachel Karpman*** (rachelkarpman@gmail.com). *Total positivity, networks and cluster variables: from type A to type C.*

The totally nonnegative Grassmannian $Gr_{\geq 0}(k,n)$ is the space of full-rank $k \times n$ matrices whose maximal minors are nonnegative real numbers, modulo row operations. Postnikov defined a stratification of $Gr_{\geq 0}(k,n)$ by *positroid cells*, and introduced a beautiful combinatorial theory to study this stratification. In particular, he constructed a family of coordinate charts for each positroid cell, defined in terms of planar networks called *plabic graphs*. Each chart from a plabic graph gives a *cluster* in a conjectural cluster structure on the positroid cell.

In this talk, we extend Postnikov's construction to the Lagrangian Grassmannian, a partial flag variety of type C. Here, the appropriate networks are symmetric versions of Postnikov's plabic graphs. Using these symmetric networks, we define coordinate charts on the natural analogs of positroid cells for the Lagrangian Grassmannian, and discuss potential connections to cluster algebras. (Received July 17, 2016)

1121-05-160 **Karen Gunderson*** (karen.gunderson@umanitoba.ca), Department of Mathematics, University of Manitoba, Winnipeg, MB R3T 2N2, Canada. *Infinite trees and bootstrap percolation.*

A bootstrap process is a type of cellular automaton, acting on the vertices of a graph which are in one of two states: 'healthy' or 'infected'. For any positive integer r, the r-neighbour bootstrap process uses the following update rule: infected vertices remain infected forever and each healthy vertex with at least r infected neighbours becomes itself infected. These updates occur simultaneously and are repeated at discrete time intervals. Percolation is said to occur if all vertices are eventually infected.

Of interest is the random case, where each vertex is infected independently with a fixed probability p. For an infinite graph, one would like to know the values of p for which the probability of percolation is positive. I will give some of the history of this problem for regular trees and present some new results for bootstrap percolation on certain classes of randomly generated trees: Galton–Watson trees. (Received July 17, 2016)

1121-05-161 **Karim Adiprasito*** (sunya00@gmail.com). *Hodge theory for polytopes and matroids.*

We discuss applications of Hodge theory, a part of algebraic geometry, to problems in combinatorics. We moreover discuss situations in which these deep algebraic theorems themselves can be shown combinatorially, extending our knowledge of cohomology of closed currents in toric varieties.

joint work with June Huh and Eric Katz (Received July 18, 2016)

1121-05-165 **Pavel Galashin*** (galashin@mit.edu), Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA 02139, and **Pavlo Pylyavskyy**. *Zamolodchikov periodicity and integrability.*

We call a quiver Zamolodchikov periodic (resp., Zamolodchikov integrable) if the values of the associated T-system at each vertex are periodic (resp., satisfy a linear recurrence). It has been shown by Keller that quivers obtained as products of two Dynkin diagrams are Zamolodchikov periodic. We prove that a quiver is Zamolodchikov periodic if and only if it admits a strictly subadditive labeling. Next, we show that if a quiver is Zamolodchikov integrable, then it admits a subadditive labeling. We classify all quivers admitting a subadditive or a strictly subadditive labeling. Finally, we concentrate on the quivers of type $\hat{A} \otimes A$. In this case, we express the coefficients of the recurrences in terms of the partition functions for domino tilings of a cylinder. (Received July 18, 2016)

1121-05-166 **Gabor Sarkozy*** (gsarkozy@cs.wpi.edu), Department of Computer Science, WPI, 100 Institute Road, Worcester, MA 01609. *Monochromatic covers in edge-colored graphs and hypergraphs.*

We survey some results on the following problem: Say we are given fixed positive integers s, t and a family of graphs ${{F}}$. Minimizing over all t-edge colorings of the complete graph on n vertices, we ask for the maximum number of vertices that can be covered by at most s monochromatic members of ${{F}}$. This problem unites two classical problems: at one end of the spectrum ($s = 1$) we have the Ramsey problem, while at the other end we have cover problems. But there are some interesting problems "in-between" as well. Several of the results are joint with András Gyárfás and/or Endre Szemerédi. (Received July 18, 2016)

1121-05-168 **Greta Panova*** (greta.panova@gmail.com), 209 south 33rd street, Philadelphia, PA 19104. *Bounds on the Kronecker coefficients.*

The Kronecker coefficients of the symmetric group represent a major challenge within algebraic combinatorics as they still do not have a manifestly positive formula. More recently their importance has emerged in Geometric Complexity Theory, where they are used as upper bounds on multiplicities used to distinguish the determinant from the permanent in a computational complexity setting.

In this talk we will survey various results relating the Kronecker coefficients to other quantities like values of irreducible characters of the symmetric group, integer partitions and q-binomial coefficients, and plethysms.

These results are based on papers joint with Christian Ikenmeyer, Igor Pak and Ernesto Vallejo. (Received July 18, 2016)

1121-05-169 **Alexander Garver*** (alexander.garver@gmail.com) and **Thomas McConville** (thomasmc@mit.edu). *Noncrossing Tree Partitions.*

We introduce noncrossing tree partitions, which generalize the classical noncrossing set partitions. As in the classical case, they form a lattice whose partial order is given by refinement, and there is a Kreweras complement on noncrossing tree partitions. We will explain how noncrossing tree partitions provide a new classification of the c-matrices of a type A cluster algebra. This is joint work with Thomas McConville. (Received July 18, 2016)

1121-05-171 **Nancy Abdallah*** (nancy.abdallah@liu.se), Hus B, rum 2A:649, Campus Valla, Linköping University, 58183 Linköping, Sweden, and **Axel Hultman**, House B, 3A:686, Campus Valla, Linköping University, 581 83 Linköping, Sweden. *Combinatorial Invariance of Kazhdan-Lusztig-Vogan Polynomials.*

Let θ be an involutive automorphism of the symmetric group S_{2n} such that $\theta(s_i) = s_{2n-i}$, and $\iota(\theta)$ be the set of twisted identities in S_{2n}, i.e.

$$\iota(\theta) = \{\theta(\omega^{-1})\omega \ / \ \omega \in S_{2n}\}.$$

We construct a special matching on lower intervals $[e, \omega] \subset \iota(\theta)$ that helps us to compute the Kazhdan-Lusztig-Vogan polynomials. We prove by that that these polynomials are combinatorially invariant for lower intervals $[e, \omega]$. (Received July 18, 2016)

1121-05-173 **Rebecca Patrias*** (patri080@umn.edu), **Ethan Alwaise**, **Ben Anzis**, **Shuli Chen**, **Yibo Gao**, **Jesse Kim** and **Zhaoqi Li**. *Vanishing Schur Functions.* Preliminary report.

Choose a random homomorphism from the symmetric functions to any finite field. What is the probability that a given Schur function is sent to zero? This is a preliminary report based on research done with undergraduates at the University of Minnesota Combinatorics REU in 2016. (Received July 18, 2016)

1121-05-176 **Emanuele Delucchi***, Chemin du musee 23, 1700 Fribourg, Switzerland. *Matroids over hyperfields for arrangements of hyperplanes.* Preliminary report.

I will briefly describe Matt Baker's notion of matroid over a hyperfield and investigate its connections with - and applications to - the study of arrangements of hyperplanes. (Received July 18, 2016)

1121-05-185 **Arran Christopher Hamm*** (hamma@winthrop.edu), 204 Longsight Ln Apt 108, Rock Hill, SC 29730. *A Generalization of Two-Graphs.* Preliminary report.

A two-graph is a 3-uniform hypergraph, $\mathcal{G}$, satisfying that every set of four vertices contains an even number of edges of $\mathcal{G}$. Two-graphs were introduced in the 1950's by D. G. Higman to study certain doubly transitive groups, but were found to have connections to configurations of equiangular lines and switching classes of graphs among other things. One can generalize the definition of two-graph rather naturally; define an even k-graph to be a k-uniform hypergraph, $\mathcal{H}$, satisfying that every set of $k+1$ vertices contains an even number of edges of $\mathcal{H}$.

This talk will provide background on the theory of two-graphs as well as analogous results for even k-graphs. (Received July 18, 2016)

1121-05-191 **Tim Austin*** (tim@cims.nyu.edu), Courant Institute, New York University, 251 Mercer St, New York, NY 10012. *Szemerédi's Theorem: combinatorics, ergodic theory and algebra.*

Put roughly, Szemerédi's theorem asserts that if N is large enough and a subset $E \subseteq \{1, 2, \ldots, N\}$ is not too small, then E must contain fairly long arithmetic progressions.

Numerous generalizations and quantitative improvements have been found since Szemerédi proved this in 1975. It remains a subject of active research partly because all that work has revealed a rich analytic structure underlying the relevant behaviour of arithmetic progressions in sets such as E. In the case of Szemerédi's original theorem, that structure is qualitatively well understood, but many of the quantitative estimates seem far from optimal. Among its generalizations, even the qualitative picture is very incomplete.

I will begin with a rough and highly selective sketch of some more modern approaches to Szemerédi's theorem. Then I will describe some additional difficulties that prevent those modern approaches from reaching the Furstenberg–Katznelson theorem, which generalizes Szemerédi's theorem to several dimensions. Lastly, I will describe recent work on an algebraic 'toy' problem which has some of the same difficulties, and which already contains a surprisingly intricate algebraic structure. (Received July 18, 2016)

1121-05-200 **A. Czygrinow** (aczygri@asu.edu), **H.A. Kierstead** (kierstead@asu.edu) and **T. Molla*** (molla@illinois.edu). *Ladders in dense graphs.* Preliminary report.

Suppose G is graph on n vertices. A 2-factor of G is a spanning 2-regular subgraph. In 1993, Aigner and Brandt proved that if G has minimum degree $\frac{2n-1}{3}$, then G contains every 2-factor on n vertices. Three years later, Kierstead and Fan proved that the same minimum degree condition implies that G contains the square of a hamiltonian path, and the square of a path on n vertices contains every 2-factor on n vertices.

When n is even, one can ask for a bipartite 2-factor of G. An implication of the El-Zahar conjecture, recently proved for sufficiently large graphs by Abbasi, Khan, Sárközy and Szemerédi, is that when n is even, every graph G on n vertices with minimum degree $n/2$ contains every bipartite 2-factor. We prove that, for sufficiently large and even n, if G has minimum degree $n/2$, then G contains a spanning subgraph with maximum degree 3 that contains every bipartite 2-factor on n vertices. This spanning subgraph usually is a ladder, a graph on n vertices with edge set consisting of the union of a perfect matching $\{x_1y_1, \ldots, x_{\frac{n}{2}}y_{\frac{n}{2}}\}$ (the rungs) and the edges of the paths $x_1 \ldots x_{\frac{n}{2}}$ and $y_1 \cdots y_{\frac{n}{2}}$ (the rails). (Received July 18, 2016)

1121-05-204 **Bruno Benedetti*** (bruno@math.miami.edu), Department of Mathematics, 1365 Memorial Drive, Coral Gables, FL 33146, **Michela Di Marca** (dimarca@dima.unige.it), Dipartimento di Matematica, Via Dodecaneso, 35, 16146 Genoa, Italy, and **Matteo Varbaro**, Dipartimento di Matematica, Via Dodecaneso, 35, 16146 Genoa, Italy. *Regularity of complete intersections of lines.* Preliminary report.

In commutative algebra, Castelnuovo and Mumford introduced long ago a notion of 'regularity' for ideals of polynomials. In combinatorics one uses the word 'regularity' for graphs in which all vertices have the same degree. A priori these two integers are unrelated even if they happen to be called the same. It turns out that sometimes they do coincide. If A is an arithmetically-Gorenstein arrangements of lines in which all singularities are planar, and R is the Castelnuovo-Mumford regularity of the coordinate ring of A, we show that the dual graph of A is R-regular; or in other words, each line meets exactly R other lines of the arrangement. (Received July 18, 2016)

1121-05-206 **Ira M. Gessel*** (gessel@brandeis.edu), Department of Mathematics, MS 050, Brandeis University, Waltham, MA 02453. *The Konvalinka-Amdeberhan conjecture.* Preliminary report.

Motivated by Sara Billey, Matjaž Konvalinka, and Frederick Matsen's formula for unlabeled tanglegrams (arXiv:1507.04976 [math.CO]), Konvalinka and Tewodros Amdeberhan conjectured that a generalization of this formula always gives integers.

Konvalinka and Ameberhan's conjecture follows from the fact that the plethystic inverse of the symmetric function $L_m \circ (1 - p_1)$ is integral, where L_m is the primitive necklace symmetric function given by

$$L_m = \frac{1}{m} \sum_{d|m} \mu(d) p_d^{m/d}.$$

I will also discuss the conjectured Schur-positivity of these symmetric functions and the problem of finding a combinatorial interpretation for them. (Received July 18, 2016)

1121-05-210 **Ira M. Gessel*** (gessel@brandeis.edu), Department of Mathematics, MS 050, Brandeis University, Waltham, MA 02476, and **Yan Zhuang**. *Shuffle-compatible permutation statistics.* Preliminary report.

We call a permutation statistic st *shuffle-compatible* if for any two disjoint permutations π and σ, the distribution of st on the shuffles of π and σ depends only on $\mathrm{st}(\pi)$, $\mathrm{st}(\sigma)$, and the lengths of π and σ. For example, it follows from Richard Stanley's theory of P-partitions that the descent set, the descent number des, the major index maj, and the ordered pair $(\mathrm{des}, \mathrm{maj})$ are shuffle compatible, and it follows from John Stembridge's theory of enriched P-partitions that the peak set and the number of peaks are shuffle-compatible.

To any shuffle-compatible permutation statistic one can associate an algebra whose multiplication describes the distribution of the statistic on shuffles.

We will discuss an approach to shuffle-compatible permutation statistics using noncommutative symmetric functions, and describe some of the associated algebras. (Received July 18, 2016)

1121-05-211 **James M Carraher**, **William B Kinnersley*** (billk@uri.edu), **Benjamin Reiniger** and **Douglas B West**. *Saturation Games on Graphs.*

Let $\mathcal{F}$ be a family of graphs. We say that a graph G is *$\mathcal{F}$-free* if no member of $\mathcal{F}$ appears as a subgraph of G. In the *$\mathcal{F}$-saturation game*, the players Max and Min collaboratively build an $\mathcal{F}$-free graph G on n vertices. The players alternately add edges to G, with the restriction that G must always remain $\mathcal{F}$-free. The game continues until no further edges can be added. Max aims to maximize the length of the game, while Min aims to minimize it; when both players play optimally, the length of the game is known as the *game saturation number* of $\mathcal{F}$, denoted $\mathrm{sat}_g(\mathcal{F}; n)$.

In this talk, we give bounds on $\mathrm{sat}_g(\mathcal{F}; n)$ for a variety of choices of $\mathcal{F}$. We also pose some interesting open questions and conjectures. (Received July 18, 2016)

1121-05-212 **Miriam Farber*** (mfarber@mit.edu) and **Pavel Galashin**. *Weak Separation, Pure Domains and Cluster Distance.*

Following the proof of the purity conjecture for weakly separated sets, recent years have revealed a variety of wider classes of pure domains in different settings. In this work we prove the purity for domains consisting of sets that are weakly separated from a pair of "generic" sets I and J. Our proof also gives a simple formula for the rank of these domains in terms of I and J. This is a new instance of the purity phenomenon which essentially differs from all previously known pure domains. We apply our result to calculate the cluster distance and to give lower bounds on the mutation distance between cluster variables in the cluster algebra structure on the coordinate ring of the Grassmannian. Using a linear projection that relates weak separation to the octahedron recurrence, we also find the exact mutation distances and cluster distances for a family of cluster variables. (Received July 18, 2016)

1121-05-216 **Anders Björner*** (bjorner@kth.se), Kungl. Tekniska Högskolan, SE-10044 Stockholm, Sweden. *Continuous matroids revisited.*

Abstract: The concept of a "matroid", launched in the 1930s, provides an axiomatisation of the notion of independence. In recent years matroids, and some relatives (oriented matroids, arithmetic matroids, Bergman fans, ...), have come to play a central role in various contexts where combinatorics interacts with algebra and geometry.

In this talk I will discuss extending the matroid concept in a different direction, namely having a continuous rank function. This idea is inspired by the example of von Neumann's "continuous geometries" from 1936.

I will first review work done in collaboration with L. Lovász in the 1980s which produced several examples, including continuous analogs of set partitions and field extensions. I will then discuss what would be a good axiomatisation of "continuous matroids". This should include the mentioned examples as well as the von Neumann geometries, these latter suggesting ties to operator algebras. (Received July 18, 2016)

1121-05-221 **Brittney Ellzey*** (b.ellzey@math.miami.edu). *Chromatic Quasisymmetric Functions of Directed Graphs.* Preliminary report.

Chromatic quasisymmetric functions were introduced by Shareshian and Wachs as a refinement of Stanley's chromatic symmetric functions. Shareshian and Wachs define chromatic quasisymmetric functions for graphs with node set $[n]$. One can view these as acyclic directed graphs by orienting each edge from smaller node to larger node. In this talk we consider a more general notion of chromatic quasisymmetric functions for directed graphs that are not required to be acyclic. We describe a class of directed graphs, called directed circular indifference graphs, whose chromatic quasisymmetric functions are symmetric. This class consists of the natural unit interval graphs considered by Shareshian and Wachs, as well as circular versions of these graphs. We

discuss results on expansions of the chromatic quasisymmetric functions of these directed graphs in the power sum, Schur, and elementary bases, which generalize work of Stanley, Shareshian-Wachs, and Athanasiadis. These results include a quasisymmetric refinement of Stanley's expansion of the chromatic symmetric function of the cycle in the elementary basis. We also present a generalization of the Shareshian-Wachs refinement of the Stanley-Stembridge e-positivity conjecture for our directed circular indifference graphs. (Received July 19, 2016)

1121-05-223 **Rafael S. González D'León*** (rafaeldleon@uky.edu). *Algebras and operads through poset topology and symmetric functions.*

We illustrate how some algebras and operads can be understood using poset topology techniques applied to certain families of posets. In particular, it is a classical result that the multilinear component of the free Lie algebra is isomorphic (as a representation of the symmetric group) to the top (co)homology of the proper part of the poset of partitions tensored with the sign representation. We generalize this result in order to study the multilinear component of the free Lie algebra with multiple compatible Lie brackets. An analogous result in the category of associative algebras allows us to define and understand the algebraic properties of a colored generalization of the exterior algebra. (Received July 18, 2016)

1121-05-228 **Gabriel Frieden*** (gfrieden@umich.edu). *Affine geometric crystal on the Grassmannian.*

We construct a type $A^{(1)}_{n-1}$ affine geometric crystal structure on the Grassmannian $\mathrm{Gr}(k,n)$. The tropicalization of this structure recovers the combinatorics of crystal operators on semistandard Young tableaux of rectangular shape (with $n-k$ rows), including the affine crystal operator $\widetilde{e_0}$. In particular, the promotion operation on these tableaux essentially corresponds to cyclically shifting the Plücker coordinates of the Grassmannian. (Received July 18, 2016)

1121-05-230 **Amanda Redlich*** (aredlich@bowdoin.edu). *Strategic graph decompositions.*

Motivated by recent work by Kolaitis and Kopparty on zero-one laws for random graphs, I define a new type of graph decomposition. This approach to decomposition proves an extension of the Kolaitis-Kopparty paper. It can also be thought of as a combinatorial game for two players. In this talk I present winning strategies for the simplest version of the game, connect these strategies to random graphs, and indicate potential extensions to more complex variations. Joint work with Bobby DeMarco. (Received July 18, 2016)

1121-05-231 **Kevin Dilks*** (kevin.dilks@ndsu.edu). *q-Gamma Nonnegativity.* Preliminary report.

One special class of polynomials that has historically been of interest has been those with all real roots. In the case where a polynomial has non-negative and symmetric coefficient sequence, a weaker condition than real rootedness is having a non-negative expansion with respect to a distinguished basis . A number of combinatorial polynomials are known to expand positively in this basis, with the coefficients given either by an explicit formula or by a weighted sum over some distinguished set of combinatorial objects. In this talk, we will describe some natural q-analogs of these gamma nonnegativity expansions. The q-analogs of expansions given by explicit formulas are proved, and those with combinatorial interpretation are conjectured, both of which suggest further refinement of what is known combinatorially about the univariate formulas. (Received July 18, 2016)

1121-05-236 **Tom Roby*** (tom.roby@uconn.edu). *Homomesies Lurking in the Twelvefold Way.* Preliminary report.

Given a group acting on a finite set of combinatorial objects, one can often find natural statistics on these objects which are *homomesic*, i.e., over each orbit of the action, the average value of the statistic is the same. Since the notion was codified a few years ago, homomesic statistics have been uncovered in a wide variety of situations within dynamical algebraic combinatorics. We discuss several examples lurking in Rota's *Twelvefold Way* related to actions on injections, surjections (joint work with Michael Joseph), and bijections/permutations (joint work with Michael LaCroix) of finite sets. (Received July 19, 2016)

1121-05-239 **Catherine Erbes**, **Michael Ferrara**, **Timothy LeSaulnier**, **Ryan Martin**, **Casey Moffatt** and **Paul Wenger*** (pswsma@rit.edu). *The Asymptotic Behavior of the Potential Function.*

A sequence π of non-negative integers is *graphic* if there is a simple graph G whose degree sequence is π; in this case, G is a *realization* of π. Given a graph H, the sequence π is *potentially H-graphic* if there is a realization of π that contains H as a subgraph.

In 1991, Erdős, Jacobson, and Lehel defined the *potential number of H*, denoted $\sigma(H,n)$, to be the minimum integer such that every n-term graphic sequence with sum $\sigma(H,n)$ is potentially H-graphic. Since the sum of the terms of π is twice the number of edges in a realization of π, determining the potential number can be thought

of as a potential version of the classical Turán problem. Here we present results on the asymptotic behavior of the potential function for arbitrary graphs, including precise asymptotics and stability results. This is joint work with Catherine Erbes, Michael Ferrara, Timothy LeSaulnier, Ryan Martin, and Casey Moffatt. (Received July 19, 2016)

1121-05-241 **Quang-Nhat Le***, 8 Stimson Ave, Providence, RI 02906, and **Ricardo Diaz** and **Sinai Robins**. *Fourier analysis and counting lattice points inside polytopes.*

Counting lattice points inside polyhedral sets has been used to study the growth of group presentations. For example, Moon Duchin and Michael Shapiro have employed this in their study of the growth of presentations of the integer Heisenberg group. In a larger context, the theory of lattice-point enumerating functions of polytopes is a classical subject, pioneered by Eugene Ehrhart, with far-reaching applications in number theory, algebraic geometry, statistics, etc.

Previously, the theory concerned mostly with the specific case of integer dilates of integer or rational polytopes. In a joint work with Ricardo Diaz and Sinai Robins, we use the framework of the Fourier transform and the Poisson summation formula to extend the classical theory to the general case of real dilates of real polytopes. We are mostly concerned with Macdonald's solid-angle sums, which is a weighted lattice-point count closely related to the weightless count. We are also able to obtain a closed form for the subdominant asymptotic term (codimension-1 coefficient) of the solid-angle sum; the dominant term is trivially the volume of the given polytope. (Received July 19, 2016)

1121-05-242 **Michael S. Chmutov*** (mchmutov@gmail.com), **Pavlo Pylyavskyy** and **Joel Lewis**. *Affine Robinson-Schensted correspondence in Kazhdan-Lusztig theory.*

Using affine Robinson-Schensted correspondence, we describe the structure of undirected edges in the Kazhdan-Lusztig cells in affine type A. Equivalently, we give a comprehensive description of the Knuth equivalence classes of affine permutations. In addition, we lift several well-known properties of the Robinson-Schensted correspondence to the affine setting. (Received July 19, 2016)

1121-05-243 **Jonah Blasiak***, Department of Mathematics, Drexel University, Philadelphia, PA 19104. *Kronecker coefficients and noncommutative super Schur functions.*

The theory of noncommutative Schur functions is an algebraic approach to finding positive combinatorial formulae for the Schur expansions of symmetric functions. In joint work with Ricky Liu, we develop a theory of noncommutative super Schur functions and apply it to prove a positive combinatorial rule for the Kronecker coefficients where one of the partitions is a hook, recovering previous results of Liu and myself. This approach also establishes a precise connection between this rule and a heuristic for Kronecker coefficients first investigated by Lascoux. (Received July 19, 2016)

1121-05-247 **Michael Joseph*** (michael.j.joseph@uconn.edu). *Homomesies in Actions of Toggle Groups.*

We consider systems consisting of a finite set S of objects, and an invertible map that partitions S into orbits. For many such systems one can find statistics on S that have the same average across any orbit; we call such statistics "homomesic". In this talk, our invertible maps will be products of toggling involutions. We consider two examples in detail: one on the set of noncrossing partitions of $[n] := \{1, 2, \ldots, n\}$, and another on independent sets of a path graph. We will also discuss some consequences of the homomesy results. (Received July 19, 2016)

1121-05-254 **Gregory S. Warrington***, Department of Mathematics and Statistics, University of Vermont, Burlington, VT 05401, and **Nicholas A. Loehr**. *Cycle indices, plethysm and quasisymmetric functions.* Preliminary report.

We'll discuss some results relating to the keywords in the title. (Received July 19, 2016)

1121-05-259 **Brendan Pawlowski*** (pawlows@umich.edu). *A representation-theoretic interpretation of positroid classes.*

To any (affine) permutation one can associate its (affine) Stanley symmetric function, which encodes some combinatorial information about its reduced words. Upon removing the Schur terms whose shape is not contained in a fixed rectangle, the resulting symmetric function is Schur-nonnegative, and its Schur coefficients describe: (1) Schubert structure constants for the product of a Schur function and Schubert polynomial; (2) cohomology classes of positroid varieties in a Grassmannian; (3) three-point Gromov-Witten invariants for Grassmannians. We describe a representation of the symmetric group whose Frobenius characteristic is this symmetric function. As a special case, this includes Postnikov's conjecture that toric Schur functions are Frobenius characteristics of toric Specht modules. (Received July 19, 2016)

1121-05-279 **Julianna Tymoczko*** (jtymoczko@smith.edu), Department of Mathematics and Statistics, Smith College, Northampton, MA 01063. *The combinatorics of nilpotent orbits and Springer fibers.*

In this survey talk, we describe the combinatorics of nilpotent orbits and Springer fibers. In type A_n the conjugacy classes of nilpotent $n \times n$ matrices are parametrized by partitions (from the decomposition of the matrix into Jordan blocks). These partitions in turn can be used to compute the dimension of the conjugacy class and to obtain information about its closure.

If we use the right conventions, Springer fibers come from the intersection of a particular nilpotent orbit with the upper-triangular matrices, projected down to the full flag variety. Some of the combinatorics of nilpotent orbits translates directly to this setting, while other parts are modified in interesting ways.

We describe these and other phenomena, including some open questions. Time permitting, we will also discuss other Lie types briefly. (Received July 19, 2016)

1121-05-282 **Thomas Lam***, tfylam@umich.edu. *Combinatorics of electrical networks.*

I will talk about the simplest electrical networks, consisting only of resistors. The axioms of electricity governing these networks were discovered by Kirchhoff and Ohm in the 1800s. It has long been known that electrical properties of a network are related to the enumeration of trees in the corresponding graph. I will discuss this connection from a modern perspective where tree-counts are used as coordinates on the space of planar electrical networks, allowing one to define a compactification of the space of electrical networks. (Received July 20, 2016)

06 ► Order, lattices, ordered algebraic structures

1121-06-90 **Nir Gadish*** (nirg@math.uchicago.edu), 5734 S University Ave, Chicago, IL 60637. *Representation stability of families of linear subspace arrangements.*

Church-Ellenberg-Farb used the language of FI-modules to prove that the cohomology of certain sequences of hyperplane arrangements with S_n-actions satisfies representation stability. I will introduce a lift of their results to the level of the arrangements themselves, and define when a collection of arrangements is "finitely generated". Using this notion we can greatly widen the stability results to:

- General linear-subspace arrangements, not necessarily of hyperplanes.
- A wide class of group actions, replacing FI by a general category C.

The cohomology of such collections of arrangements satisfies a strong form of representation stability, with many concrete applications. For example, this implies that their Betti numbers are always given by certain polynomials. (Received July 13, 2016)

11 ► Number theory

1121-11-4 **Andres Romero*** (andres_b_romero@nnmc.edu), Dept of Math and Physical Sciences, Northern New Mexico College, 921 Paseo de Onate, Espanola, NM 87532, and **James Mckeough** (james_c_mckeough@nnmc.edu) and **Ajit S Hira** (hira@nnmc.edu), Dept of Math and Physics, Northern New Mexico College, 921 Paseo de Onate, Espanola, NM 87532, and **Shannon Whitaker** (shannon_n_whitaker@nnmc.edu). *Problem of the Infinity of Twin Primes and a New Algorithm.*

A new algorithm on the generation of twin primes will be presented, and will be demonstrated on the twin prime pairs up to 50,000. The relevance of this algorithm to the problem of the Infinity of Twin Primes and Generalizations will be shown. In 2013, Yitang Zhang proved that there are infinitely many primes that are apart by less than 70,000,000. Zhang's work has given strong impetus to research efforts aimed at narrowing this gap. We will demonstrate the relevance of our algorithm to the Goldbach Conjecture. Our work examines the distributions of Cousin Primes and Sexy Primes, in addition to distribution of Twin Primes. The generation of primes is important in the use of most public-key schemes, for the creation of key pairs and in the computation stage of many cryptographic setups. (Received May 03, 2016)

1121-11-201 **Peter Lucas Cohen*** (pcohen@bowdoin.edu), 190 Smith Union, Bowdoin College, Brunswick, ME 04011, **Aaditya Sharma** (as17@williams.edu), 1518 Paresky, Williamstown, MA 01267, **Anand Hemmady** (anandhemmady@gmail.com), 1650 Bear Gulch Road, Woodside, CA 94062, **Roger Van Peski** (rpeski@princeton.edu), Fine Hall, Washington Rd., Princeton, NJ 08544, **Yen Nhi Truong Vu** (ytruongvu17@amherst.edu), 16 Barrett Hill Drive, Amherst College, Amherst, MA 01002, and **Carsten R Sprunger** (csprun@umich.edu) and **Chung Hang [Kevin] Kwan** (kevinkwanch@gmail.com), Rm. 3205, Tak Yue House, Hau Tak Estate, Tseung Kwan O, Kowloon, Hong Kong, Hong Kong, **Oscar E Gonzalez** (oscarq39@gmail.com), Box 70377, San Juan, PR 00931, and **Steven J Miller** (steven.j.miller@williams.edu), 202 Bronfman Science Center, 18 Hoxsey Street, Williamstown, MA 01267. *Extending agreement in the Katz-Sarnak Density Conjecture.*

The Katz-Sarnak density conjecture states that the scaling limits of the distributions of zeros of families of automorphic L-functions near the central point agree with the scaling limits of eigenvalue distributions near 1 of classical subgroups of the unitary groups. This conjecture is often tested by computing n-level density. Previous work proved that families of cuspidal newforms have n-level densities agreeing with orthogonal type for test functions with Fourier transform supported in $[-\frac{1}{n-2}, \frac{1}{n-2}]$. We extend the computations on both the number theory and random matrix theory sides. On the random matrix theory side, we use combinatorics to develop a generalization of the work done by Hughes and Miller in order to expand the region of support. Through this combinatorial approach we have shown cancellation of the vast majority of terms and computed the remaining ones, leading to tractable expressions of n-level densities for support in the range of of $[-\frac{1}{n-k}, \frac{1}{n-k}]$ for any $k < n/2$ a natural number. On the number theory side, under the Generalized Riemann Hypothesis, we handle new terms by converting the Kloosterman sums into sums over characters and then expand the support by cancellation of non-principal characters. (Received July 18, 2016)

1121-11-258 **Adrian Barquero-Sanchez**, **Lindsay Cadwallader** and **Olivia Cannon***, ocannon@bowdoin.edu, and **Tyler Genao** and **Riad Masri**. *Faltings Heights of CM Elliptic Curves and Special Gamma Values.*

The Dedekind Eta function is one of the most important functions in number theory. But how is it evaluated? We prove a formula that allows us to evaluate products of eta values at certain roots in terms of special Gamma values. We also use this to calculate the Faltings heights of certain elliptic curves. (Received July 19, 2016)

1121-11-269 **Samuel Freedman*** (samjfree@umich.edu) and **Harjasleen Malvai** (harjasleen_malvai@brown.edu). *Generalized Dedekind Sums.* Preliminary report.

While editing Riemann's work on modular forms, Richard Dedekind defined a sum that describes a transformation essential to the eta function. This so-called classical Dedekind sum $s(a,c) = \sum_{k=1}^{|c|-1} \left(\left(\frac{k}{c}\right)\right)\left(\left(\frac{ka}{c}\right)\right)$ with $((x)) = \{x\} - \frac{1}{2}$ is odd, periodic (with period 1) and satisfies a reciprocity law.

In this project, we considered a generalization of the Dedekind sum (due to Long and Reid) associated with certain once-punctured hyperbolic tori. The generalized sum corresponding to the maximally symmetric hexagonal torus agrees with the classical Dedekind sum. After writing a computer program, we made conjectures about the generalized sum corresponding to the square torus. We proved that its accompanying sum is periodic and satisfies a reciprocity law as well, using the geometric symmetries of the underlying torus. (Received July 19, 2016)

13 ► Commutative rings and algebras

1121-13-91 **Federico Galetto*** (galetto.federico@gmail.com). *Equivariant resolutions of De Concini-Procesi ideals.* Preliminary report.

De Concini-Procesi ideals are a family of ideals in the polynomial ring which are indexed by partitions. They appear in different contexts from algebraic topology to algebraic geometry. Among their interesting features, these ideals are stable under the action of the symmetric group permuting the variables. I will illustrate how to construct equivariant free resolutions for these ideals when the indexing partition is hook-shaped. (Received July 13, 2016)

1121-13-162 **Michele Torielli*** (torielli@math.sci.hokudai.ac.jp), Department of Mathematics,Hokkaido University, Kita 10, Nishi 8, Kita-ku, Sapporo, 060-0810, Japan, and **Anna Maria Bigatti** and **Elisa Palezzato**. *Sectional matrices and geometrical consequences of their extremal behaviour.* Preliminary report.

In this talk I will recall the definition of the sectional matrix of an homogenous ideal as given by Bigatti and Robbiano. I will describe the main properties of the sectional matrix and give some geometrical consequences of this properties, especially in the case of ideals of points in projective space. This is part of a work in progress with Bigatti and Palezzato. (Received July 18, 2016)

14 ► Algebraic geometry

1121-14-105 **Peter Crooks*** (peter.crooks@utoronto.ca), Department of Mathematics, University of Toronto, 40 St. George Street, Room 6290, Toronto, Ontario M5S 2E4, Canada, and **Hiraku Abe**. *Hessenberg Varieties for the Minimal Nilpotent Orbit.*

To each nilpotent orbit of a simple complex algebraic group G, one can associate a family of nilpotent Hessenberg varieties. These are subvarieties of the flag variety of G, with examples including Springer fibers and the Peterson variety.

In this presentation, we will examine the family of nilpotent Hessenberg varieties arising from the minimal nilpotent orbit. In particular, we will explain a combinatorial procedure for determining the Poincaré polynomials and irreducible components of these varieties in Lie type A. Secondly, we will offer two presentations of the T-equivariant cohomology rings of our varieties. The first arises from GKM theory, while the second comes from exhibiting the T-equivariant cohomology rings as quotients of $H_T^*(G/B)$.

This presentation will represent joint work with Hiraku Abe. (Received July 14, 2016)

1121-14-130 **Jonathan Mboyo Esole*** (mboyoesole@gmail.com). *Hyperplane arrangements and elliptic fibrations.*

We study the birational geometry of elliptic fibrations using hyperplane arrangements to predict the network of flop transitions between crepant resolutions of Weierstrass models. (Received July 16, 2016)

1121-14-167 **Sean D Lawton*** (slawton3@gmu.edu), 4400 University Dr, Exploratory Hall, L106, Fairfax, VA 22030. *Varieties of Characters.*

Let G be a connected reductive affine algebraic group. We define the variety of G-characters of a finitely generated group Γ and show that the quotient of the G-character variety of Γ by the action of the trace preserving outer automorphisms of G normalizes the variety of G-characters when Γ is a free group, free abelian group, or a surface group. This is joint work with Adam Sikora. (Received July 18, 2016)

1121-14-264 **Jerzy Weyman*** (jerzy.weyman@uconn.edu), Department of Mathematics, 196 Auditorium Rd U-3009, Storrs, CT 06269, and **Witold Kraskiewicz**. *Geometry of orbit closures for Vinberg representations.* Preliminary report.

I will discuss my work with Witold Kraskiewicz on geometry of orbit closures for Vinberg Representations. (Received July 19, 2016)

15 ► Linear and multilinear algebra; matrix theory

1121-15-154 **M. Boij**, **A. Iarrobino**, **L. Khatami*** (khatamil@union.edu), **B. Van Steirteghem** and **R. Zhao**. *Equations of loci in tables of commuting Jordan types.*

The Jordan type of a nilpotent matrix is the partition giving the sizes of the Jordan blocks in the normal Jordan form of the matrix. In this talk we discuss all partitions that have a fixed partition Q as the generic Jordan type in their nilpotent commutator. We report on a joint work with A. Iarrobino, B. Van Steirteghem and R. Zhao in which we provide a complete description of all such partitions for a partition Q with at most two parts. In particular we arrange all such partitions in a table that we denote by $\mathcal{T}(Q)$. We then report on an ongoing joint project with M. Boij, A. Iarrobino, B. Van Steirteghem and R. Zhao in which we study the equations of loci in $\mathcal{T}(Q)$. (Received July 17, 2016)

1121-15-268 **Samuel E Swain*** (sswain@bowdoin.edu). *Kochen-Specker Uncolorability of $\mathbb{Z}_{5^n}$.*
The Kochen-Specker theorem from quantum physics restricts noncontextual hidden variable theories by demonstrating that, for certain collections of real projection matrices, a coloring does not exist. A Kochen-Specker coloring of 3x3 symmetric idempotent (projection) matrices over a commutative ring assigns the color black or white to every matrix in such a way that every set of commeasurable elements has one white matrix and the rest black. These triples of commeasurable elements are those that commute with each other, that is, projections onto orthogonal subspaces. We will show that there is no such coloring for the matrices with entries from $\mathbb{Z}_{5^n}$ for all $n \geq 1$ by showing that the subset of all rank-1 projection matrices is uncolorable. This should ultimately motivate an argument of colorability over $\mathbb{Z}_5$, the 5-adic integers. (Received July 19, 2016)

16 ► Associative rings and algebras

1121-16-7 **Lia Vas*** (l.vas@usciences.edu), University of the Sciences, 600 S 43rd St, Philadelphia, PA 19104. *K-theory classification of algebras which are more general than they seem.*
If R is a graded ring with involution, the group $K_0^{\mathrm{gr}}(R)$ takes over the role of the standard Grothendieck group $K_0(R)$. We show that K_0^{gr} completely classifies graded ultramatricial $*$-algebras over a graded field with a "nice enough" involution. This result may seem to be a specialization of the well known classification results of ultramatricial algebras over a field because it may appear as if we are adding structure to the field. However, we illustrate that it is actually a generalization: if the grading is trivial and the involutive structure is not considered, our result implies the well known classification. If either the involutive structure is not considered or the grading is trivial, we obtain some other well known results as corollaries. As an application, we show that the graded version of the Isomorphism Conjecture holds for a class of Leavitt path algebras.

This is joint work with Roozbeh Hazrat. (Received June 10, 2016)

1121-16-15 **Gene Abrams**, **Francesca Mantese*** (francesca.mantese@univr.it) and **Alberto Tonolo**. *Leavitt path algebras are Bézout.*
Let E be a directed graph, K any field, and let $L_K(E)$ denote the Leavitt path algebra of E with coefficients in K. We show that $L_K(E)$ is a Bézout ring, i.e., that every finitely generated one-sided ideal of $L_K(E)$ is principal. Then we use the Bézout property of Leavitt path algebras to investigate the injectivity of a naturally-occuring class of modules over $L_K(E)$, by means of a divisibility notion which arises in this setting. (Received June 19, 2016)

1121-16-16 **Alexandru Chirvasitu*** (chirva@uw.edu), University of Washington, Department of Mathematics, Box 354350, Seattle, WA 98195, and **S. Paul Smith** and **Liang Ze Wong**. *Homogenized quantum $\mathfrak{sl}_2$ and its non-commutative geometry.*
For non-root-of-unity complex parameters $q \in \mathbb{C}^\times$, we realize the q-deformed enveloping algebra $U_q = U_q(\mathfrak{sl}_2)$ as the coordinate ring of a non-commutative open subscheme of a "quantum $\mathbb{P}^3$". The latter is the dual object $\mathrm{Proj}_{nc}(S)$ corresponding to a graded algebra S with the Hilbert series of a 4-variable polynomial ring, equipped with a degree-two central element c such that the localization $S[c^{-1}]_0$ is isomorphic to U_q.

We then show how the internal geometry of the noncommutative projective space $\mathrm{Proj}_{nc}(S)$ (i.e. its lines, points, so-called "fat points", the incidence relations between these, etc.) mirrors and recovers the representation theory of U_q by recovering Verma modules, finite-dimensional irreducible modules, BGG resolutions, and so on. (Received June 21, 2016)

1121-16-19 **Alexandru Chirvasitu** and **Chelsea Walton*** (notlaw@temple.edu), Philadelphia, PA 19122, and **Xingting Wang**. *Universal quantum groups associated to a pair of preregular forms.*
I will discuss recent joint work with Alexandru Chirvasitu and Xingting Wang (arXiv:1605.06428), where we define the universal quantum group $\mathcal{H}$ that preserves a pair of Hopf comodule maps whose underlying vector space maps are preregular forms defined on dual vector spaces. This generalizes the construction of Bichon and Dubois-Violette (2013), where the target of these comodule maps are the ground field. We also recover the quantum groups introduced by Dubois-Violette and Launer (1990), by Takeuchi (1990), by Artin, Schelter, and Tate (1991), and by Mrozinski (2014), via our construction. As a consequence, we obtain an explicit presentation of a universal quantum group that coacts simultaneously on a pair of N-Koszul Artin-Schelter regular algebras with arbitrary quantum determinant. (Received June 22, 2016)

1121-16-29 **Thomas Cassidy*** (tcassidy@bucknell.edu), Mathematics Department, 1 Dent Drive, Bucknell University, Lewisburg, PA 17837, and **Michaela Vancliff**. *Skew Clifford Constructions.* Preliminary report.

I will describe on-going work with M. Vancliff on skew versions of Clifford algebras. Motivated by results of Le Bruyn, we previously introduced N-graded skew Clifford algebras and showed how an associated geometry could be used to produce several families of quadratic Artin-Schelter regular algebras. More recently, we have defined a family of algebras as a skew generalization of the classical Clifford algebras. I will describe how these new algebras differ from the classical model, and discuss connections with the N-graded skew Clifford algebras. (Received June 30, 2016)

1121-16-41 **J. Hennig*** (jhennig1@ualberta.ca) and **S. Sierra**. *Path algebras of quivers and representations of locally finite Lie algebras.*

We explore the (noncommutative) geometry of representations of locally finite Lie algebras. Let L be one of these Lie algebras, and let $I \subset U(L)$ be the annihilator of a locally simple L-module. We show that for each such I, there is a quiver Q so that locally simple L-modules with annihilator I are parameterized by "points" in the "noncommutative space" corresponding to the path algebra of Q. We classify the quivers that occur and along the way discover a beautiful connection to characters of the symmetric groups S_n. (Received July 05, 2016)

1121-16-47 **G. Abrams**, **G. Aranda Pino** and **Z. Mesyan***, Department of Mathematics, University of Colorado, Colorado Springs, CO 80918, and **C. Smith**. *Leavitt Path Algebras and Possible Prime Spectra of Rings.*

We associate in a natural way to any partially ordered set $(P, \leq)$ a directed graph E_P (where the vertices of E_P correspond to the elements of P, and the edges of E_P correspond to related pairs of elements of P), and then describe the prime spectrum of the resulting Leavitt path algebra $L_K(E_P)$. This construction allows us to realize a wide class of partially ordered sets as the prime spectra of rings, which includes many partially ordered sets not previously known to be so realizable. (Received July 05, 2016)

1121-16-51 **Daniel O Yee*** (doyee@uwm.edu), 2727 N. Maryland Avenue, apt. #308, Milwaukee, WI 53211. *Examples of Connected Hopf Algebras satisfying the Noetherian or Ore Conditions.* Preliminary report.

Suppose $\mathfrak{g}$ is a Lie algebra over a field of characteristic zero, then the enveloping algebra $U(\mathfrak{g})$ is a connected Hopf algebra and in some cases is Noetherian, or more generally an Ore domain. Motivated by a construction of Wang, Zhang and Zhuang, we introduce connected Hopf algebras $A(\mathfrak{g})$ generated by anti-cocommutative elements and ask if they satisfy the Noetherian or Ore conditions. (Received July 15, 2016)

1121-16-53 **Pace P Nielsen*** (pace@math.byu.edu), Department of Mathematics, Provo, UT 84602. *Idempotent lifting and beyond.*

The ability to lift idempotents modulo every one-sided ideal characterizes the important class of exchange rings. In such a ring idempotents not only lift, but they lift strongly. We investigate other forms of lifting in such rings and generally; including the ability to lift regular elements, isomorphic idempotents, and conjugate idempotents modulo an ideal. Interrelations between these concepts are clarified. (Received July 07, 2016)

1121-16-66 **Ellen E. Kirkman*** (kirkman@wfu.edu), **K. Chan** (kenchan@math.washington.edu), **C. Walton** (notlaw@temple.edu) and **J. J. Zhang** (zhang@math.washington.edu). *Hopf actions on AS regular algebras: Auslander's Theorem.*

Let $\Bbbk$ be an algebraically closed field of characteristic zero. Maurice Auslander proved that when a finite subgroup G of $\mathrm{GL}_n(\Bbbk)$, containing no reflections, acts on $A = \Bbbk[x_1, \ldots, x_n]$ naturally, with fixed subring A^G, then the skew group algebra $A\#G$ is isomorphic to $\mathrm{End}_{A^G}(A)$ as algebras. In work with K. Chan, C. Walton and J.J. Zhang, we prove Auslander's Theorem in a noncommutative setting. Let A be an Artin-Schelter regular algebra of dimension 2, and H be a semisimple Hopf algebra acting on A so that A is a graded H-module algebra under an action that is inner faithful and has trivial homological determinant; then $A\#H$ is isomorphic to $\mathrm{End}_{A^H}(A)$ as algebras. (Received July 10, 2016)

1121-16-93 **Gordana G. Todorov*** (g.todorov@neu.edu), Mathematics Department, Northeastern University, 360 Huntington Av., Boston, MA 02115, and **Karin Baur** and **Eleonore Faber**, MA, and **Sira Gratz** and **Khrystyna Serhiyenko**. *Cluster mutations and mutations of Conway-Coxeter friezes.* Preliminary report.

We study mutations of Conway-Coxeter friezes which are compatible with the fundamental notion of cluster mutations in the associated cluster algebra and cluster category of Dynkin type A. Further, we provide a formula

for the number of submodules in a module over the path algebra of a quiver that is cluster mutation equivalent to a Dynkin diagram of type A. (Received July 13, 2016)

1121-16-97 **Stephen Hermes** and **Kiyoshi Igusa*** (igusa@brandeis.edu), Mathematics Department, Brandeis University, Waltham, MA 02454. *No gap conjecture for tame hereditary algebras.*

The "No Gap Conjecture" of states that the set of lengths of maximal green sequences for hereditary algebras over an algebraically closed field has no gaps. This follows from a stronger conjecture that any two maximal green sequences can be "polygonally deformed" into each other. We prove this stronger conjecture for all tame hereditary algebras over any field. The proof follows an idea of Garver-McConville who use unpublished results of Nathan Reading to essentially solve the No Gap Conjecture for all simply-laced cluster-tilted algebras of finite type. (Received July 13, 2016)

1121-16-109 **Susan Sierra**, **Spela Spenko**, **Michaela Vancliff** and **Padmini Veerapen***, pveerapen@tntech.edu, and **Emilie Wiesner**. *On Noncommutative Algebraic Geometry and the Lie superalgebra* $\mathfrak{sl}(1|1)$.

This is joint work with Sierra, Spenko, Vancliff, and Wiesner which began at the Women in Noncommutative Algebra and Representation Theory (WINART) workshop at BIRS. Le Bruyn and Smith show how noncommutative algebraic geometry, in the spirit of Artin, Tate, and Van den Bergh, can be applied to the Lie algebra, $\mathfrak{sl}(2,\mathbb{C})$ and Le Bruyn and Van den Bergh generalize these results to any n-dimensional Lie Algebra. We discuss here how these results can be extended to the Lie superalgebra $\mathfrak{sl}(1|1)$.

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(Received July 14, 2016)

1121-16-122 **Charlie R Beil*** (charlie.beil@bristol.ac.uk), Howard House, Queen's Ave, Bristol, BS8 1SN, United Kingdom. *Nonnoetherian Dimer Algebras and Noncommutative Crepant Resolutions.*

It is known that every cancellative dimer algebra is a noncommutative crepant resolution (NCCR), and every 3-dimensional affine toric Gorenstein singularity admits an NCCR given by a cancellative dimer algebra. However, dimer algebras which are cancellative are quite rare, and we consider the question: how close are nonnoetherian (homotopy) dimer algebras to being NCCRs? To address this question, I will propose a generalization of NCCRs to nonnoetherian tiled matrix rings. I will then describe a class of dimer algebras, as well as a class of noncommutative blowups, which are nonnoetherian NCCRs. (Received July 15, 2016)

1121-16-195 **Alexi T. Block Gorman** and **Alexander J. Diesl*** (adiesl@wellesley.edu), 106 Central Street, Wellesley, MA 02481, and **Thomas J. Dorsey**. *An Ideal-Theoretic Notion of Nil Clean (Preliminary Report).* Preliminary report.

A ring is called *nil clean* if every element can be written as the sum of a nilpotent element and an idempotent element. This condition, while natural, is somewhat restrictive. In this new investigation, we consider rings which have the property that every (two-sided) ideal can be written as the sum of a nilpotent ideal and an idempotent ideal. In the commutative case, this coincides with the strongly *pi*-regular property; in the noncommutative case, the situation is far more interesting. (Received July 18, 2016)

1121-16-214 **Jonas T Hartwig***, jth@iastate.edu. *Weight modules over noncommutative Kleinian fiber products.*

I will present a classification of all irreducible weight modules over a family of noncommutative algebras. On the one hand, these algebras arise as biparametric deformations of fiber products of two Kleinian singularities of type A. On the other hand, they are prototypical examples of twisted generalized Weyl algebras (for which the problem of classifying irreducible weight modules is still open in general). Lastly, I will point out several intriguing connections to higher spin 6-vertex models with semi-periodic boundary conditions. (Received July 18, 2016)

1121-16-229 **Robert Won*** (wonrj@wfu.edu). *The noncommutative schemes of generalized Weyl algebras.* Preliminary report.

The first Weyl algebra, A_1, admits a natural $\mathbb{Z}$-grading. Paul Smith showed that gr-A_1, the category of graded A_1-modules, is equivalent to the category of quasicoherent sheaves on a certain quotient stack. Using autoequivalences of gr-A_1, Smith constructed a commutative ring C, graded by finite subsets of the integers and proved that gr-C is equivalent to gr-A_1. Here, we generalize results of Smith by using autoequivalences of a graded module category to construct rings with equivalent graded module categories. For certain generalized Weyl algebras, we use autoequivalences defined in a so that these constructions yield commutative rings. (Received July 18, 2016)

1121-16-235 **Tyler Kloefkorn*** (tkloefkorn@math.arizona.edu). *Weakly Cohen-Macaulay posets and a class of finite-dimensional Koszul algebras.*

Given a finite ranked poset Γ, we study an associated finite-dimensional graded quadratic algebra, R_Γ. Assuming Γ satisfies a combinatorial condition known as uniform, R_Γ is related to a well-known algebra, the *splitting algebra* A_Γ. Splitting algebras were first introduced by Gelfand, Retakh, Serconek, and Wilson, and they originated from the problem of factoring non-commuting polynomials. We ask: Is R_Γ Koszul? The Koszulity of R_Γ is related to the Cohen-Macaulay property of Γ. Kloefkorn and Shelton proved that if Γ is a finite ranked cyclic poset, then Γ is Cohen-Macaulay if and only if Γ is uniform and R_Γ is Koszul. We define a new generalization of Cohen-Macaulay, weakly Cohen-Macaulay. We prove: if Γ is a finite ranked cyclic poset, then Γ is weakly Cohen-Macaulay if and only if R_Γ is Koszul. (Received July 19, 2016)

1121-16-257 **Miodrag Iovanov*** (miodrag-iovanov@uiowa.edu), Iowa City, IA 52245, and **Gerard Koffi**. *Incidence algebras and their representations.*

We give a unified approach via incidence algebras to several types of representations present in literature: distributive, square-free, with finitely many orbits, or with finitely many invariant subspaces. We introduce deformations of incidence algebras of posets, classify them and their square-free representations in terms of cohomology of the simplicial realization of the poset. We find several equivalent characterizations of deformations and of incidence algebras, such as that deformations are precisely the locally hereditary semidistributive algebras, and incidence algebras are algebras with a faithful square-free representation or equivalently acyclic algebras with a faithful distributive module. As a consequence, we show that any distributive acyclic representation of a finite dimensional algebra can be presented as the defining representation of an incidence algebra. Time permitting, we present a few other applications: we rederive several results in the literature of incidence algebras as well classify generic distributive or square-free representations in the acyclic case, and give consequences on representation and Grothendieck rings of incidence algebras and on a conjecture of Bongartz and Ringel. (Received July 19, 2016)

1121-16-270 **Costel G Bontea*** (costel.bontea@gmail.com) and **Dmitri Nikshych**. *On the Brauer-Picard group of a finite symmetric tensor category.*

The Brauer-Picard group of a finite tensor category $\mathcal{C}$ is the group of equivalence classes of invertible exact $\mathcal{C}$-bimodule categories. It plays a crucial role in the construction and classification of group-graded extensions of $\mathcal{C}$ and also relates to structures appearing in mathematical physics.

If H is a finite dimensional Hopf algebra then the finite dimensional representations of H form a finite tensor category. The task of computing the Brauer-Picard group of such categories is a difficult one and, with few exceptions, no general results are known.

In this talk I will present the techniques used in computing the Brauer-Picard group of a family of finite tensor categories associated to a class of Hopf algebras called Nichols Hopf algebras. This is joint work with Dmitri Nikshych. (Received July 19, 2016)

1121-16-276 **Thomas J Dorsey*** (dorsey@ccrwest.org), 4320 Westerra Ct., San Diego, CA 92121. *Recent developments on clean and strongly clean rings.*

We will discuss recent progress on clean and strongly clean rings. (Received July 19, 2016)

18 ► Category theory; homological algebra

1121-18-196 **Dmitri Nikshych*** (dmitri.nikshych@unh.edu), Department of Mathematics and Statistics, Kingsbury Hall, 33 Academic Way, Durham, NH 03824. *Braided graded fusion categories.* Preliminary report.

We discuss construction of braided fusion categories graded by a finite Abelian group G with a given trivial component $\mathcal{C}$ (i.e., braided G-extensions of fusion categories). Such extensions arise from monoidal functors from G to the braided part of the Picard Gr-category of $\mathcal{C}$.

We describe obstructions to existence of such extensions and their parameterization in terms of Abelian cohomology. We consider several concrete examples of extensions and compute their Picard groups. (Received July 18, 2016)

1121-18-250 **Robert Usher*** (rusher@uoregon.edu), Department of Mathematics, Fenton Hall, University of Oregon, Eugene, OR 97403. *Fermionic 6j-symbols in superfusion categories.*

We will describe how the study of superfusion categories (roughly speaking, fusion categories enriched over the category of super vector spaces) reduces to that of fusion categories over sVect. In particular, we describe the underlying fusion category of a superfusion category, and state a version of Ocneanu rigidity for superfusion categories. (Received July 19, 2016)

20 ► Group theory and generalizations

1121-20-6 **Funda Gul** (msohrab1@stevens.edu), Department of Mathematical sciences, Stevens Institute of Technology, Hoboken, NJ 07030, **Alexei G. Myasnikov** (amiasnikov@gmail.com), Department of Mathematical Sciences, Stevens Institute of Technology, Hoboken, NJ 07030, and **Mahmood Sohrabi*** (msohrab1@stevens.edu), Department of Mathematical Sciences, Stevens Institute of Technology, Hoboken, NJ 07030. *Distortion of embeddings of a torsion-free finitely generated nilpotent group into a unitriangular group.*

We present several results on the distortion of various well-known embeddings of a finitely generated torsion-free nilpotent group G into an integral unitriangular groups $UT_n(\mathbb{Z})$. Time permitting we also present a polynomial time algorithm for finding distortion of a given subgroup of G. (Received May 17, 2016)

1121-20-22 **Albert Garreta-Fontelles*** (garreta.a@gmail.com), **Alexei Miasnikov** and **Denis Ovchinnikov**. *Systems of equations in random nilpotent groups.*

We present a new model for generating random nilpotent groups G, and we briefly survey two other models that were introduced recently. We then provide results concerning equations in nilpotent groups, and we address the following question: when are systems of equations decidable in a random G? (Received July 10, 2016)

1121-20-31 **Funda Gul**, NJ , and **Armin Weiß***, armin.weiss@gmail.com. *On the dimension of matrix embeddings of torsion-free nilpotent groups.*

Since the work of Jennings (1955), it is well-known that any finitely generated torsion-free nilpotent group can be embedded into unitriangular integer matrices $UT_N(Z)$ for some N. In 2006, Nickel proposed an algorithm to calculate such embeddings. In this work, we show that if $UT_n(Z)$ is embedded into $UT_N(Z)$ using Nickel's algorithm, then $N \geq 2^{n/2-2}$ if the standard ordering of the Mal'cev basis (as in Nickel's original paper) is used. In particular, we establish an exponential worst-case running time of Nickel's algorithm.

On the other hand, we also prove a general exponential upper bound on the dimension of the embedding by showing that for any torsion free, finitely generated nilpotent group the matrix representation produced by Nickel's algorithm has never larger dimension than Jennings' embedding. Moreover, when starting with a special Mal'cev basis, Nickel's embedding for $UT_n(Z)$ has only quadratic size. Finally, we consider some special cases like free nilpotent groups and Heisenberg groups and compare the sizes of the embeddings. (Received July 01, 2016)

1121-20-55 **David C. Vella*** (dvella@skidmore.edu), Dept. Mathematics, Skidmore College, 815 N. Broadway, Saratoga Springs, NY 12866. *Borel Subgroups of Modality Zero.*

Let G be a quasi-simple algebraic group over an algebraically closed field k, and let B be a Borel subgroup of G. If b is the Lie algebra of B, then B acts on b and on n, the nilradical of b, via the adjoint representation. The orbits of B in n are the nilpotent B-orbits. Informally speaking, the modality of B is the 'maximum number of parameters on which a family of nilpotent B-orbits in n may depend'. Thus, the modality of B is zero if and

only if there are only finitely many nilpotent B-orbits in n. It turns out that there are only five examples of G in which B has modality zero. In this talk, we outline how to prove that result (a 1990 result due to Kashin); and also in those five cases, I present the defining equations of each orbit, and thereby derive the dimensions and closure order of the nilpotent orbits (recent results which are joint work with Madeleine Burkhart.) (Received July 07, 2016)

1121-20-71 **Matthew Zaremsky*** (zaremskym@gmail.com). *Symmetric automorphisms of free groups and finiteness properties of certain subgroups.*

An automorphism of the free group F_n is called *symmetric* if it sends each basis element to a conjugate of a basis element, and *pure symmetric* if it sends each basis element to a conjugate of itself. The groups ΣAut_n and $P\Sigma Aut_n$ of symmetric and pure symmetric automorphisms of F_n appear in a variety of situations and are closely related to the classical (pure) braid groups. In this talk I will discuss the finiteness properties of certain subgroups of these groups; an easy-to-state example is that it turns out the commutator subgroup of ΣAut_n is finitely generated if and only if $n \geq 3$, and finitely presented if and only if $n \geq 4$. If time permits I will discuss some of the tools used, including Bieri-Neumann-Strebel-Renz invariants, Morse theory, and the complex of symmetric marked cactus graphs. (Received July 11, 2016)

1121-20-74 **Sean Cleary*** (scleary@ccny.cuny.edu) and **Ariadna Fossas Tenas** (ariadna.fossastenas@gmail.com). *Random elements and subgroups of Thompson's groups T and V.*

Earlier work of Cleary, Elder, Rechnitzer and Taback described some of the behavior of randomly-selected subgroups of Thompson's group F. Here, we describe some of the properties of random elements and subgroups of Thompson's groups T and V. (Received July 11, 2016)

1121-20-78 **Xiangdong Xie***, xiex@bgsu.edu. *Rigidity of quasiisometries and quasiconformal maps.*

Quasiisometries between negatively curved spaces induce quasiconformal maps between the ideal boundaries. Rigidity of quasiisometries correspond to the rigidity of quasiconformal maps. The ideal boundary of negatively curved homogeneous manifolds are (one-point compactification of)nilpotent Lie groups equipped with homogeneous "distances". We will explain various results showing that quasiconformal maps between nilpotent Lie groups (equipped with homogeneous distances) are very rigid in general. (Received July 12, 2016)

1121-20-80 **Nicholas Touikan*** (ntouikan@stevens.edu), Stevens Institute of Technology, Department of Mathematical Sciences, 1 Castle Point Terrace, Hoboken, NJ 07030, and **Inna Bumagin**. *On the set of homomorphisms to a relatively hyperbolic group.* Preliminary report.

There has been a long running program to generalize results about hyperbolic groups to relatively hyperbolic groups by reducing the problem to the peripheral subgroups. In this talk I will present one such result.

If $\Gamma = (\Gamma; P_1, \ldots, P_r)$ is a relatively hyperbolic group and G is a finitely generated group, then, provided the parabolic subgroups satisfy certain properties, there exists a Makanin-Razborov diagram encoding the set $\mathrm{Hom}(G, \Gamma)$ up to a finite set of varieties $\mathrm{Hom}(T_i, P_{n_i})$ of homomorphisms to the parabolic subgroups.

Many of the ideas that go into this result came from other authors, specifically Sela, Alibegovic, Groves, Reinfeldt-Weidmann, Jaligot-Sela; so I will focus on one of our main contributions, which is to vary the geometry of certain Γ-spaces in order to control asymptotic cones. (Received July 12, 2016)

1121-20-95 **Moon Duchin**, **Hao Liang** and **Michael Shapiro***, michael.shapiro@tufts.edu. *Equations in nilpotent groups.*

We consider equations over nilpotent groups. We show that there is an algorithm which takes as its input a single equation and decides whether it has a solution in the Heisenberg group. We also show that there is no algorithm that takes as its input a set of equations and decides whether they have a common solution in the Heisenberg group.

The way to see this is to show that equations in the Heisenberg group can be turned into systems of quadratic integer equations in such a way that the integer equations can be solved if and only if the Heisenberg equation(s) can be solved. The negative case is then the unsolvability of Hilbert's tenth problem.

These methods allow us to say more about some step 2 nilpotent groups and higher class and rank free nilpotent groups. (Received July 13, 2016)

1121-20-96 **Devin Murray*** (dmurray@brandeis.edu). *The Contracting Boundary of CAT(0) Groups.*

Unlike the Gromov boundary for hyperbolic groups, the visual boundary for CAT(0) groups is not a quasi-isometry invariant. Charney and Sultan introduced the contracting boundary, which is a subset of the visual

boundary endowed with a direct limit topology, in order to obtain a boundary for CAT(0) spaces which are QI invariant.

It turns out that the topology of the contracting boundary is fairly different from what one would expect. However, the contracting boundary does resemble the Gromov boundary in many ways. It has similar dynamical properties, and the topology of the contracting boundary can be used to determine hyperbolicity and the convexity of subgroups. I will also discuss some new connections between the contracting boundary and the rigidity of CAT(0) groups. (Received July 13, 2016)

1121-20-98 **Matt Clay**, **Max Forester** and **Joel Louwsma*** (jlouwsma@niagara.edu), Department of Mathematics, Niagara University, PO Box 2044, Niagara University, NY 14109. *Quasimorphisms on groups that act on trees.*

We construct efficient quasimorphisms on groups that act on trees and show that their defect is at most 6. Calculations in the Baumslag–Solitar group $BS(2,3)$ show that this is the smallest possible defect that can be achieved in this generality. A consequence of our result is that every suitable element of a group that acts on a tree must have stable commutator length at least 1/12. In Baumslag–Solitar groups, we show that no element can have stable commutator length between 0 and 1/12. (Received July 13, 2016)

1121-20-99 **Matthew B. Day** and **Richard D. Wade*** (wade@math.ubc.ca). *Subspace Arrangements and BNS Invariants.*

We introduce a natural chain complex associated to a collection of subspaces of a vector spaces, and discuss the associated homology. We will give some background on Bieri-Neumann-Strebel invariants of groups, and show how the BNS invariant of a group leads to a nice subspace arrangement, whose associated homology is (yet) another invariant of the group. This can give a useful way of distinguishing between finitely presented groups - we will give some examples involving right-angled Artin groups. (Received July 13, 2016)

1121-20-100 **Thomas Koberda*** (thomas.koberda@gmail.com), **Johanna Mangahas** and **Samuel J Taylor**. *The geometry of purely loxodromic subgroups of right-angled Artin groups.*

We prove that finitely generated *purely loxodromic* subgroups of a right-angled Artin group $A(\Gamma)$ fulfill equivalent conditions that parallel characterizations of convex cocompactness in mapping class groups $\mathrm{Mod}(S)$. In particular, such subgroups are quasiconvex in $A(\Gamma)$. In addition, we identify a milder condition for a finitely generated subgroup of $A(\Gamma)$ that guarantees it is free, undistorted, and retains finite generation when intersected with $A(\Lambda)$ for subgraphs Λ of Γ. These results have applications to both the study of convex cocompactness in $\mathrm{Mod}(S)$ and the way in which certain groups can embed in right-angled Artin groups. (Received July 13, 2016)

1121-20-104 **Nic Koban*** (nicholas.koban@maine.edu) and **Peter Wong**. *A Further Investigation into Twisted Conjugacy and Geometric Invariants.* Preliminary report.

Given a group G, there is a relationship between the geometric invariant $\Omega^1(G)$ and the index of the subgroup of automorphisms of G that have an infinite number of twisted conjugacy classes. The invariant $\Omega^1(G)$ is analogous to the BNS invariant $\Sigma^1(G)$, and it has the nice property that its cardinality is either 0, 1, 2, or ∞. In the case where $\Omega^1(G)$ is one point, all of the automorphisms of G have infinitely many twisted conjugacy classes, but in the case where $\Omega^1(G)$ is two points, the index of the subgroup is at most two. We will present further investigation into this situation to determine which groups with $\Omega^1(G)$ being two points have all of the automorphisms with infinitely many twisted conjugacy classes. (Received July 14, 2016)

1121-20-117 **George J McNinch*** (george.mcninch@tufts.edu), Dept Mathematics, Tufts University, 503 Boston Ave, Medford, MA 02474. *Nilpotent elements and sections.*

Let X be a nilpotent element in the Lie algebra of a split semisimple algebraic group G over a field k whose characteristic is "very good" for G. It can be useful to view X as the "value at the closed point" for a section of some related Lie theoretic structure defined over a DVR A with residue field k. This sometimes permits one to related numerical or combinatorial data over k and over the field of fractions K of A.

We will describe two settings for such arguments. The first involves a recent result of McNinch-Testerman. When X is even, we use a section of a certain A-Lie algebra to relate the dimension of the center of the centralizer of X to the dimension of the center of the Levi factor of the parabolic subgroup attached to X.

In the second setting, we consider a split semisimple group scheme H over A for which $H_k = G$. When A is complete, we explain how one can find a nilpotent section Y in $\mathrm{Lie}(H)$ whose image in $\mathrm{Lie}(G)$ is X and for which $Y \in \mathrm{Lie}(H) \subset \mathrm{Lie}(H_K)$ is labelled by the same combinatorial data. It follows that the "type" of the reductive quotient of $C_G(X)$ is independent of "very good" characteristic. (Received July 14, 2016)

1121-20-127 **Adam Piggott*** (adam.piggott@bucknell.edu). *On groups presented by monadic rewriting systems.*

We prove that the groups presented by finite convergent monadic rewriting systems with generators of finite order are exactly the free products of finitely many finite groups, thereby confirming Gilman's Conjecture in a special case. (Received July 15, 2016)

1121-20-139 **Gilbert Baumslag**, **Charles F. Miller III** and **Gretchen Ostheimer***, Gretchen.Ostheimer@hofstra.edu. *Decomposability of Finitely Generated Torsion-free Nilpotent Groups.*

The class of finitely generated torsion-free nilpotent groups has proven to play an important role in the study of infinite solvable groups, both in understanding the structure of infinite solvable groups and in the development of algorithms for studying them. Here we describe an algorithm for deciding if a given finitely generated torsion-free nilpotent group is decomposable as the direct product of two non-trivial subgroups, and we show how to compute such a decomposition if it exists. Central to our decidability proof are new insights about the way that the decompositions of a finitely generated torsion-free nilpotent group are related to the decompositions of its rational closure. (Received July 16, 2016)

1121-20-147 **Charles Cunningham*** (ccunning@bowdoin.edu), Bowdoin College, Department of Mathematics, 8600 College Station, Brunswick, ME 04011. *The Geometry of Outer Automorphism Groups of Universal Right-angled Coxeter Groups.*

We investigate the combinatorial and geometric properties of automorphism groups of universal right-angled Coxeter groups. McCullough-Miller space is a polyhedral complex which is virtually a geometric model for the outer automorphism group of a universal right-angled Coxeter group, $\mathrm{Out}(W_n)$. As it is currently an open question as to whether or not $\mathrm{Out}(W_n)$ is CAT(0) or not, it would be helpful to know whether McCullough-Miller space can always be equipped with an $\mathrm{Out}(W_n)$-equivariant CAT(0) metric. We show that the answer is in the negative. This is particularly interesting as there are very few non-trivial examples of proving that a space of independent interest is not CAT(0). (Received July 17, 2016)

1121-20-156 **Tarik Aougab**, **Matthew G Durham*** (durhamma@umich.edu) and **Samuel Taylor**. *Characterizing subgroup stability in finitely generated groups.*

Stability for subgroups of finitely generated groups is a strong quasiconvexity condition which generalizes the Morse property, quasiconvexity in hyperbolic groups, and convex cocompactness in mapping class groups. We give a new characterization of stability which allows us to pull back stability under proper actions on proper metric spaces. This result has several applications to mapping class groups, outer automorphism groups of free groups, and relatively hyperbolic groups. (Received July 17, 2016)

1121-20-182 **Jonah Benjamin Gaster*** (gaster@bc.edu), **Joshua Evan Greene** and **Nicholas G Vlamis**. *Coloring curves on surfaces.*

The *curve graph* of a closed oriented surface of genus g has vertices given by simple closed curves, and edges that correspond to curves that can be realized disjointly. In the context of proving that the mapping class group has finite asymptotic dimension, Bestivina-Bromberg-Fujiwara exhibited a finite coloring of the curve graph, i.e. a map from the vertices to a finite set so that vertices of distance one have distinct images. In joint work with Josh Greene and Nicholas Vlamis we give more attention to the minimum number of colors needed. We show: The separating curve graph has chromatic number coarsely equal to $g\log(g)$, and the subgraph spanned by vertices in a fixed non-zero homology class is uniquely $g-1$-colorable. In the latter case, we use uniqueness to find an action of an element of the Torelli group on the color classes for each primitive homology class. This information can be assembled into a homomorphism of the Torelli group, which we identify with a precursor to the Johnson homomorphism. Time permitting, we discuss related questions, results, and conjectures. (Received July 18, 2016)

1121-20-190 **Christophe Hohlweg*** (hohlweg.christophe@uqam.ca), Montreal, Québec H3C3P8, Canada. *Garside Shadows and Automata in Coxeter groups.*

Garside shadows in a Coxeter system (W,S) appear in relation to the question of solving the conjugacy problem in the context of a general Artin-Tits Braid group. In this talk we will discuss properties and open problems about a family of finite state automata that recognize the language of finite reduced words for (W,S) and built out of finite Garside shadows. (based on a joint work with Philippe Nadeau and Nathan Williams) (Received July 18, 2016)

1121-20-197 **Andrew P. Sánchez*** (andrew.sanchez@tufts.edu). *Bubble Sets in the Heisenberg Group.*

In the continuous Heisenberg group, a Carnot–Carathéodory metric is determined by a choice of inner product on the horizontal space. We define the isoperimetric constant C_{iso} as the sup of $(Volume)^{3/4}/(Surface\,Area)$, and define the isoperimetric profile as the family of sets (up to scaling) that achieve C. We ask the question: for the Heisenberg group with a CC metric, what is the isoperimetric profile? In 1982, Pansu conjectured that if the L^2 norm is chosen, the isoperimetric profile is a bubble set – that is, the surface given by all lifts of closed geodesics through the origin. In this talk I will discuss the same question in polygonal norms such as L^1. (Received July 18, 2016)

1121-20-202 **Johanna Mangahas*** (mangahas@buffalo.edu). *After the Masur–Minsky machinery.* Preliminary report.

So much mathematics has been built on the work of Masur and Minsky on the action of mapping class groups on curve complexes. Besides revealing a great deal about mapping class groups, researchers have successfully made use of "curve complexes for" groups such as $\mathrm{Out}(F_n)$ or right-angled Artin groups. More recently, the rich interaction between curve complexes of subsurfaces—i.e., projection between curve complexes, and hierarchies—has been fit into more general axiomatic settings, by different teams for different applications. For this expository talk I will try to survey some of the new technology available, from the biased point of view of my own favorite questions. (Received July 18, 2016)

1121-20-203 **Johanna Mangahas*** (mangahas@buffalo.edu) and **Samuel J. Taylor**. *Contexts for convex cocompactness.*

I will introduce both the classical notion of convex cocompactness for Kleinian groups and its adaptation for subgroups of mapping class groups by Farb and Mosher. I will also talk about joint work with Sam Taylor relating mapping class group convex cocompactness to quasiconvexity within right-angled Artin groups. (Received July 18, 2016)

1121-20-207 **Melanie Stein*** (melanie.stein@trincoll.edu), **Jennifer Taback** and **Peter Wong**. *Automorphisms of higher rank lamplighter groups.*

The well-known lamplighter groups $L_q = \Gamma_2(q)$ have higher rank generalizations $\Gamma_d(q)$, which are known as Diestel-Leader groups. With respect to appropriate generating sets, these groups have Cayley graphs which are horocylic products of trees. We characterize $Aut(\Gamma_d(q))$, and apply our result to count the twisted conjugacy classes. (Received July 18, 2016)

1121-20-213 **Mike Cantrell*** (michaelaaroncantrell@gmail.com). *Quasi-isometric & Integrable Measure Equivalence Rigidity of Nilpotent Groups via Ergodic Theory.* Preliminary report.

In http://arxiv.org/abs/1509.08966 I gave an ergodic theoretic proof of Pansu's quasi-isometry rigidity theorem for nilpotent groups. Along the way, I proved an integrable measurable cocycle analog of Pansu's differentiation theorem for Lipschitz maps between Carnot spaces, answered a question of Tim Austin and give an independent proof and strengthening of Tim Austin's result that integrable measure equivalent groups have bi-Lipschitz asymptotic cones.

I will describe these results, and time (and research) permitting, I will discuss work in progress generalizing the QI rigidity to other naturally associated nilpotent Lie groups. (Received July 18, 2016)

1121-20-224 **Khalid Bou-Rabee*** (khalid.math@gmail.com), New York, NY 10023, and **W. Patrick Hooper**. *A geometric approach to the Bounded Burnside Problem.* Preliminary report.

The Bounded Burnside Problem asks when is a finitely generated group where every elements has order k finite? We give a new geometric approach to this problem where a mysterious nilpotent group appears in a crucial way. This covers joint work with Patrick Hooper. (Received July 18, 2016)

1121-20-237 **Moon Duchin*** (moon.duchin@tufts.edu). *Counting in groups: Fine asymptotic geometry.*

Starting with a group and a generating alphabet, we can ask the question: how many group elements can be "spelled" with n letters? The resulting function is called the growth function, and these have been a subject of intense interest since at least the 1960s. Regarded coarsely, the rate of growth gives a group invariant. But one can also ask "finer" questions, like whether the sequence of growth numbers satisfies a recursion. I'll develop some of the theory of growth functions and rationality, focusing on the example of the Heisenberg group. (Received July 19, 2016)

1121-20-244 **Alexei Miasnikov*** (amiasnik@stevens.edu), NJ. *Nilpotent groups: interplay between algebra, geometry, and number theory.*

In nilpotent groups algebra, geometry and number theory all play an important part and their methods here are curiously intertwined. I will try to illustrate this on some examples concerning solving equations and classification problems in nilpotent groups. (Received July 19, 2016)

1121-20-256 **Andy Eisenberg*** (andy.eisenberg@okstate.edu), **Charles Cunningham**, **Adam Piggott** and **Kim Ruane**. *Right-angled Coxeter Group Recognition and Decomposition.*

Right-angled Coxeter groups (RACGs) are a class of groups with many nice combinatorial, algorithmic, and geometric properties. In this talk, we'll discuss a recognition procedure, developed in joint work with Charlie Cunningham, Adam Piggott, and Kim Ruane, to determine whether a given group is a RACG. This procedure naturally exposes some semi-direct product decompositions which can be seen directly in the defining graphs of RACGs. (Received July 19, 2016)

1121-20-265 **Kim E Ruane*** (kim.ruane@tufts.edu), Tufts University Mathematics Department, 503 Boston Avenue, Medford, MA 02155, and **Chris Hruska**. *Splittings of CAT(0) Groups with Isolated Flats.*

In joint work with C. Hruska, we prove that if a one-ended G is a group acting geometrically on a CAT(0) space with Isolated Flats Property, then the well-defined boundary ∂G is locally connected if and only if G does not have a "geometric" splitting in the sense of Mihalik-Ruane-Tschantz. To prove this result, we must first recognize the boundary as a tree of spaces in the sense of Swiatkowski and then prove a general topology result which says that a tree of connected and locally connected compacta is again locally connected. (Received July 19, 2016)

22 ► Topological groups, Lie groups

1121-22-64 **Mboyo Esole**, **Steven Glenn Jackson**, **Ravi Jagadeesan** and **Alfred G Noel*** (alfred.noel@umb.edu), Department of Mathematics, 100 Morrissey Boulevard, Boston, MA 02125. *Hyperplane Arrangements Generated by Weights of Fundamental Representations of Lie Algebras.* Preliminary report.

We study the central hyperplane arrangements generated by the weights of the first and second fundamental representations of complex Lie algebras restricted to their dual Weyl chamber. The combinatorial structure of these arrangements can be interpreted in Physics as the enumeration of the phases of the Coulomb and mixed Coulomb-Higgs branches as described by the Intriligator-Morrison-Seiberg superpotential. (Received July 09, 2016)

1121-22-107 **Thomas Folz-Donahue** and **Steven Glenn Jackson*** (jackson@math.umb.edu), Department of Mathematics, Univeristy of Massachusetts, 100 Morrissey Boulevard, Boston, MA 02125, and **Todor Milev** and **Alfred G. Noel**. *Sign signatures and characters of Weyl groups.* Preliminary report.

Let W be a Weyl group, and let V be a representation of W. The *sign signature* of V is the set of all parabolic subgroups of W admitting a sign character on V. The sign signature is closely related to the *tau invariant* studied in the context of W-graphs and the Springer correspondence.

We discuss the parametrization of representations by sign signatures. When W is of classical type, irreducible representations are completely determined by their sign signatures, and we give a combinatorial recipe that recovers the partition or partition pair associated with a given representation from its sign signature. (Received July 14, 2016)

1121-22-215 **Tullia Dymarz**, **Michael Kelly**, **Sean Li** and **Anton Lukyanenko*** (lukyanen@umich.edu). *Separated nets in nilpotent groups.*

We generalize several results on separated nets in Euclidean space to separated nets in connected simply connected nilpotent Lie groups. We show that every such group G contains separated nets that are not biLipschitz equivalent. We define a class of separated nets in these groups arising from a generalization of the cut-and-project quasi-crystal construction and show that generically any such separated net is bounded displacement equivalent to a separated net of constant covolume. In addition, we use a generalization of the Laczkovich criterion to provide 'exotic' perturbations of such separated nets. (Received July 18, 2016)

28 ► Measure and integration

1121-28-128 **Guy C. David*** (guydavid@math.nyu.edu) and **Raanan Schul**. *The Analyst's Traveling Salesman Theorem in limits of metric graphs.*

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 July 15, 2016)

30 ► Functions of a complex variable

1121-30-23 **Vyron S. Vellis*** (vyron.vellis@gmail.com), 145-I Foster Drive, Willimantic, CT 06226. *Quasisymmetric and bi-Lipschitz extensions on Euclidean spaces.*

Let $E \subset \mathbb{R}^n$ and $f : E \to \mathbb{R}^n$ be a quasisymmetric (resp. bi-Lipschitz) map. When is it possible to extend f to a quasisymmetric (resp. bi-Lipschitz) self homeomorphism of $\mathbb{R}^n$? For $n = 1$ we give a complete answer while for $n = 2$ we generalize previous extension results of Beurling, Ahlfors and Tukia to uniform domains with relatively connected boundary. For $n \geq 3$ we show that any quasisymmetric (resp. bi-Lipschitz) map $f : E \to \mathbb{R}^n$ of a totally disconnected set $E \subset \mathbb{R}^n$ with bounded geometry can be extended to a quasisymmetric (resp. bi-Lipschitz) self homeomorphism of $\mathbb{R}^{n+1}$. (Received June 27, 2016)

1121-30-40 **Matthew Daniel Romney*** (romney2@illinois.edu). *Quasiconformal mappings on the Grushin plane.*

Recent research in geometric analysis studies the problem of deciding when a metric space can be parametrized by a well-known model space such as Euclidean space under a quasiconformal mapping. There are several competing definitions of quasiconformality between metric spaces or metric measure spaces, so it becomes an interesting problem to determine how these relate to each other in general metric space settings. We will investigate these questions for the case of the Grushin plane, a classical example of a sub-Riemannian manifold. We prove an appropriate equivalence of definitions of quasiconformality in the Grushin plane, and we discuss limitations of this equivalence. This is joint work with C. Gartland and D. Jung. (Received July 05, 2016)

1121-30-181 **Luca Capogna** and **Jeremy T Tyson*** (tyson@illinois.edu), 1409 West Green Street, Urbana, IL 61801. *Quasiconformal geometry of boundaries of hyperbolic spaces Part I.*

This is the first of a two part expository lecture series on quasiconformal mappings of boundaries of Gromov hyperbolic spaces, with particular emphasis on the boundaries of rank one symmetric spaces. In the first part we will introduce quasiconformal mappings in metric spaces, and in particular in Gromov hyperbolic spaces. We will then discuss how these objects play a role in the proof of Mostow's rigidity theorem in the general rank one symmetric setting and the study of quasiconformal mappings of sub-Riemannian manifolds. (Received July 18, 2016)

1121-30-183 **Alex D. Austin*** (aaustin@math.ucla.edu) and **Jeremy T. Tyson** (tyson@math.uiuc.edu). *A new proof of a Liouville-type theorem for the Heisenberg group.* Preliminary report.

Previous methods for establishing that a 1-quasiconformal mapping of a domain in the Heisenberg group, $\mathbb{H}$, is C^∞ smooth, and so the restriction of the action of an element of $SU(1,2)$, have relied on results in non-linear PDE (Capogna, 1997), or regularity results for a holomorphic extension of the mapping, treating $\mathbb{H}$ as the boundary of a strongly pseudoconvex domain in $\mathbb{C}^2$ (Korányi and Reimann 1985, Tang 1996).

We present a new proof that C^2 smooth 1-quasiconformal mappings are C^∞ smooth, drawing on elements of the theory of quasiconformal flows, as developed in $\mathbb{H}$ by Korányi and Reimann. We rely only on the linear PDE theory, specifically the hypoellipticity of the Folland-Stein operators. All computations take place in $\mathbb{H}$ itself, and are of an elementary nature. This approach was inspired by work, in the Euclidean setting, of Zhuomin Liu (2013), who in turn was generalizing a method of Sarvas (1979). (Received July 18, 2016)

1121-30-199 **Alex D. Austin*** (aaustin@math.ucla.edu). *The quasiconformal Jacobian problem and sub-Riemannian manifolds bi-Lipschitz equivalent to the Heisenberg group.*

The sub-Riemannian Heisenberg group, $(\mathbb{H}, g_0)$, is a Carnot group with a particularly rich family of quasiconformal mappings. As such, it is an ideal location for a first look at the quasiconformal Jacobian problem outside

the Euclidean setting. The theory of quasiconformal mappings on $\mathbb{H}$ is sufficiently well developed, that contributions to the quasiconformal Jacobian problem have relevance to determining the bi-Lipschitz equivalence class of $(\mathbb{H}, g_0)$. The main result of my thesis implies that if the total variation of the measure associated to a continuous logarithmic potential u is sufficiently small, then $(\mathbb{H}, g_0)$ and $(\mathbb{H}, e^u g_0)$ are bi-Lipschitz equivalent. In this talk I will focus on the passage from analysis to geometry, introducing the quasiconformal Jacobian problem, and giving a careful explanation of how my result has something to say about weighted sub-Riemannian metrics. (Received July 18, 2016)

31 ► Potential theory

1121-31-285 **Nicola Garofalo**, University of Padova , and **Jeremy T Tyson*** (tyson@illinois.edu), University of Illinois at Urbana Champaign, Urbana, IL. *Hiesz potentials and p-superharmonic functions in Carnot groups of Heisenberg type.*

I will discuss a superposition principle for Riesz potentials of nonegative continuous functions on Carnot groups of Heisenberg type. Specifically, the Riesz potential Ra(u) of a nonnegative continuous function u on a Heisenberg type Carnot group G is necessarily either p-subharmonic or p-su perharmonic, depending on p and a. The Riesz potentials in question are defined using Kaplan's homogeneous norm. This result extends to a wide class of step two nonabelian stratified Lie groups a remarkable superposition theorem of Crandall-Zhang and Lindqvist-Manfredi. This talk is based on an old paper of the author with Nicola Garofalo. (Received July 25, 2016)

32 ► Several complex variables and analytic spaces

1121-32-145 **Loredana Lanzani*** (llanzani@syr.edu), Mathematics Department, 215 Carnegie Bldg., Syracuse, NY 13244, and **Elias M. Stein**. *The Cauchy Integral in Several Complex Variables.*

I will give a survey of recent joint work with E.M. Stein concerning the study of Lebesgue-space regularity (or lack thereof) for the higher-dimensional analogue of the Cauchy integral, under minimal assumptions on the ambient domain's boundary regularity. Time permitting, I will discuss applications to the orthogonal projection operators onto the Hardy and Bergman spaces. (Received July 17, 2016)

34 ► Ordinary differential equations

1121-34-189 **Jordan D Rosenthal-Kay** (jordan.rosenthal_kay@tufts.edu), **Harjasleen Malvai*** (harjasleen_malvai@brown.edu), **Julia Bujalski** (bujalskij@emmanuel.edu) and **Grace Dwyer** (ged4gr@virginia.edu). *Continuous Time Opinion Formation on Directed Weighted Graphs.* Preliminary report.

Ideas that challenge the status quo either evaporate or dominate. The literature that mathematically studies the evolution of ideas treats space as uniform and considers individuals in an isolated community, using an ODE model. We extend these models to include multiple communities and their interaction by using a directed weighted graph. We study in detail some special cases, state general properties, and indicate pathways for further research. (Received July 18, 2016)

35 ► Partial differential equations

1121-35-5 **Phi L Le*** (phillevn@outlook.com) and **Steve Hofmann** (hofmanns@missouri.edu). *BMO solvability and absolute continuity of harmonic measure.*

We show that for a uniformly elliptic divergence form operator L, defined in an open set Ω with Ahlfors-David regular boundary, BMO-solvability implies scale invariant quantitative absolute continuity (the weak-A_∞ property) of elliptic-harmonic measure with respect to surface measure on $\partial\Omega$. We do not impose any connectivity hypothesis, qualitative or quantitative; in particular, we do not assume the Harnack Chain condition, even within individual connected components of Ω. In this generality, our results are new even for the Laplacian. Moreover, we obtain a converse, under the additional assumption that Ω satisfies an interior Corkscrew condition, in the special case that L is the Laplacian. (Received May 05, 2016)

1121-35-12 **Brian Seguin*** (bseguin@luc.edu), Department of Mathematics and Statistics, 1032 W. Sheridan Rd., Chicago, IL 60660. *Homogenization of locally periodic microstructures with anisotropy and residual stress.*

Many biological and engineering materials have nonperiodic microstructures for which classical periodic homogenization results do not apply. Certain nonperiodic microstructures may be approximated by locally periodic microstructures for which homogenization techniques are available. Motivated by the consideration that such materials are often anisotropic and can posses residual stresses, I will introduce a broad class of locally periodic microstructures and present the resulting effective macroscopic equations. The effective residual stress and effective elasticity tensor are determined by solving unit cell problems at each point in the domain. However, I will show that for a certain class of locally periodic microstructures, solving the unit cell problem at only one point in the domain completely determines the effective elasticity tensor. I will also outline how certain nonperiodic microstructures can be approximated by locally periodic ones. (Received June 16, 2016)

1121-35-28 **Timothy E Faver*** (tef36@drexel.edu), Timothy Faver, Department of Mathematics, Korman Center, Drexel University, Philadelphia, PA 19104, and **J. Douglas Wright**. *Periodic traveling waves in diatomic Fermi-Pasta-Ulam-Tsingou lattices.*

We construct periodic traveling waves for diatomic Fermi-Pasta-Ulam-Tsingou (FPUT) lattices consisting of two distinct masses and only one kind of spring. After diagonalizing certain operators in the traveling wave equations and exploiting symmetries in the problem, the resulting system becomes highly amenable to the technique of bifurcation from a simple eigenvalue due to Crandall, Rabinowitz, and Zeidler. However, subsequent analysis of the traveling wave problem requires rather precise estimates on the solutions that are uniform in wave speeds arbitrarily close to the speed of sound, and the bifurcation approach does not explicitly provide these estimates. Instead, inspired by the proofs of classical bifurcation, we convert our system to a fixed point problem and obtain both the solutions and the uniform estimates via a quantitative contraction mapping argument. This is joint work with J. Douglas Wright. (Received June 30, 2016)

1121-35-39 **Zhongwei Shen***, Department of Mathematics, University of Kentucky, Lexington, KY 40506. *Recent Progress in Almost-Periodic Homogenization.* Preliminary report.

In this talk I will discuss recent progress in homogenization of second-order elliptic equations and systems with rapidly oscillating coefficients. We assume that the coefficients are bounded measurable and almost-periodic in the sense of H. Weyl. The results to be presented include estimates of approximate correctors, sharp convergence rates, and uniform regularity estimates. (Received July 04, 2016)

1121-35-46 **Leonid Berlyand*** (lvb2@psu.edu), Mathematical Department, Penn State, University Park, PA 16802, **Mykhailo Potomkin** (mup20@ucs.psu.edu), Mathematical Department, Penn State, University Park, PA 16802, and **Volodymyr Rybalko** (vrybalko@ilt.kharkov.ua), Nauky ave. 47, Kharkiv, Ukraine. *Sharp interface limit and traveling waves in a phase field model of cell motility.*

We study a system of two PDEs arising in modeling of motility of eukaryotic cells on substrates. This system consists of the Allen-Cahn equation for the scalar phase field function coupled with a vectorial parabolic equation for the orientation of the actin filament network. The two key properties of this system are (i) presence of gradients in the coupling terms and (ii) mass (volume) preservation constraints. We pass to the sharp interface limit to derive the equation of the motion of the cell boundary, which is mean curvature motion modified by a novel nonlinear term. We establish the existence of two distinct regimes of the physical parameters. In the supercritical regime we established surprising features of the motion of the interface such as discontinuities of velocities, and hysteresis in the 1D model, and instability of the circular shape and rise of asymmetry in the 2D model. We also proved existence of traveling waves. Because of properties (i)-(ii), classical comparison principle techniques do not apply to this system. Furthermore, the system can not be written in a form of gradient flow, which is why Gamma-convergence techniques also can not be used. This is joint work with V. Rybalko and M. Potomkin. (Received July 05, 2016)

1121-35-102 **Oleksandr Misiats*** (om25@nyu.edu), 15 Washington pl, 4M, New York, NY 10003, and **Robert Kohn** and **Stefan Muller**. *Analysis of microstructures in martensite-austenite phase transitions using sharp variational bounds.*

We consider a variational problem of minimizing the sum of the surface and elastic energies of the order parameter u in a two-dimensional rectangular domain. This model, originally suggested by Kohn and Muller, comes from martensitic phase transitions, in which two distinct phases of the martensite correspond to $u_y(x,y) = 1$ and $u_y(x,y) = -1$. In particular, minimizers develop self-similar microstructures in the case when the boundary condition is not compatible with either of the phases. In my talk, I will describe several patterns of the behavior

of minimizers depending on the choice of boundary conditions, derive sharp global and local energy bounds, and discuss the applications to 2D and 3D elasticity models. (Received July 14, 2016)

1121-35-119 **Stan Alama*** (alama@mcmaster.ca), Department of Math & Stats, McMaster University, 1280 Main St West, Hamilton, ON L8S 4K1, Canada, **Lia Bronsard** (bronsard@mcmaster.ca), Dept of Math & Stat, McMaster University, 1280 Main St West, Hamilton, ON L8S 4K1, Canada, and **Ihsan A Topaloglu** (itopalog@math.mcmaster.ca), Dept of Math & Stat, McMaster University, 1280 Main St West, Hamilton, ON L8S 4K1, Canada. *Minimizers of an Energy Modeling Nanoparticle-Polymer Blends.*

We identify the Γ-limit of an energy related to nanoparticle/block copolymer models as the number of particles goes to infinity and as the size of the particles and the phase transition thickness of the polymer phases approach zero. The limiting energy consists of two terms: the perimeter of the interface separating the phases and a penalization term related to the density distribution of the infinitely many small nanoparticles; and, can be considered as a toy model where a penalization term affects the phase transition morphology. We prove that local minimizers of the limiting energy admit regular phase boundaries and derive necessary conditions of local minimality via the first and second variations of the limiting energy functional. Finally we discuss possible critical and minimizing patterns in two dimensions and how these patterns vary from global minimizers of the purely local isoperimetric problem. (Received July 14, 2016)

1121-35-121 **Yaniv Almog*** (almog@math.lsu.edu), Department of Mathematics, Lockett Hall, LSU, Baton Rouge, LA 70803. *The Clausius-Mossotti formula for dilute random media of perfectly conducting inclusions.*

We consider a large number of randomly dispersed spherical, identical, perfectly conducting inclusions (of infinite conductivity) in a bounded domain. The host medium's conductivity is finite and can be inhomogeneous. In the dilute limit, with some boundedness assumption on a large number (proportional to the global volume fraction raised to the power of $-1/2$) of marginal probability densities, we prove convergence in H^1 norm of the expectation of the solution of the steady state heat equation, to the solution of an effective medium problem, where the conductivity is given by the Clausius-Mossotti formula. Error estimates are provided as well. (Received July 15, 2016)

1121-35-126 **Zihui Zhao***, zhaozh@uw.edu. *Absolute continuity of harmonic measure and the solvability of elliptic equations.*

For a domain Ω, people have been interested in the relationship between the harmonic measure ω and the surface measure σ of the boundary. In particular, if $\omega \ll \sigma$, what can we say about the geometry of the domain and the solutions to elliptic equations in Ω; and vice versa? This talk will focus on the analytic side of the story. We consider a quantitative version of absolute continuity $\omega \in A_\infty(\sigma)$, and we show it is equivalent to the BMO-solvability of elliptic equations: for any continuous function $f \in BMO(\sigma)$, let u be the solution to $-div(A(x)\nabla u) = 0$ with boundary data f, then $|\nabla u|^2\delta(x)dx$ is a Carleson measure, with constant bounded by $\|f\|^2_{BMO}$. BMO-solvability is in fact the limit case of standard L^p-solvability. (Received July 15, 2016)

1121-35-142 **Elena Cherkaev*** (elena@math.utah.edu), University of Utah, Dept. Mathematics, 155 S. 1400 E., JWB 233, Salt Lake City, UT 84112. *Can One Hear the Structure of a Composite?*

Spectral representation of the effective properties of an anisotropic composite material results in a Stieltjes function with a matrix valued measure. This spectral measure in the Stieltjes integral representation contains all information about the microstructure of the composite and can be uniquely recovered from effective measurements known in an interval of frequency. We discuss applications to forward and inverse homogenization, in particular, we show that matrix Pade approximants provide an efficient way to construct spectrally closely matched microstructures. (Received July 19, 2016)

1121-35-151 **Irina Mitrea*** (imitrea@temple.edu), 1805 N Broad Street, 638 Wachman Hall, Department of Mathematics, Temple University, Philadelphia, PA 19122. *Harmonic Analysis and Complex Variables Techniques in Scattering Theory.*

This talk serves as an illustration of the principle that combining techniques originating in Complex Variables, Geometric Measure Theory, and Harmonic Analysis creates a potent mix. The focus is on Scattering Theory for null-solutions of perturbed Dirac operators in exterior Ahlfors-David regular domains, treated via methods and tools of Complex Variables flavor such as higher dimensional versions of the Cauchy's operator, Hardy spaces, Fatou theorems, unique continuation property, etc. (Received July 17, 2016)

1121-35-153 **Efstathios Georgios Charalampidis*** (charalamp@math.umass.edu), Department of Mathematics and Statistics, Lederle Graduate Research Tower, 710 N. Pleasant Street, Amherst, MA 01003-9305, and **Panayotis G. Kevrekidis**, **Boris Malomed** and **Dimitri J. Frantzeskakis**. *Multi-component nonlinear waves in one and two dimensional coupled nonlinear Schrödinger (NLS) systems: Theory and Numerical Computations.*

In this talk, we will present a two-component NLS system in one and two spatial dimensions with equal, repulsive cubic interactions and different dispersion coefficients in the two components. We will consider states that support a dark solitary wave (or, its 2D sibling called a vortex) in the one-component, and explore the possibility of the formation of bright solitonic bound states in the second component. Bifurcation points are identified by studying the underlying linear limit and nonlinear states can be formed by performing parametric continuation over the system's parameters. Then, regimes of potential stability (or instability) of the reported states will be identified by means of the Bogoliubov-de Gennes analysis. Furthermore, and for unstable states, we will demonstrate results on direct numerical simulations and discuss the dynamics of the instability. Finally, we will present future directions which are currently in progress including the application of a deflated continuation approach for the numerical computation of nonlinear states if time permits.

This is joint work with Panayotis G. Kevrekidis, Boris A. Malomed, Dimitri J. Frantzeskakis and Patrick Farrell. (Received July 17, 2016)

1121-35-158 **Peter V Gordon*** (pgordon@uakron.edu), Department of Mathematics, The University of Akron, Akron, OH 44325. *Gelfand type problem for co-flow jets.*

In this talk I will discuss a model for autoignition of laminar co-flow jets. Such jets consist of two parts: an inner part with oxidizer that is surrounded by an outer part with fuel or reverse. The derivation of the model is based on combination of Burke-Schumann theory of diffusion flames and Semenov-Frank-Kamenerskii theory of thermal explosion. The main advantage of this model is that it gives a sharp characterization for autoignition of a jet as blow up of solution of underlying PDE. This model falls into a general class of Gelfand type problems which were studied in mathematical literature since early 1960's. I will also discuss analysis of the model that reveals dependency of the autoignition position on principal physical and geometric parameters involved. Moreover, explicit expressions for autoignition position in asymptotic regimes relevant to applications will be given. This a joint work with U.G. Hegde, M.C. Hicks and M.J. Kulis of NASA Glenn Research Center. (Received July 17, 2016)

1121-35-164 **Murat Akman*** (murat.akman@icmat.es), Calle de Nicolas Cabrera, No:13-15, Campus de Cantoblanco, UAM, 28049 Madrid, Spain. *Rectifiability, interior approximation, and absolute continuity of Harmonic measure.*

In this talk, we study the rectifiability of a closed set $E \subset \mathbb{R}^{n+1}$ having locally finite $n-$dimensional Hausdroff measure H^n and satisfying a condition weaker than the lower Ahlfors-David regularity. We show that almost all of E can be covered by a countable union of boundaries of bounded Lipschitz domains contained in the complement of E. By considering $\Omega = \mathbb{R}^{n+1} \setminus E$ and additionally assuming that Ω is connected domain and satisfies an infinitesimal interior thickness condition then we prove that $H^n|_{\partial\Omega}$ is absolutely continuous with respect to harmonic measure for Ω. We also state some local results concerning the decomposition of the boundary into rectifiable and purely unrectifiable parts.

This is a joint work with S. Bortz, S. Hofmann, and J. M. Martell. (Received July 18, 2016)

1121-35-175 **Thomas Bellsky*** (thomas.bellsky@maine.edu), 326 Neville Hall, University of Maine, Orono, ME 04469. *Examining ecological stability by reaction-diffusion equations.*

This talk will discuss modeling the stability of localized vegetation in a semi-arid desert ecosystem with pulse solutions to a coupled reaction-diffusion system. Specifically, we examine the interaction of pulses for a particular family of fast-slow, weakly-damped reaction-diffusion systems. Utilizing a renormalization group methodology, we rigorously derive laws of motion for multi-pulses. Our main result rigorously demonstrates the stability of the manifold of pulse solutions. (Received July 18, 2016)

1121-35-179 **Max D. Engelstein***, Department of Mathematics, MIT, 77 Massachusetts Ave, Cambridge, MA 02139. *The Geometry of Parabolic NTA Domains.*

Introduced by Jerison and Kenig in the 1980s, non-tangentially accessible (NTA) domains are a natural setting in which to study the boundary behavior of harmonic functions. In the 1990s, Lewis and Murray defined parabolic NTA domains in order to consider similar questions for the heat equation. In this talk, we classify all parabolic NTA domains in $\mathbb{R}^2$ and explain some of the consequences of this classification to parabolic potential theory and free boundary problems. (Received July 18, 2016)

1121-35-184 **Luca Capogna*** (lcapogna@wpi.edu), Department of Mathematical Sciences, Worcester Polytechnic Institute, Worcester, MA 01609. *A Liouville theorem for quasiconformal mappings in sub-Riemannian manifolds.*

In a joint work with Enrico Le Donne (Jyvaskyla) and Alessandro Ottazzi (UNSW), we prove that every 1−quasiconformal map between domains in a sub-Riemannian contact manifold is a conformal diffeomorphism. More in general, we show that this result holds in every equiregular subRiemannian manifold that admits a regularity theorem for the subelliptic $p-$laplacian operator. The proofs involve ideas and techniques from analysis in metric space, differential geometry and PDE. Our work extends to the subRiemannian setting previous results of Gehring and Reshetnyak in Euclidean spaces, and Ferrand in the Riemannian setting. (Received July 18, 2016)

1121-35-208 **Drew Swartz** and **Aaron Nung Kwan Yip*** (yip@math.purdue.edu), Dept. Math., Purdue University, 150 N. University Street, West Lafayette, IN 47907. *Dynamics of a second order gradient model for phase transitions.*

We prove in a radially symmetric geometry, the convergence in the sharp interfacial limit, to motion by mean curvature of a second order gradient model for phase transition. This is in spirit similar to the classical Allen-Cahn theory of phase boundary motion. However the corresponding dynamical equation is fourth order thus creating some challenging difficulties for its analysis. A characterization and stability analysis of the optimal profile are performed which are in turn used in the proof of convergence of an asymptotic expansion. (Received July 18, 2016)

1121-35-219 **Guozhen Lu*** (gzlu@wayne.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269. *Concentration-compactness on the Heisenberg group and Riemannian manifolds.*

We will report works on Lions type concentration-compactness principle on the Heisenberg group and Riemannian manifolds where symmetrization argument does not work. We adapt an argument of level sets for functions under consideration to avoid the symmetrization argument used in the Euclidean setting to establish such a concentration-compactness principle there. We then apply the concentration-compactness principle to establish the existence of solutions to certain classes of quasilinear PDEs. These are joint works with Jungang Li and Maochun Zhu. (Received July 18, 2016)

1121-35-222 **Tao Huang**, NYU-ECNU Institute of Mathematical Sciences a, Shanghai, Peoples Rep of China, and **Changyou Wang***, Department of Mathematics, Purdue University, West Lafayette, IN 47907. *Boundary bubbling analysis of approximate harmonic maps under either weak or strong anchoring conditions in dimension two.* Preliminary report.

We will discuss the bubbling phenomena of approximate harmonic maps in dimension two that have either (i) bounded L^2-tension fields under the weak anchoring condition, or (ii) bounded $L\log L\cap M^{1,\delta}$-tension fields under the strong anchoring condition. (Received July 18, 2016)

1121-35-245 **Guanying Peng*** (penggg@ucmail.uc.edu), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221-0025. *Gamma-convergence for an anisotropic superconductivity model with magnetic fields.* Preliminary report.

We analyze minimizers of the Lawrence-Doniach energy for layered superconductors occupying a bounded generalized cylinder, $\Omega\times(0,L)$, in $\mathbb{R}^3$, where Ω is a bounded simply connected smooth domain in $\mathbb{R}^2$. For an applied magnetic field $\vec{H}_{ex}=h_{ex}\vec{e}_3$ that is perpendicular to the layers with $h_{ex}\sim|\ln\epsilon|$ as $\epsilon\to 0$, where ϵ is the reciprocal of the Ginzburg-Landau parameter, we prove compactness results for various physical quantities of energy minimizers, and derive a Gamma-limit of the Lawrence-Doniach energy as ϵ and the interlayer distance tend to zero, under the additional assumption that the layers are weakly coupled. (Received July 19, 2016)

1121-35-249 **Patrick Cummings*** (patrickc@bu.edu) and **C. E. Wayne**. *Modified Energy Functionals and the NLS Approximation.*

We consider a model equation that captures important properties of the water wave equation. We discuss a new proof of the fact that wave packet solutions of this equation are approximated by the nonlinear Schrödinger equation. This proof both simplifies and strengthens previous results of Wayne and Schneider so that the approximation holds for the full interval of existence of the approximate NLS solution rather than just a subinterval. Furthermore, the proof avoids the problems associated with inverting the normal form transform by working with a modified energy functional motivated by Craig and Hunter et. al. (Received July 19, 2016)

1121-35-277 **Lia Bronsard*** (bronsard@mcmaster.ca), 1280 Main St W, McMaster Univ, Dept of Math and stats, Hamilton, ON L8S 4K1, Canada, **Stan Alama** (alama@mcmaster.ca), 1280 Main St W, Hamilton, ON L8S 4K1, Canada, and **Xavier Lamy**. *Minimizers of the Landau-de Gennes energy around a spherical colloid particle.*

We consider energy minimizing configurations of a nematic liquid crystal around a spherical colloid particle, in the context of the Landau-de Gennes model. The nematic is assumed to occupy the exterior of a ball, and satisfy homeotropic weak anchoring at the surface of the colloid and approach a uniform uniaxial state far from the colloid. We study the minimizers in two different limiting regimes: for balls which are small compared to the characteristic length scale, and for large balls. The relationship between the radius and the anchoring strength is also relevant. For small balls we obtain a limiting quadrupolar configuration, with a "Saturn ring" defect for relatively strong anchoring, corresponding to an exchange of eigenvalues of the Q-tensor. In the limit of very large balls we obtain an axisymmetric minimizer of the Oseen—Frank energy, and a dipole configuration with exactly one point defect is obtained. This is joint work with Stan Alama and Xavier Lamy. (Received July 19, 2016)

1121-35-283 **Dmitry Golovaty*** (dmitry@uakron.edu), Department of Mathematics, The University of Akron, Akron, OH 44325-4002. *Euler elastica as a Γ-limit of discrete bending energies of one-dimensional chains of atoms.*

I will discuss a one-dimensional atomistic model that describes the cross-section of a graphene sheet as a collection of rigid links connected by torsional springs. I will use a Γ-convergence argument to rigorously justify an upscaling procedure for the discrete bending energy of the atomistic model. The argument establishes that as the bond length in the atomistic model goes to 0, the bending energies Γ-converge to Euler's elastica. This is a joint work with Malena Espanol and Pat Wilber. (Received July 20, 2016)

37 ► Dynamical systems and ergodic theory

1121-37-18 **Kelly McQuighan*** (kmcquigh@bu.edu) and **Gene Wayne**. *Towards metastability in the Burgers equation with periodic boundary conditions.*

Roughly speaking, metastable solutions are capture transient behavior which persists for long times. Recent work on Burgers equation on the real line and on Navier-Stokes equation with periodic boundary conditions have provided some insight into various mechanisms for metastability. In this talk we discuss a candidate metastable solution for the viscous Burgers equation with periodic boundary conditions. We construct the "frozen-time" spectrum for this solution using ideas from singular perturbation and Melnikov theory. Finally, we indicate future directions in which this spectrum can be used to understand metastability for the full PDE. (Received June 22, 2016)

1121-37-37 **M. R. S. Kulenovic***, Department of Mathematics, University of Rhode Island, Kingston, RI 02881. *Global stability of a quadratic anti-competitive system of rational difference equations in the plane with Allee effects.*

We investigate global dynamics of the following systems of difference equations

$$\begin{cases} x_{n+1} &= \frac{y_n^2}{a+x_n^2} \\ y_{n+1} &= \frac{x_n^2}{b+y_n^2} \end{cases}, \quad n=0,1,2,\dots$$

where the parameters a, b are positive numbers and initial conditions x_0 and y_0 are arbitrary nonnegative numbers. We find all possible dynamical scenario for this system. (Received July 03, 2016)

1121-37-62 **Arzu Bilgin** and **Ann Brett***, ann.brett@jwu.edu, and **Mustafa Kulenovic** and **Esmir Pilav**. *Global Dynamics of Cooperative Discrete System in the Plane.*

We consider the cooperative system

$$x_{n+1} = a\,x_n + \frac{b\,y_n^2}{1+y_n^2} \quad y_{n+1} = \frac{c\,x_n^2}{1+x_n^2} + d\,y_n, \quad n=0,1,\dots,$$

where all parameters a, b, c, d are positive numbers and the initial conditions x_0, y_0 are non-negative numbers. We describe the global dynamics of this system in a number of cases. An interesting feature of this system is that it exhibits a coexistence of locally stable interior equilibrium and a locally stable positive periodic solution,

as well as the Allee effect. This system has potential in modeling since all transition functions are either linear or sigmoid Beverton Holt functions. (Received July 09, 2016)

1121-37-198 **Quang-Nhat Le*** (qnhatle@math.brown.edu), 8 Stimson Ave, Providence, RI 02906. *A family of autonomous discrete dynamical systems in projective geometry.*

Polygon iterations provide an abundance of interesting autonomous dynamical systems in geometry, especially in Euclidean and affine geometries. Recently, the advance of computers has allowed the study of polygon iterations in projective geometry, which was previously limited by the high computational complexity of the associated rational maps, to take off. Notable examples are the pentagram map and the projective midpoint map, both first studied by Richard Schwartz as potential analogues of the classical midpoint map.

In this talk, we will discuss recent work on a one-parameter family of projectively natural polygon iterations that includes both the pentagram map and the projective midpoint map. They can be regarded as autonomous discrete dynamical systems on the non-compact space of polygons, modulo projective transformations. Except for 2 parameters, corresponding to the pentagram map and its inverse, these polygon iterations are observed to possess a single globally attracting fixed point, which allows us to define their Julia sets. Coincidentally, when observing the varying Julia sets, we discovered that this family contains two projective analogues of Varignon's theorem for quadrilaterals. (Received July 18, 2016)

1121-37-262 **Aminur Rahman*** (ar276@njit.edu), Culimore Hall, University Avenue, Department of Mathematical Sciences, Newark, NJ 07103. *Neimark-Sacker bifurcations and evidence of chaos in a discrete dynamical model of walkers.*

Bouncing droplets on a vibrating fluid bath can exhibit wave-particle behavior, such as being propelled by interacting with its own wave field. These droplets seem to walk across the bath, and thus are dubbed walkers. Experiments have shown that walkers can exhibit exotic dynamical behavior indicative of chaos. While the integro-differential models developed for these systems agree well with the experiments, they are difficult to analyze mathematically. In recent years, simpler discrete dynamical models have been derived and studied numerically. The numerical simulations of these models show evidence of exotic dynamics such as period doubling bifurcations, Neimark–Sacker (N–S) bifurcations, and even chaos. For example, in [Gilet, PRE 2014], based on simulations Gilet conjectured the existence of a supercritical N-S bifurcation as the damping factor in his one-dimensional path model. We prove Gilet's conjecture and more; in fact, both supercritical and subcritical (N-S) bifurcations are produced by separately varying the damping factor and wave-particle coupling for all eigenmode shapes. Then we compare our theoretical results with some previous and new numerical simulations, and find complete qualitative agreement. (Received July 19, 2016)

39 ► Difference and functional equations

1121-39-25 **Arzu Bilgin*** (bilgin_a@my.uri.edu), 11 Robert Ford Road, Watertown, MA 02472, **Mustafa Kulenovic**, Department of Mathematics, Kingston, RI 02881, and **Esmir Pilav**. *Basins of Attraction of Period-Two Solutions of Monotone Difference Equations.*

We investigate the global character of the difference equation of the form

$$x_{n+1} = f(x_n, x_{n-1}), \quad n = 0, 1, \ldots$$

with several period-two solutions, where f is increasing in all its variables. We show that the boundaries of the basins of attractions of different locally asymptotically stable equilibrium solutions or period-two solutions are in fact the global stable manifolds of neighboring saddle or non-hyperbolic equilibrium solutions or period-two solutions. An application of our results give global dynamics of three feasible models in population dynamics which includes the nonlinearity of Beverton-Holt and sigmoid Beverton-Holt types. (Received June 29, 2016)

1121-39-48 **Erin Denette*** (edenette@uri.edu), University of Rhode Island, Kingston, RI 02881, and **Mustafa Kulenovic** and **Esmir Pilav**. *KAM Theory and Other Results Applied to a Certain System of Difference Equations.*

This talk will explore the dynamics of a particular system of difference equations by using KAM (Kolmogorov-Arnold-Moser) theory, time reversal symmetries, and Morse's Lemma. (Received July 06, 2016)

1121-39-54 **Toufik Khyat*** (toufik17@uri.edu), kingston, RI 02881. *The Naimark-Sacker bifurcation for certain perturbation of the Beverton-Holt equation.*

We present the bifurcation analysis of difference equation

$$x_{n+1} = \frac{x_n}{cx_{n-1}^2 + dx_n + f}, \quad n = 0, 1, \ldots,$$

where $c, d, f > 0$ and the initial conditions $x_{-1}, x_0 \geq 0$ are such that the denominator of this equation is always positive. This equation can be considered as a nonlinear perturbation of the classical Beverton-Holt equation

$$x_{n+1} = \frac{x_n}{dx_n + f}, \quad n = 0, 1, \ldots,$$

which exhibits simple behavior and convergence to one of two equilibrium points and exchange of stability bifurcation. The introduction of quadratic term x_{n-1}^2 changes its behavior and leads to the Naimark-Sacker bifurcation and existence of periodic solution which is a local attractor, which will be described in this talk. The asymptotic formula for periodic solution will be obtained. (Received July 07, 2016)

1121-39-87 **Elliott J. Bertrand*** (ebertrand@uri.edu), Department of Mathematics, University of Rhode Island, 5 Lippitt Road, Kingston, RI 02881, and **Mustafa R.S. Kulenovic** (mkulenovic@uri.edu), Department of Mathematics, University of Rhode Island, 5 Lippitt Road, Kingston, RI 02881. *Generalized Beverton-Holt Difference Equations.* Preliminary report.

We investigate second-order generalized Beverton-Holt difference equations of the form

$$x_{n+1} = \frac{af(x_n, x_{n-1})}{1 + f(x_n, x_{n-1})}, \quad n = 0, 1, \ldots,$$

where f is a function nondecreasing in both arguments, the parameter a is a positive constant, and the initial conditions x_{-1} and x_0 are arbitrary nonnegative numbers. We will discuss several interesting examples of such equations and present some general theory. In particular, we will analyze the global dynamics of the class of difference equations for which f is chosen to be a concave function. (Received July 12, 2016)

1121-39-129 **Emmanouil Drymonis*** (edrymoni@providence.edu), Department of Mathematics and Computer Sc., Providence College, Providence, RI 02918. *Eventual Monotonicity in Nonlinear Difference Equations.* Preliminary report.

We investigate the global character of solutions of a second-order rational difference equation. We present some new results together with some known techniques which establish the eventually monotonic character of solutions for a class of nonlinear difference equations in a certain range of their parameters. Open problems and conjectures are provided for further investigations. (Received July 16, 2016)

1121-39-217 **David Timothy McArdle***, 5 Lippitt Road, Kingston, RI 02881. *Results on the Dynamics of a Class of Discrete Time Structured Population Models.* Preliminary report.

We consider the following difference equation:

$$x_{n+1} = Ax_n + f_1(c_1^T x_n)b_1 + f_2(c_2^T x_n)b_2$$

where A is an $n \times n$ matrix with spectral radius less than unity, b_1, b_2, c_1 and c_2 are positive vectors in $\mathbb{R}^n$ and $f_1, f_2 : [0, \infty) \to [0, \infty)$ with $f_1(0) = f_2(0) = 0$. This difference equation is based on one studied by R. Rebarber and coworkers. We establish sufficient conditions for the existence of a unique interior fixed point in $\mathbb{R}_+^n$ and for the local stability of the origin. (Received July 18, 2016)

1121-39-238 **Daniel Hadley*** (dhadley@uri.edu), Department of Mathematics, University of Rhode Island, kingston, RI 02881. *Local and Global Dynamics of Difference Equation*

$$x_{n+1} = \frac{x_{n-1}}{ax_n^2 + cx_{n-1}^2 + x_{n-1}}, \quad n = 0, 1, \ldots$$

. Preliminary report.

We present the local and global dynamics of difference equation

$$x_{n+1} = \frac{x_{n-1}}{ax_n^2 + cx_{n-1}^2 + x_{n-1}}, \quad n = 0, 1, \ldots,$$

where all coefficients and the initial conditions are non-negative and such that the denominator is always positive. This difference equation exhibits the period doubling bifurcation. (Received July 19, 2016)

41 ► Approximations and expansions

1121-41-8 **Vira Babenko*** (vera.babenko@gmail.com), **Vladyslav Babenko** and **Mariya Polischuk**. *On the optimal recovery of integrals of set-valued functions.*

We explore the problem of optimization of the approximate integration of set-valued functions from the class defined by a given majorant of their moduli of continuity. Given information is values of these functions at n fixed or free points of their domain. We consider the cases of exact information and information with error. Obtained results can be generalized to functions with values in L-spaces. (Received June 12, 2016)

1121-41-140 **Liangliang Zhang*** (mathinheart@gmail.com), 533 Cambridge Street, Unit 110, Allston, MA 02134, and **Jerome Detemple**, **Matthew Lorig**, **Marcel Rindisbacher** and **Stephan Sturm**. *An Analytical Expansion Method for Forward-Backward Stochastic Differential Equations.*

An expansion method to approximate non-linear uncoupled forward-backward stochastic differential equations (FBSDEs) is developed. Convergence of the method is shown. A numerical example illustrates the approximation in an option pricing model with stochastic volatility. (Received July 16, 2016)

42 ► Fourier analysis

1121-42-34 **James Michael Wilson*** (jmwilson@uvm.edu), Department of Mathematics, University of Vermont, 16 Colchester Avenue, Burlington, VT 05405. *Bounded variation and almost-orthogonality.*

We prove a theorem which implies the following: Let $N \geq 2$ be arbitrary. Suppose that, for every dyadic cube Q in $\mathbf{R}^d$, we have N convex subsets $\{R_i(Q)\}_1^N$ of Q, and N complex numbers $\{c_i(Q)\}_1^N$, such that $|c_i(Q)\,| \leq 1$ and $\sum_1^N c_i(Q)|R_i(Q)| = 0$. Define $\tilde{h}_{(Q)}(x) \equiv |Q|^{-1/2}(\sum_1^N c_i(Q)\chi_{R_i(Q)}(x))$. Then, for all finite linear combinations $\sum \lambda_Q \tilde{h}_{(Q)}$,

$$\left(\int_{\mathbf{R}^d} \left|\sum \lambda_Q \tilde{h}_{(Q)}(x)\right|^2 dx\right)^{1/2} \leq (2+\sqrt{2})Nd\left(\sum |\lambda_Q|^2\right)^{1/2}.$$

We use our theorem to show stability of almost-orthogonal expansions of certain linear operators and stability of Lipschitz-smooth wavelet systems when they are "discretized". (Received July 05, 2016)

43 ► Abstract harmonic analysis

1121-43-27 **Theresa C Anderson*** (tcanderson@math.wisc.edu), Madison, WI 53706, and **David E Weirich**. *Why Gehring's inequality fails in Spaces of Homogeneous Type.*

Recently, Andrei Lerner discovered a franework for singular integrals that I and Armen Vagharshakyan extended to spaces of homogeneous type. This led to wide range of applications such as the A_2 theorem. However, a much more classical inequality fails in these spaces that seems to have been undiscovered until very recently. We'll discuss the failure of Gahring's inequality and the consequences. (Received June 30, 2016)

44 ► Integral transforms, operational calculus

1121-44-177 **Benjamin Jaye*** (bjaye@kent.edu), Mathematical Sciences Building, Kent State University, Kent, OH 44240. *Non-oscillatory conditions which govern the boundedness of Calderón-Zygmund operators.*

We shall describe forthcoming joint work with Fedor Nazarov and Xavier Tolsa which gives a necessary and sufficient conditions on a measure μ in $\mathbb{R}^d$ for the boundedness of all s-dimensional Calderón-Zygmund operators ($s \in (0,d)$) in $L^2(\mu)$ in terms of energy conditions involving modifications of Wolff potentials. The results generalize work by David and Semmes, and Mattila and Preiss, concerning the behaviour of various classes of singular integral operators on Ahlfors-David regular sets. (Received July 18, 2016)

45 ► Integral equations

1121-45-49 **Katharine Ott*** (kott@bates.edu), **Russell Brown** and **Peter Perry**. *Action of a scattering map.*

We consider a scattering map that arises in the $\overline{\partial}$ approach to the scattering theory for the Davey-Stewartson II equation and show that the map is an invertible map between certain weighted L^2 Sobolev spaces. (Received July 06, 2016)

46 ► Functional analysis

1121-46-116 **Zead Mustafa*** (zead@qu.edu.qa), Dept. of Mathematics, Statistics and Physics, Doha - Qatar, 2713, Qatar, and **Mohammed Jaradat**, **Arslan Ansari**, **Branislav Popović** and **Husein Jaradat**. *C-class functions with new approach on coincidence point results for generalized (ψ, φ)-weakly contractions in ordered b-metric spaces.*

In this paper, by using the C-class functions and a new approach we present some coincidence point results for four mappings satisfying generalized (ψ, ϕ)-weakly contractive condition in the setting of ordered b-metric spaces. Also, an application and example are given to support our results. (Received July 14, 2016)

1121-46-155 **Mehrdad Kalantar*** (kalantar@math.uh.edu). *Open quantum subgroups of locally compact quantum groups.*

We introduce the notion of an open quantum subgroup of a locally compact quantum group and give several equivalent characterizations in terms of group-like projections, inclusions of quantum group C*-algebras and properties of respective quantum homogenous spaces. Similarly to the classical case, open quantum subgroups turn out to be closed, but in contrast to the classical case this fact is rather non-trivial. This is joint work with Pawel Kasprzak and Adam Skalski. (Received July 17, 2016)

1121-46-251 **Michael P Brannan*** (mbrannan@math.tamu.edu) and **Benoit Collins**. *Quantum channels from quantum group invariants.*

Quantum channels are trace-preserving completely positive maps between matrix algebras, and these objects are of central importance in quantum information theory. Thanks to Stinespring's Dilation Theorem, the structure of a given quantum channel is encoded in a certain subspace of a tensor product of two finite dimensional Hilbert spaces. Thus, to construct "interesting" quantum channels, one has to find "interesting" subspaces of tensor product Hilbert spaces. In practice, one relevant property of the subspace is that it is highly entangled, in the sense that the subspace is very far from the cone of decomposable tensors in the tensor product. In this talk I will describe a class of highly entangled subspaces arising from the invariant theory of free orthogonal quantum groups. It turns out that the rich structure of the quantum group invariants we are considering allows us to gain a good understanding of the corresponding quantum channels (such as minimum output entropy estimates and the outputs of tensor products of these channels). This is based on joint work with Benoit Collins. (Received July 19, 2016)

47 ► Operator theory

1121-47-108 **Philip M Gipson*** (philip.gipson@cortland.edu), Dept. of Mathematics, SUNY Cortland, Cortland, NY 13045. *On Equivalence for Representations of Toeplitz Algebras.*

A Toeplitz algebra is a self-adjoint operator algebra which is universal for being generated by a finite family of isometric operators. These algebras and their representations into $\mathcal{B}(\mathcal{H})$, the algebra of bounded ajointable operators on Hilbert space, are surprisingly pervasive throughout the theory of operator algebras. In this talk we present two new notions of equivalence for representations of a Toeplitz algebra, free- and quasifree-equivalence, which take their inspiration from the theory of Hilbert modules. We will conclude with two new theorems which use our equivalences to generalize known results in the theory of endomorphisms of operator algebras. (Received July 14, 2016)

1121-47-174 **Fumio Hiroshima** (hiroshima@math.kyushu-u.ac.jp), 744 Motooka, Nishiku, Fukuoka, Japan, and **Susumu Osawa*** (osawa@math.sci.hokudai.ac.jp), Nishi 8cyoume, kitaku, Sapporo, 0600810. *Mass Renormalization in the Nelson Model.*

The asymptotic behavior of the effective mass $m_{\rm eff}(\Lambda)$ of the so-called Nelson model in quantum field theory is considered, where Λ is a ultraviolet cutoff parameter of the model. Let m be the bare mass of the model. It is shown that for sufficiently small coupling constant $|\alpha|$ of the model, $m_{\rm eff}(\Lambda)/m$ can be expanded as $m_{\rm eff}/m = 1+\sum_{n=1}^{\infty} a_n(\Lambda)\alpha^{2n}$. A physical folklore is that $a_n(\Lambda) \sim [\log \Lambda]^{(n-1)}$ as $\Lambda \to \infty$. We then succeeded in rigorously showing that

$$0 < \lim_{\Lambda\to\infty} a_1(\Lambda) < C, \quad C_1 \leq \lim_{\Lambda\to\infty} a_2(\Lambda)/\log\Lambda \leq C_2$$

with some constants C, C_1 and C_2. (Received July 18, 2016)

49 ► Calculus of variations and optimal control; optimization

1121-49-149 **Tiziana Giorgi*** (tgiorgi@nmsu.edu), **Carlos J. García-Cervera** and **Sookyung Joo**.
Analysis of a Landau-de Gennes model for the $B_{1RevTilted}$ phase of bent-core liquid crystals.
The $B_{1\mathrm{RevTilted}}$ is a columnar phase of bent-core molecule liquid crystals, in which it is possible to reorient the spontaneous polarization by applying an electric field. The reorientation can be achieved by either a rotation around the smectic cone or the molecular axis, or a combination of both. In our work, we derive the closed form of the Γ-limit, in the large column regime, of a simple energy functional used in the physics literature to model experimental results of this switching mechanism. (Received July 17, 2016)

1121-49-232 **Andrew Lorent*** (alorent@gmail.com), University of Cincinnati, 2815 Commons Way, 4199 French Hall West, Cincinnati, OH 45220. *An absolute three well Liouville theorem.*
We will discuss the rigidity results for differential inclusions into sets of matrices of the form $SO(n)A_1 \cup SO(n)A_2...SO(n)A_n$. For the case when $n = 1$ an optimal quantitative Liouville theorem was established by Friesecke-Muller-James. This by now classic result has had an enormous impact on Calculus of Variations. For $n = 2$ under the (necessary) assumption that the total oscillation of the gradient was bounded by a small fixed constant (depending on A_1, A_2) an optimal quantitative two well Liouville theorem was established by Jerrard and Lorent in 2008, followings partial results by Lorent 2005, Conti-Schweizer 2006, Chermisi-Conti 2008. Simple examples show there is no Liouville theorem of any kind when $n = 4$, which leaves open the question of $n = 3$. All methods for $n = 2$ fail for general matrices when $n = 3$. We will sketch the history of this subject and will present an absolute three well Liouville theorem for $n = 3$ where A_1, A_2, A_3 are diagonal matrices. (Received July 18, 2016)

1121-49-246 **Weijie Pang*** (wpang@wpi.edu), **Zachary Feinstein** (zfeinstein@wustl.edu), **Birgit Rudloff** (brudloff@wu.ac.at), **Eric Schaanning** (eschaanning@gmail.com), **Stephan Sturm** (ssturm@wpi.edu) and **Mackenzie Wildman** (mackenzie.wildman@gmail.com).
Sensitivity of the Eisenberg-Noe Network Model to the Relative Liabilities.
The financial system is increasingly interconnected. Cyclical interdependences among corporations may cause that the default of one firm seriously affects other firms and even the whole financial network, as illustrated the default of Lehman Brothers during the 2008 financial crisis. To describe financial networks, L. Eisenberg and T. Noe introduced network models that became popular among researchers and practitioners. To describe the connections between firms, they use the liabilities between two firms to construct relative liability matrices. Based on this description, they compute the payouts of firms to their counterparties. However, in practice, there is no accurate record of the liabilities and researchers have to resort to estimation processes. Thus it is very important to understand possible errors of payouts due to the estimation errors. In our research, we describe estimation errors via sizes and directions of perturbations in the relative liability matrices. We quantify the effect of estimation errors to payouts using directional directives and derive the formula $D_B(p(A)) = (I - \Lambda A^T)^{-1}\Lambda B^T p(A)$ in the regular financial network. For a given estimation error size, we compute the effect to the payout along the worst estimation error. (Received July 19, 2016)

51 ► Geometry

1121-51-70 **Genevieve S Walsh*** (genevieve.walsh@gmail.com), Tufts University Mathematics Dept, Medford, MA 02155. *Boundaries of Kleinian groups.* Preliminary report.
The boundary of a hyperbolic group yields much information about the group structure, although in general it does not determine the quasi-isometry type of the group. For a convex co-compact Kleinian group K, the boundary of K is the same as the limit set of K. We give several interesting examples and explore how much the group boundary of K determines Kleinian group. This is joint work with Peter Haissinsky and Luisa Paoluzzi. (Received July 11, 2016)

1121-51-89 **Piotr Hajlasz*** (hajlasz@pitt.edu). *The Lipschitz and the Holder topology of the Heisenberg groups.* Preliminary report.
The Heisenberg group is homeomorphic to the Euclidean space so from the perspective of the classical topology it is not particularly interesting. The situation is however, different if we restrict to Lipschitz and Holder continuous maps. For example if we consider Lipschitz or Holder homotopy groups. I will discuss new results in

this direction. Part of this research has been done in collaboration with other mathematicians. (Received July 12, 2016)

1121-51-123 **Giuseppe Martone*** (gmartone@usc.edu), University of Southern California, and **Tengren Zhang**, California Institute of Technology. *Positively ratioed representations and length functions in higher rank.*

For a compact surface S with negative Euler characteristic, Hitchin and maximal representations are well studied higher rank analogues of Teichmüller space. In this setting, one can define many length functions generalizing the hyperbolic length on S. For a representation ρ and a length function ℓ, we will define what it means to be a (ρ, ℓ)-positively ratioed representation. This is a sufficient condition for the existence of a shortest non-peripheral simple closed curve on S. We relate the length of such curve to the topological entropy of the representation. The main tool is a construction of a measure on the space of geodesics of S associated to a (ρ, ℓ)-positively ratioed representation. This is joint work with Tengren Zhang. (Received July 15, 2016)

1121-51-172 **Brian Collier***, briancollier01@gmail.com. *Connected components of the SO(p,q) character variety.*

We will discuss the connected components of the moduli space of representations of the fundamental group of a closed surface of genus at least 2 into the Lie group SO(p,q). In particular, we will show there are more components than expected and discuss which components consist of discrete and faithful representations. (Received July 18, 2016)

1121-51-188 **Luca Capogna***, Department of Mathematical Sciences, Worcester Polytechnic Institute, Worcester, MA 01609, and **Jeremy T. Tyson** (tyson@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, 1409 West Green Street, Urbana, IL 61801. *Quasiconformal geometry of boundaries of hyperbolic spaces Part II.*

This is the second of a two part expository lecture series on quasiconformal mappings of boundaries of Gromov hyperbolic spaces, with particular emphasis on the boundaries of rank one symmetric spaces. We will discuss the how sub-Riemannian structures arise from visual metrics in general rank one symmetric and beyond. We will review some results concerning quasiconformal mappings in sub-Riemannian setting, discuss restrictions and extensions to visual boundaries and conclude indicating the role of these ideas in the early development of the theory of analysis in metric spaces. (Received July 18, 2016)

1121-51-192 **Jean-Philippe Burelle*** (jburelle@umd.edu), Mathematics Department, University of Maryland, College Park, MD 20742, and **Nicolaus Treib** (ntreib@mathi.uni-heidelberg.de), Mathematisches Institut, Ruprecht-Karls-Universität Heidelberg, Im Neuenheimer Feld 205, 69120 Heidelberg, Germany. *Schottky Presentations of Maximal Representations.* Preliminary report.

Maximal Representations form a class of geometrically interesting representations of a surface group into a Lie group of Hermitian type. They are defined by requiring the Toledo invariant, a topological invariant of the representation, to be maximal.

In the special case of a surface with non-empty boundary, we explain how to construct explicit presentations for any such representation using the theory of partial cyclic orders. In the case of the group $Sp(2n, \mathbb{R})$, we define hypersurfaces in RP^{2n-1} that are pairwise identified by the generators of the group and bound a fundamental domain for a properly discontinuous action on an open dense subset of projective space. (Received July 18, 2016)

52 ► Convex and discrete geometry

1121-52-73 **Pablo Soberón*** (p.soberonbravo@northeastern.edu), 463 Lake Hall, 360 Huntington Avenue, Boston, MA 02115. *A probabilistic approach to Tverberg-type results.*

Tverberg's theorem is a classic gem in combinatorial geometry. We show how the probabilistic method can be applied to obtain robust versions of this result. In particular, given positive integers r, d, t; we study the number of points needed in R^d to guarantee the existence of a partition of them into r parts such that, even after any t points are removed, the convex hulls of what is left in each part have non-empty intersection. (Received July 11, 2016)

1121-52-136 **Gaku Liu*** (gakuliu@math.mit.edu). *A counterexample to the extension space conjecture for realizable oriented matroids.*

The extension space conjecture of oriented matroid theory states that the space of all one-element, non-loop, non-coloop extensions of a realizable oriented matroid of rank d has the homotopy type of a sphere of dimension $d-1$. We disprove this conjecture by showing the existence of a realizable uniform oriented matroid of high rank and corank 3 with disconnected extension space. The proof is non-explicit and uses probabilistic methods. (Received July 16, 2016)

1121-52-159 **Max Wakefield*** (wakeful@usna.edu), 572-C Holloway Rd, Dept of Mathematics, US Naval Academy, Annpolis, MD 21402. *Non-free arrangements.* Preliminary report.

An arrangement is free when the module of logarithmic vector fields tangent to the arrangement is a free module over the symmetric algebra. The literature of free arrangements is vast and has a compelling conjecture (Terao's conjecture) continually advancing the field. Comparatively there has been little studied about the module of of logarithmic vector fields for a non-free arrangement. In this talk we discuss some simple results on how to track the degrees of the generators of the module of derivations. Using a restriction argument one can find bounds for the maximal degree generator. We develop bounds for this maximal degree generator for certain families of arrangements including graphic and hypersolvable arrangements. (Received July 17, 2016)

53 ► Differential geometry

1121-53-144 **Virginie Charette*** (v.charette@usherbrooke.ca), Department of Mathematics, Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, QC J1K 2R1, Canada, and **Youngju Kim** (geometer1@kias.re.kr), 120 Neungdong-ro, Gwangjin-gu, Seoul, 143-701, South Korea. *Foliations by crooked planes.*

Crooked planes are used to bound fundamental domains for the actions of *affine Schottky groups*; these are groups of Lorentzian isometries of R^3, whose linear parts are purely hyperbolic. One might wonder how "flexible" crooked planes may be : for instance, can we use them to foliate R^3, or subsets of R^3 (fundamental domains, in particular)?

Given a regular curve in Minkowski spacetime, we describe necessary and sufficient conditions for this curve to support a family of pairwise-disjoint crooked planes. Using this criterion, we describe crooked foliations along orbit curves of one-parameter groups of Lorentzian isometries. (Received July 17, 2016)

55 ► Algebraic topology

1121-55-45 **Michelle S. Berry**, **Victoria Diaz** and **Emily T. Winn*** (etwinn17@g.holycross.edu), College of the Holy Cross, P.O. Box 2918, 1 College Street, Worcester, MA 01610, and **Max Zhou**, **Brandy Guntel Doleshal** and **Taylor Martin**. *Determining a Twisted Torus Link's Number of Components.*

A link is a smooth embedding of a finite number of disjoint copies of S^1 into S^3. Links of one component are known as knots. We are particularly interested in twisted torus links, as no complete classification of them currently exists. Specifically, we are interested in finding easy ways to determine the number of components that a twisted torus link has. Twisted torus links of one component are especially interesting because there exist more ways to classify knots than there are ways to classify links. In this paper, we will examine patterns in the parameters of a twisted torus link that reveal general and specific information about components.
(Received July 18, 2016)

1121-55-88 **Chen He*** (he.chen@husky.neu.edu). *Classification and equivariant cohomology of circle actions on 3d manifolds.* Preliminary report.

The classification of Seifert manifolds was given in terms of numeric data by Seifert in 1933, and then generalized by Orlik and Raymond in 1968 to circle actions on closed 3d manifolds. In this paper, we further generalize the classification to circle actions on 3d manifolds with boundaries by adding a numeric parameter and a union of cycle graphs. Then we describe the equivariant cohomology of 3d manifolds with circle actions in terms of ring, module and vector-space structures. We also compute equivariant Betti numbers and Poincaré series for these manifolds and discuss the equivariant formality. (Received July 12, 2016)

1121-55-186 **Pavle V. M. Blagojevic*** (pavle.v.m.blagojevic@gmail.com), Institut für Mathematik, Arnimallee 2, 14195 Berlin, Germany. *Local multiplicity of continuous maps between manifolds.*

Let M and N be smooth (real or complex) manifolds, and let M be equipped with some Riemannian metric. A continuous map $f\colon M \longrightarrow N$ admits a local k-multiplicity if, for every real number $\omega > 0$, there exist k pairwise distinct points $x_1, \dots, x_k$ in M such that $f(x_1) = \cdots = f(x_k)$ and $\operatorname{diam}\{x_1, \dots, x_k\} < \omega$.

In this talk we present a systematic study of the existence of local k-mutiplicities and derive criteria for their existence in terms of Stiefel–Whitney classes of the vector bundle $f^*\tau N \oplus (-\tau M)$.

(This lecture is based on the joint work with Roman Karasev) (Received July 18, 2016)

1121-55-271 **Nelson Abdiel Colon***, nel.abdiel@gmail.com, and **Charles Frohman**. *Frobenius Algebras Derived from the Kauffman Bracket Skein Algebra.*

If the variable in the Kauffman bracket A is set equal to $e^{\pi i N}$ where N is an odd integer, then the Kauffman bracket skein algebra of a compact oriented surface F, $K\_N(F)$ is a ring extension of $\chi(F)$ the $SL\_2(C)$-characters of the fundamental group of F. We can derive an algebra from $K\_N(F)$ by either passing to the field of fractions of $\chi(F)$, or specializing at a place $\phi : \chi(F) \to C$. In either case, the action of $KN(F)$ on itself by left multiplication leads to a trace on $K\_N(F)$ taking values in the base field. We work examples to show that the fields constructed this way are usually Frobenius algebras. (Received July 19, 2016)

1121-55-275 **Julianna Tymoczko*** (jtymoczko@smith.edu), Department of Mathematics and Statistics, Smith College, Northampton, MA 01063. *Using graph theory to construct the equivariant cohomology of certain affine Springer fibers.*

We can compute the equivariant cohomology of a large family of algebraic varieties from an algebraic construction on a combinatorial graph. Geometers and topologists often refer to this construction as GKM theory (after Goresky-Kottwitz-MacPherson); in analysis and applied math, the basic construction is called a spline. We give a very brief overview of the combinatorial construction and then show how to construct the equivariant cohomology of an infinite variety that is a particular affine Springer fiber. (Received July 19, 2016)

57 ► Manifolds and cell complexes

1121-57-20 **Eric G. Samperton*** (egsamp@math.ucdavis.edu) and **Greg Kuperberg** (greg@math.ucdavis.edu). *A TQC-inspired proof of a classical complexity result for 3-manifolds.*

I will discuss the computational complexity of classical enumerative invariants of 3-manifolds. If G is a fixed, finite non-abelian simple group, then counting homomorphisms from the fundamental group of a triangulated 3-manifold M to G is #P-complete. As a corollary of the proof, determining whether $pi_1(M)$ admits a nontrivial homomorphism to G is NP-complete. Another corollary is that deciding when a 3-manifold admits an m-sheeted connected covering space is NP-complete, for fixed $mgeq5$. Our method is similar to certain constructions in topological quantum computing. We encode reversible classical logic gates by analyzing the action of the mapping class group of a surface S on the homomorphisms from $pi_1(S)$ to G. The hardness result follows by encoding reversible circuits into 3-manifolds using these gadgets. (Received July 16, 2016)

1121-57-26 **Scott Taylor** (sataylor@colby.edu) and **Maggy Tomova*** (maggy-tomova@uiowa.edu), Iowa City, IA 52240. *Additive invariants for links and graphs in 3-manifolds.* Preliminary report.

We define two new families of invariants for (3-manifold, graph) pairs which detect the unknot and are additive under connected sum of pairs and (-1/2) additive under trivalent vertex sum of pairs. The first of these families is closely related to both bridge number and tunnel number. The second of these families is a variation and generalization of Gabai's width for knots in the 3-sphere. (Received June 29, 2016)

1121-57-32 **Tian Yang*** (yangtian@math.stanford.edu), 116 Charles Marx Way, Palo Alto, CA 94304. *Volume conjectures for Reshetikhin-Turaev and Turaev-Viro invariants.*

In a joint work with Qingtao Chen, we consider a family of Turaev-Viro type invariants for a 3-manifold M with non-empty boundary, indexed by an integer $r \geqslant 3$, and propose a volume conjecture for hyperbolic M that these invariants grow exponentially at large r with a growth rate the hyperbolic volume of M. The crucial step is the evaluation at the root of unity $\exp(2\pi\sqrt{-1}/r)$ instead of that at the usually considered root $\exp(\pi\sqrt{-1}/r)$. Evaluating at the same root $\exp(2\pi\sqrt{-1}/r)$, we then conjecture that, the original Turaev-Viro invariants and

the Reshetikhin-Turaev invariants of a closed hyperbolic 3-manifold M grow exponentially with growth rates respectively the hyperbolic and the complex volume of M. This uncovers a different asymptotic behavior of the values at other roots of unity than that at $\exp(\pi\sqrt{-1}/r)$ predicted by Witten's Asymptotic Expansion Conjecture, which may indicate some different geometric interpretation of the Reshetikhin-Turaev invariants than the $SU(2)$ Chern-Simons theory. Evidences will be provided to support these conjectures, both numerical and mathematical. (Received July 01, 2016)

1121-57-35 **Anastasiia Tsvietkova*** (n.tsvet@gmail.com). *Isotopy classes of crossing arcs in hyperbolic alternating links.*

For hyperbolic alternating links, it has been suspected for many years that every arc in the reduced alternating diagram running from an overcrossing to an undercrossing is isotopic to a geodesic. This was conjectured by Sakuma and Weeks in 1995. Since then, it has been proved only for several families of links. We obtain conditions that guarantee that a link complement has a complete hyperbolic structure, and every such arc is isotopic to a simple geodesic. Our conditions also ensure that crossing arcs are the edges of an ideal geodesic triangulation. We provide new infinite families of links for which this holds. (Received July 03, 2016)

1121-57-68 **Feng Luo*** (fluo@math.rutgers.edu), 110 Frelinghuysen Road, Piscataway, NJ 07059, and **Jian Sun** and **Tianqi Wu**. *Discrete conformal geometry of polyhedral surfaces and its convergence.*

Our recent joint work with D. Gu established a discrete version of the uniformization theorem for compact polyhedral surfaces. In this talk, we prove that discrete uniformizaton maps converge to conformal maps when the triangulations are sufficiently fine chosen. We will also discuss the relationship between the discrete uniformization theorem and convex polyhedral surfaces in the hyperbolic 3-space. This is a joint work with J. Sun and T. Wu. (Received July 11, 2016)

1121-57-69 **Colin Adams*** (cadams@williams.edu), Bronfman Science Center, 18 Hoxsey St., Williamstown, MA 01267, and **Gregory Kehne**. *Decompositions of Multi-crossing Knot and Link Complements into Bipyramids.*

D. Thurston discovered a method of decomposing a link complement by inserting an octahedron into each crossing in a projection. For a hyperbolic link, this provides an upper bound on volume in terms of crossing number. Here, we generalize to multi-crossing projections, where more than two strands cross at a crossing. We discuss various applications. (Received July 11, 2016)

1121-57-81 **Tyrone Ghaswala** and **Rebecca R Winarski*** (winarskr@uwm.edu). *Lifting Homeomorphisms and Cyclic Branched Covers of Spheres.*

Birman and Hilden ask: given finite branched cover X over S^2, does every homeomorphism of S^2 lift to a homeomorphism of X? For covers of degree 2, the answer is yes, but the answer is sometimes yes and sometimes no for higher degree covers. In joint work with Ghaswala, we completely answer the question for cyclic branched covers. When the answer is yes, there is an embedding of the mapping class group of S^2 into a finite quotient of the mapping class group of X. (Received July 12, 2016)

1121-57-82 **Mehdi Yazdi*** (yazdi@princeton.edu). *On Thurston's Euler Class One Conjecture.*

In 1976, Thurston proved that taut foliations on closed hyperbolic 3–manifolds have Euler class of norm at most one, and conjectured that, conversely, any Euler class with norm equal to one is Euler class of a taut foliation. I construct counterexamples to this conjecture and suggest an alternative conjecture. (Received July 12, 2016)

1121-57-83 **Nicholas Owad***, nick@owad.org. *Bridge spectra of cables of 2-bridge knots.*

We compute the bridge spectra of cables of 2-bridge knots. Then we will give some directions we hope to extend the result and some obstructions to other directions. (Received July 12, 2016)

1121-57-84 **Trenton F Schirmer*** (trentschirmer@gmail.com). *Trisections and Heegaard Splittings of Link Complements.*

A *trisection* of a closed 4-manifold is a decomposition of into three $(4,1)$-handlebodies which intersect pairwise in 3-dimensional handlebodies, and whose triple interesection is a closed surface.

Given a framed link diagram defining a handle decomposition of a 4-manifold X, a trisection of X arises naturally from a choice of Heegaard splitting for that link complement. Conversely, trisections of X give rise to framed link diagrams equipped with Heegaard surfaces which define X.

My talk will discuss how this construction works in more detail, explain how it has been used so far (in joint work with Meier and Zupan) and then turn to a discussion of some interesting open problems in the theory of trisections. (Received July 12, 2016)

1121-57-92 **Kenneth L Baker*** (kenken@math.miami.edu), Ungar 515, 1365 Memorial Drive, Coral Gables, FL 33146, and **John Luecke** (luecke@math.utexas.edu), The University of Texas, RLM 8.100, 2515 Speedway Stop C1200, Austin, TX 78712. *Asymmetric L-space knots in S^3.* Preliminary report.

We describe the first construction of Heegaard Floer L-space knots in S^3 that are not strongly invertible. More specifically, we will present a novel construction of asymmetric hyperbolic knots in S^3 that admit an integral surgery to the double branched cover of an alternating link. (Received July 13, 2016)

1121-57-111 **Cameron McA Gordon*** (gordon@math.utexas.edu), University of Texas, Department of Mathematics, C1200, Austin, TX 78712. *Foliations and cyclic branched covers.*

For a closed, orientable, prime 3-manifold M it is conceivable that the following three properties are equivalent: (1) M has a co-orientable taut foliation, (2) $\pi_1(M)$ is left-orderable, and (3) M is not a Heegaard Floer L-space. (It is known that (1) implies (3); all other implications are open in general.) We will describe some results on this for n-fold cyclic branched covers $\Sigma_n(K)$ of prime knots K. For example, it seems reasonable to conjecture that if K is a satellite knot then $\Sigma_n(K)$ always has a co-orientable taut foliation. (Received July 14, 2016)

1121-57-118 **Ryan Blair*** (ryan.blair@csulb.edu), **Heidi Furlong** and **Leslie Rodriguez**. *Twist Number and the Alternating Volume of Knots.*

Every knot in S^3 is ambient isotopic to one component of a two-component, alternating, hyperbolic link. In the paper being presented, we define the alternating volume of a knot K to be the minimum volume of any link L in a natural class of alternating, hyperbolic links such that K is ambient isotopic to a component of L. Our main result shows that the alternating volume of a knot is coarsely equivalent to the twist number of a knot. (Received July 14, 2016)

1121-57-120 **Sangbum Cho** and **Yuya Koda*** (ykoda@hiroshima-u.ac.jp), 1-3-1 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-8526, Japan. *The Goeritz groups of Heegaard splittings for 3-manifolds.*

The Goeritz group of a Heegaard splitting for a closed orientable 3-manifold is defined to be the subgroup of the mapping class group of the Heegaard surface consisting of mapping classes that extend to both handlebodies. It is natural to study the structures of these groups, and so finding their generating sets or presentations has been an interesting problem. However, generating sets or presentations of them have been obtained only for few manifolds with their splittings of small genus. In this talk, we give a short historical overview of this problem and introduce its recent progress together with some applications. (Received July 15, 2016)

1121-57-124 **Nicholas G Vlamis*** (vlamis@umich.edu), 530 Church Street, Ann Arbor, MI 48109, and **Andrew Yarmola**. *Basmajian's identity in higher Teichmüller theory.*

Basmajian's original identity gives the area of the boundary of a compact hyperbolic manifold as a summation over the orthospectrum. We will demonstrate an extension of this identity to the setting of Hitchin representations of surface groups. We will see that for 3-Hitchin representations the identity has a natural geometric interpretation analogous to the hyperbolic setting. (Received July 15, 2016)

1121-57-135 **Shawn Xingshan Cui*** (cuixsh@gmail.com), 382 Via Pueblo Mall, Varian Laboratory of Physics, Stanford, CA 94305-4060. *Higher Categories and Topological Quantum Field Theories.*

We give a construction of Turaev-Viro type (3+1)-dimensional Topological Quantum Field Theory out of a G-crossed braided spherical fusion category for G a finite group. The resulting invariant of 4-manifolds generalizes several known invariants in literature such as the Crane-Yetter invariant and Yetter's invariant from homotopy 2-types. Some concrete examples will be provided to show the calculations. If the category is concentrated only at the sector indexed by the trivial group element, a co-cycle in $H^4(G, U(1))$ can be introduced to produce another invariant, which reduces to the twisted Dijkgraaf-Witten theory in a special case. It can be shown that with a G-crossed braided spherical fusion category, one can construct a monoidal 2-category with certain extra structure, but these structures do not satisfy all the axioms of a spherical 2-category given by M. Mackaay. Although not proven, it is believed that our invariant is strictly different from other known invariants. It remains to see if the invariant has the power to detect any smooth structures. (Received July 16, 2016)

1121-57-141 **Khalid Bou-Rabee** (kbourabee@ccny.cuny.edu), CCNY Department of Mathematics, NAC 8/133, Convent Ave at 138th Street, New York, NY 10031, and **Daniel Studenmund*** (dhs@math.utah.edu), Department of Mathematics, University of Utah, 155 S 1400 E, Salt Lake City, UT 84112. *Full residual finiteness growth of nilpotent groups.*

The *full residual finiteness growth* of a group G measures the difficulty of detecting word metric balls in G using finite quotients of G. This is one kind of quantification of the residual finiteness of G. We will discuss full residual finiteness growth of finitely generated nilpotent groups, with the goal of establishing polynomial upper bounds. (Received July 17, 2016)

1121-57-152 **Hongbin Sun*** (hongbins@math.berkeley.edu), 751 Evans Hall, Department of Mathematics, UC Berkeley, Berkeley, CA 94720. *NonLERFness of groups of non-geometric 3-manifolds.*

We will show that all irreducible non-geometric 3-manifolds have nonLERF fundamental groups, and the non-separable subgroups are given by essentially immersed surfaces.

As a further development, we will also show that a union of two hyperbolic 3-manifolds along essential curves have nonLERF fundamental groups. It implies that many high dimensional arithmetic hyperbolic manifolds have nonLERF fundamental groups. (Received July 17, 2016)

1121-57-157 **Makoto Ozawa*** (w3c@komazawa-u.ac.jp), 1-23-1 Komazawa, Setagaya-ku, Tokyo, 154-8525, Japan. *Essential embeddings of multibranched surfaces into 3-manifolds.* Preliminary report.

We consider embeddings, essential embeddings, free (Heegaard) embeddings, atoroidal embeddings and acylindrical embeddings of regular multibranched surfaces into closed orientable 3-manifolds. We show that there is no atoroidal, acylindrical essential embedding of multibranched surfaces in the 3-sphere which are formed by at least 4 once punctured tori. We also consider the genus, the essential genus and the free genus of a multibranched surface, and discuss some relationship between them. (Received July 17, 2016)

1121-57-220 **Charles Delman** and **Rachel Roberts*** (roberts@math.wustl.edu), Washington University in St Louis, St Louis, MO 63130. *Persistently foliar knots, I.*

Call a knot in the 3-sphere *persistently foliar* if every manifold obtained from it by rational (non-trivial) Dehn surgery admits a taut, co-orientable foliation. We present two methods for demonstrating that a knot is persistently foliar. In each, we proceed by constructing a co-orientable laminar branched surface with the property that the closed complementary component containing the knot is a solid torus with a positive, even number of meridional cusps; hence, it carries a lamination whose corresponding complementary component may be filled with disk leaves after any surgery with coefficient other than $1/0$. The first method, which may be viewed roughly as a generalization of Murasugi summing, builds the spine of a branched surface from the boundary of a tubular neighborhood of the knot, spheres that intersect the knot transversely, and spanning surfaces for related simpler links. The second method, which may be viewed as a generalization of disk decomposition, builds the spine from the boundary of a tubular neighborhood of the knot, a (not necessarily orientable) spanning surface, and decomposing disks. As an application, we prove that any nontorus Montesinos knot that is not a $(-2, 2n+1, 2m+1)$-pretzel, $m, n > 0$, (or its mirror image) is persistently foliar. (Received July 19, 2016)

1121-57-225 **Charles I. Delman*** (cidelman@eiu.edu), Department of Mathematics and CS, 600 Lincoln Avenue, Charleston, IL 61920, and **Rachel Roberts**. *Persistently Foliar Knots, II.*

Call a knot in the 3-sphere *persistently foliar* if every manifold obtained from it by rational (non-trivial) Dehn surgery admits a taut, co-orientable foliation. We present two methods for demonstrating that a knot is persistently foliar. In each, we proceed by constructing a co-orientable laminar branched surface with the property that the closed complementary component containing the knot is a solid torus with a positive, even number of meridional cusps; hence, it carries a lamination whose corresponding complementary component may be filled with disk leaves after any surgery with coefficient other than $1/0$.

The first method, which may be viewed roughly as a generalization of Murasugi summing, builds the spine of a branched surface from the boundary of a tubular neighborhood of the knot, spheres that intersect the knot transversely, and spanning surfaces for related simpler links. The second method, which may be viewed as a generalization of disk decomposition, builds the spine from the boundary of a tubular neighborhood of the knot, a (not necessarily orientable) spanning surface, and decomposing disks.

As an application, we prove that any nontorus Montesinos knot that is not a $(-2, 2n+1, 2m+1)$-pretzel, $m, n > 0$, (or its mirror image) is persistently foliar. (Received July 18, 2016)

1121-57-255 **Joseph D Malionek*** (jdmalion@colby.edu), 7467 Mayflower Hill, Waterville, ME 04901, and **Muyuan Zhang** (muzhang@colby.edu), 7114 Mayflower Hill, Waterville, ME 04901. *An introduction to the curve complex and some of its properties.* Preliminary report.

Consider the set of all simple closed curves on a surface. Now, create a graph where each node represents a curve and two nodes have an edge between them if the corresponding curves don't intersect. This graph is called the curve complex. The curve complex is a relatively recent invention and it is a neat way of exploring the nature of curves and surfaces using unconventional methods. We are attempting to understand large-scale properties of the curve complex. One of the interesting ways to study the curve complex is by studying its automorphism group. If we think of our surface as the boundary of a solid object, we call this object a handlebody. The disk complex is the subset of the curve complex corresponding to all curves that can be shrunk down to a point through the handlebody. One major result is that there is a uniform bound N such that any shortest path between two points in the disk complex stays within N of the disk complex, a property called quasi-convexity. We have shown that you can create infinitely long "straight lines" in the disk complex that could be useful in simplifying the proof of this result. We have also determined that certain symmetric properties of the curve and disk complexes are not strong enough to show this. (Received July 19, 2016)

1121-57-260 **Eriko Hironaka*** (exh@ams.org). *Coxeter mapping classes.*

From a Coxeter graph it is possible to define a mapping class on a compact oriented surface whose homological action is conjugate to the Coxeter element of the Coxeter system. This holds not only for classical(simply-laced) Coxeter graphs, but also for Coxeter graphs with sign-labeled vertices. In this talk, we survey some ways that Coxeter mapping classes have been used to produce interesting examples of periodic and "nearly-periodic" pseudo-Anosov mapping classes. (Received July 19, 2016)

1121-57-267 **Ian Biringer*** (ianbiringer@gmail.com). *Laminations on the boundary of a handlebody.*

If H is a handlebody with boundary S, let Mod(H) be the subgroup of Mod(S) consisting of surface homeomorphisms that extend to H. While Mod(H) isn't convex cocompact (it contains all Dehn twists around meridians), there is a rich theory surrounding its action on PML(S), and to a lesser extent, Teichmuller space. We'll briefly survey what's known, and talk a bit about the related problem of characterizing mapping classes that extend via their Nielsen-Thurston invariant laminations. (Received July 19, 2016)

1121-57-284 **Marion Campisi*** (marion.campisi@sjsu.edu), **Ryan Blair**, **Jesse Johnson**, **Scott Taylor** and **Maggy Tomova**. *Neighbors of knots in the Gordian graph.*

We will show that every knot is one crossing change away from a knot of arbitrarily high bridge number and arbitrarily high bridge distance. (Received July 20, 2016)

60 ► Probability theory and stochastic processes

1121-60-9 **Indranil SenGupta*** (indranil.sengupta@ndsu.edu), Department of Mathematics, North Dakota State University, NDSU Dept # 2750, Minard Hall 408, Fargo, ND 58108-6050, and **Semere Habtemicael** (shabtemicael@mgh.harvard.edu), Ragon Institute of MGH, MIT and Harvard, Cambridge, MA 02139-3583. *Volatility, variance, and covariance swaps for Barndorff-Nielsen and Shephard process driven financial markets.*

The objective of this presentation is to study the arbitrage free pricing of the volatility, variance and covariance swap for Barndorff-Nielsen and Shephard type Lévy process driven financial markets. One of the major challenges in arbitrage free pricing of swap is to obtain an accurate pricing expression which can be used with good computational accuracy. In this presentation we obtain analytic expressions for the pricing of the volatility, variance and covariance swap. We show that with the analytic expressions obtained from the Barndorff-Nielsen and Shephard model the error estimation in fitting the delivery price is much less than the existing models with comparable parameters. The models and pricing formulas proposed in this paper are computable in real time and hence can be efficiently used in practical applications. (Received June 13, 2016)

1121-60-13 **Laura Eslava*** (laura.eslavafernandez@mail.mcgill.ca), Department of Mathematics and Statistics, Burnside Hall, McGill University, Room 1005 – 805 Sherbrooke Street West, Montreal, Quebec H1X2B5, Canada. *Depth of high-degree vertices in Random Recursive Trees.* Preliminary report.

A random recursive tree T_n is constructed, recursively, by adding to T_{n-1} a new vertex labelled n attached to a uniformly chosen vertex in T_{n-1}; we start with T_1 being a single vertex labelled 1.

We will be concern with the degree and depth of a vertex i. Two known results for a uniformly chosen vertex in T_n is that its degree converges in distribution to a geometric r.v. with mean $1/2$ and that its depth is normally asymptotic. On the other hand, the maximum degree Δ_n of T_n is known to satisfy the almost sure convergence $\Delta_n/\log n \to 1$; however, little was known about the properties of vertices with near-maximum degree.

In this talk we present an alternative construction of T_n which is based on Kingman's coalescent and is also related to the data structure tree known as 'Union-Find'. This gives us a new insight on both the degree and depth of its vertices.

Broadly speaking, we prove the asymptotic independent normality of the depth of vertices with near-maximum degree. More precisely, we describe the convergence (along suitable subsequences) of a marked point process where, for each vertex in T_n, we place a particle at its 'shifted-degree' and mark it with a renormalization of its depth. (Received June 16, 2016)

1121-60-125 **Zhenyu Cui** and **Qi Feng*** (qi.feng@uconn.edu), 500 N Russsell St, Apt 12, West Lafayette, IN 47906, and **Ruimeng Hu**, **Gu Wang**, **Xuwei Yang** and **Bin Zou**. *Systemic Risk and Optimal Fee Structure for Central Clearing Counterparty.* Preliminary report.

We propose a novel Central Clearing Counterparty (CCP) design for the financial network of multilateral clearing, where the participation rate of individual banks depend on the volume-based fee charged by the CCP. We introduce a general demand function for individual banks and solve the optimal fee rate that maximizes the net wealth of the CCP. The optimal fee rate structure is explicitly solved for the case of a quadratic demand function. We show that partial participation of the CCP at the optimal fee rate reduces the aggregate shortfall of the financial system, and also the overall systemic risk. This justifies the alignment of interests of the profitability aspect and the regulatory aspect of the CCP. We also consider and compare the effect of partial versus full multilateral netting of interbank liabilities in terms of bank shortfalls. A simulation study illustrates our results. (Received July 15, 2016)

1121-60-132 **Oleksii Mostovyi*** (oleksii.mostovyi@uconn.edu), University of Connecticut, Department of Mathematics, 196 Auditorium Road, Storrs, CT 06269-3009. *A second-order expansion of the value function in the problem of optimal investment in incomplete markets.*

In the framework of incomplete financial market where the stock price dynamics is modeled by a continuous semimartingale, an explicit quadratic expansion for the power investor's value function and a first-order expansion for the corresponding optimal wealth process - seen as a function of the underlying market price of risk process - are provided. An example illustrating the result is also given. The talk is based on the joint work with Kasper Larsen and Gordan Zitkovic. (Received July 16, 2016)

1121-60-143 **Hyungbin Park*** (hpark@wpi.edu). *Ross recovery with recurrent and transient processes.*

Recently, Ross argued that it is possible to recover an objective measure from a risk-neutral measure. His model assumes that there is a finite-state Markov process X that drives the economy in discrete time. Many authors extended his model to a continuous-time setting with a Marko diffusion process X with state space R. Unfortunately, the continuous-time model fails to recover an objective measure from a risk-neutral measure in general. We determine under which information recovery is possible in the continuous-time model. It was proven that if X is recurrent under the objective measure, then recovery is possible. In this article, when X is transient under the objective measure, we investigate what information is sufficient to recover. (Received July 17, 2016)

1121-60-240 **Maxim Bichuch*** (mbichuch@jhu.edu), **Agostino Capponi** and **Stephan Sturm**. *Arbitrage-Free Pricing of XVA.*

We develop a framework for computing the total valuation adjustment (XVA) of a European claim accounting for funding costs, counterparty credit risk, and collateralization. Based on no-arbitrage arguments, we derive backward stochastic differential equations (BSDEs) associated with the replicating portfolios of long and short positions in the claim. This leads to the definition of buyer's and seller's XVA, which in turn identify a no-arbitrage interval. In the case that borrowing and lending rates coincide, we provide a fully explicit expression for the uniquely determined XVA, expressed as a percentage of the price of the traded claim, and for the corresponding replication strategies. In the general case of asymmetric funding, repo and collateral rates, we study the semi-linear partial differential equation (PDE) characterizing buyer's and seller's XVA and show the existence of a unique classical solution to it. To illustrate our results, we conduct a numerical study demonstrating how funding costs, repo rates, and counterparty risk contribute to determine the total valuation adjustment. (Received July 19, 2016)

1121-60-266 **Steven T Morrow*** (morrows@wit.edu). *A 'Cousin of Coboundary' Theorem for $C^\infty[0,1]$-Valued Random Fields with Moment Conditions.* Preliminary report.

This talk continues work on "Coboundary" Theorems for sequences of various types of random variables. K. Schmidt (1977) proved that if a strictly stationary sequence of real-valued random variables has the property that the family of distributions of its partial sums is tight, then the sequence is a coboundary, meaning that it is equal to the successive differences of another strictly stationary sequence. In 1995 Richard Bradley removed the strict stationarity requirement from the construction of the new sequence, yet preserving the result when the original sequence is strictly stationary. He further extended the result to $C[0,1]$-valued random variables in 1997. Other results involve the tightness assumption being replaced by the stronger condition that the partial sums be bounded in L^p, with the additional conclusion that the terms of the new sequence also have finite p-norms. This was extended to random fields, which are collections of random variables indexed by $\mathbb{Z}^d$.

This talk discusses a coboundary-type result for differentiable $C[0,1]$-valued random fields that include L^∞-boundedness of the sup-norms of the partial sums. (Received July 19, 2016)

1121-60-272 **Gu Wang*** (gwang2@wpi.edu), 100 Institute Road, Department of Mathematical Sciences, Worcester, MA 01609, and **Paolo Guasoni**. *Consumption in Incomplete Markets.*

As intertemporal consumption with market incompleteness leads to intractable value functions even in simple models, this paper develops approximate solutions to the maximization of isoelastic utility from consumption with infinite horizon in an incomplete market where state variables follow a multivariate diffusion. After proving a general verification theorem that links the solution of the Hamilton-Jacobi-Bellman (HJB) equation to the value function and optimal consumption-investment policies, the paper develops pointwise upper and lower bounds of the value function, which have closed-form solutions in typical models and lead to approximate policies with an explicit bound on the certainty-equivalent loss. In general, these policies are optimal for a fictitious complete market in which the safe rate and state variables follow different dynamics, but excess returns are the same; if the market is complete or utility is logarithmic, they are optimal even for the original market. Further, the approximations correspond to sub- and super-solutions to the original HJB equation, and lead to the existence of a solution. (Received July 19, 2016)

1121-60-280 **Scott Robertson***, Questrom School of Business, Boston University, 595 Commonwealth Ave, Boston, MA 02215. *The Pricing of Contingent Claims and Optimal Positions in Asymptotically Complete Markets.*

In this talk, we consider utility indifference prices and optimal purchasing quantities for a contingent claim, in an incomplete semi-martingale market, in the presence of vanishing hedging errors and/or risk aversion. Assuming that the average indifference price converges to a well defined limit, we prove that optimally taken positions become large in absolute value at a specific rate. To obtain this result, we draw motivation from and make connections to the celebrated Gartner-Ellis theorem from Large Deviations theory. Numerous examples will be given where the afore-mentioned price convergence takes place, including fixed markets with vanishing risk aversion, the basis risk model with high correlation and the Black-Scholes-Merton model with vanishing transaction costs. We will also show that the large claim regime could naturally arise in partial equilibrium models. Time permitting, we will discuss the main pricing assumption for general semi-martingale models and how it leads to a measure of market incompleteness, and how the optimal trading strategies are obtained. (Received July 20, 2016)

62 ► Statistics

1121-62-43 **Liam M. O'Brien*** (lobrien@colby.edu), Department of Mathematics and Statistics, 5838, Waterville, ME 04901, and **Alane B. O'Connor** and **William Alto**. *Addicted in the womb: An analysis of neonatal outcomes.*

As the number of people addicted to opioids increases, the number of newborns born with neonatal abstinence syndrome is also increasing. In this paper, we discuss how neonatal outcomes can be assessed to determine the relative efficacies of different treatments. Since standard statistical hypothesis testing cannot be used, we utilize randomization-based techniques. (Received July 05, 2016)

1121-62-44 **James C Scott*** (jcscott@colby.edu), **Neha Shah**, **Travis Porco** and **Jennifer Flood**. *What happens if we run out of drugs?: Estimating the causal effects of a tuberculosis drug shortage.*

When is it OK to claim that one thing causes another? How does one go about trying to determine causality? Is it ever appropriate to claim causality without conducting a rigorous experiment? Can Big Data help answer the question of causality? In this talk, I'll describe what epidemiologists and statisticians mean by causality and I'll demonstrate different methods that can be used to quantify the effect a specific cause has. I'll highlight some recent research that uses causal inference and a stochastic model to answer public health questions related to mycobacterium tuberculosis. (Received July 05, 2016)

1121-62-209 **Steve Chung**, **Aaron Pinkerton**, **Hunter Rehm** and **Michelle Yu*** (myu18@g.holycross.edu). *A Bayesian Approach to Predicting the Outcome of Endovenous Laser Ablation.* Preliminary report.

Varicose veins affect more than 40 million people in the United States. Endovenous Laser Ablation (EVLA) is a common and highly effective treatment method for varicose veins. The success of EVLA may depend on several key variables: laser power, time, length of vein, laser energy, and linear endovenous energy density (LEED), as well as combinations of these variables. In this study, we consider the Bayesian and parametric logistic regression models to predict the treatment outcome from these key variables. We use the Monte Carlo cross validation to assess the models. Our finding indicates that the Bayesian logistic regression is a better predictive model than the parametric logistic regression. (Received July 19, 2016)

1121-62-253 **Xuan Qu*** (xqu@bowdoin.edu), 767 Smith Union, Bowdoin College, Brunswick, ME 04011. *A Preliminary Statistical Study of Rhythmic Behaviors from a Stretch Feedback Pathway in the American Lobster, Homarus americanus.* Preliminary report.

The neurogenic heart of the American lobster, Homarus americanus, is controlled by the cardiac ganglion (CG), a simple pattern generator. The CG consists of four posterior premotor neurons and five anterior motor neurons. Driver potentials in the premotor neurons set the pace of driver potentials in the motor neurons, which then generate the action potentials down the axons, driving heart contraction. It has been shown that there are dendrites on the motor neuron endings that respond to stretch: we hypothesized that there are mechanosensitive channels present on these dendrites, to transduce the stretch information in a stretch feedback pathway. To study this, we applied tonic stretches consisting of (i) an increase in stretch phase, (ii) a hold phase, and (iii) a return form stretch phase, so to mimic the heart contraction. Different responses are observed in the driver potential in the above three stages, in terms of phase delay, change in burst duration, as well as inter-burst duty cycle duration. We carry out a statistical study with the goal, through sensitivity analysis of multiple parameters, to determine which are the factors that are most influential in determining the responses of the driver potential during the different stages of the simulated heart contraction. (Received July 19, 2016)

65 ► Numerical analysis

1121-65-14 **Eka Oche Ogbaji*** (ogbajieka@yahoo.com), Department of Mathematics and Statistics, Federal university Wukari, Wukari, **E.S Onah**, Department of Maths/Stat/Comp.Sc, University of Agriculture Makurdi, Makurdi, and **A.R Kimbir**. *Simplified Stochastic Runge-Kutta (SSR-K) scheme for a Stock Market Model.* Preliminary report.

A system of stochastic differential equations in the form of a geometric Brownian motion was formulated. This was to model a compartmental stock market situation. We simplified stochastic Runge-Kutta scheme to solve four - dimensional stochastic differential equation and show N- dimension simplified stochastic Rung-Kutta (SSR-K) scheme . In this research work, the simplification follows the principle of Runge-Kutta scheme for ordinary differential equation. We showed the theoretical analysis of convergence, stability, consistence and order of the scheme by using the existence and uniqueness theorem. We conclude that the formulated model can be use to show the real application of stock market in four compartment.We conclude that n-dimensional stochastic differential equation can be solve by using n-dimensional simplified stochastic Runge-Kutta scheme. (Received June 17, 2016)

1121-65-21 **Mei Duanmu** and **Nathaniel Whitaker*** (whitaker@math.umass.edu), Department Of Math and Stat, University of Massachusetts, Amherst, MA 01003, and **Panos Kevrekidis**, **Anna Vainchtein** and **Jonathan Rubin**. *Steady and Traveling Wave Solutions in a Chain of Periodically Forced Coupled Nonlinear Oscillators.*

Motivated by earlier studies of artificial perceptions of light called phosphenes, we analyze traveling wave solutions in a chain of periodically forced coupled nonlinear oscillators modeling this phenomenon. We examine the discrete model problem in its co-traveling frame and systematically obtain the corresponding traveling waves in one spatial dimension. Direct numerical simulations as well as linear stability analysis are employed to reveal the parameter regions where the traveling waves are stable, and these waves are, in turn, connected to the standing waves analyzed in earlier work. We also consider a two-dimensional extension of the model and demonstrate the robust evolution and stability of planar fronts and annihilation of radial ones. Finally, we show that solutions that initially feature two symmetric fronts with bulged centers evolve in qualitative agreement with experimental observations of phosphenes. (Received June 27, 2016)

1121-65-52 **Henry Asamoah Boateng*** (hboateng@bates.edu), Department of Mathematics, Bates College, Lewiston, ME 04240. *A mesh-free method for multipolar electrostatic interactions.* Preliminary report.

Multipolar electrostatics have been show to provide better accuracy than standard fixed charged models for molecular simulations but at a significantly higher cost. We present a mesh-free tree algorithm we are developing to relieve the computational bottleneck in multipolar electrostatics. (Received July 06, 2016)

68 ► Computer science

1121-68-57 **Peter Bürgisser** and **Christian Ikenmeyer***, christian.ikenmeyer@gmx.de, and **Greta Panova**, **Ketan Mulmuley** and **Michael Walter**. *Kronecker coefficients and plethysms in geometric complexity theory.*

Research on Kronecker coefficients and plethysms gained significant momentum when the topics were connected with geometric complexity theory, an approach towards computational complexity lower bounds via algebraic geometry and representation theory. This talk is about several recent results that were obtained with geometric complexity theory as motivation, namely the NP-hardness of deciding the positivity of Kronecker coefficients and an inequality between rectangular Kronecker coefficients and plethysm coefficients. While the proof of the former statement is mainly combinatorial, the proof of the latter statement interestingly uses insights from algebraic complexity theory. As far as we know algebraic complexity theory has never been used before to prove an inequality between representation theoretic multiplicities. If time permits I will quickly explain the notion of occurrence obstructions in geometric complexity theory and how a strong Kronecker positivity result proves their nonexistence. The papers are available on the arxiv: 1507.02955, 1512.03798, 1604.06431 (Received July 08, 2016)

1121-68-178 **Tucker J Atwood*** (tucker.atwood@maine.edu), 654 Embden Pond Road, Embden, ME 04958. *Creating an Order: Using Computer Programming and Data Analysis to Optimize Baseball Lineups.*

Given nine hitters, is it possible to create a baseball lineup that will maximize the number of runs scored? Using data analysis and computer programming, we have set out to find a formula that will give us an answer. We created a computer program capable of "playing" thousands of baseball games per second and have used it to test the average number of runs scored by specific lineups. Age-old traditions of Major League Baseball have been challenged, with results that may redefine the way we look at baseball lineups for years to come. (Received July 18, 2016)

70 ► Mechanics of particles and systems

1121-70-193 **David B Damiano** and **Kate L Heenan*** (klheen18@g.holycross.edu), 95 Ellington St, Longmeadow, MA 01106. *Topological Data Analysis of Ballistic Deposition Models.* Preliminary report.

In this project we adapt a method developed by MacPhearson-Schweinhart that utilize persistent homology (PH), and apply them to analyze the void structure of ballistic depositions. Their method uses PH to calculate a topological analogue of fractal dimension for one-dimensional complexes generated by probabilistic processes.

The ballistic depositions model porous granular media. We consider depositions that depend on a probability p in a novel matter. We compute their PH and fractal dimensions for varying sizes and probabilities, and obtain a relation between them. The PH is computed using a filtration of the void space by maximum radii permitted within the closed voids. (Received July 18, 2016)

1121-70-278 **Myungwon Hwang** (hwang125@purdue.edu), 585 Purdue Mall, West Lafayette, IN 47907, and **Andres F Arrieta*** (aarrieta@purdue.edu), 585 Purdue Mall, West Lafayette, IN 47907. *Nonlinear Dynamics of Lattices of Bi-stable Units with Spatially Varying Properties.* Preliminary report.

The analysis of the dynamics of periodic arrays has attracted continued attention over the years due to its mathematical complexity and applicability in condensed matter and engineering. A particular class of lattices constituted by bi-stable elements have been extensively studied analytically and numerically, showing interesting dynamical behaviors. However, few experimental investigations validating the theoretical results have been presented. Recently, the experimental study of 1-D chains of bi-stable elements with magnetic inter-site forces has shown strongly nonlinear dynamics potentially enabling interesting properties, such as unidirectional wave propagation resulting in a mechanical behavior analogous to diodes. We extended these studies by introducing spatially varying properties, hence perturbing the periodicity of the lattices. Preliminary numerical studies show that relaxation of self-similarity conditions within the lattice allow for reversing the wave propagation direction at particular spatial locations as a function of the impending wave intensity. The introduced spatial variability enables to control the confinement of the wave to desired regions within the lattice as required, with applications for energy dissipation and harvesting. (Received July 19, 2016)

74 ► Mechanics of deformable solids

1121-74-263 **Andrej Cherkaev*** (cherk@math.utah.edu), 155 S 1400 E, Department of mathematics, Unversity of Utah, Salt Lake City, UT 84112, **Predrag Krtolica** (cherk@math.utah.edu), 155 S 1400E, Department of Mathematics, University of Utah, Salt Lake City, UT 84112, and **Andrejs Treibergs** (treiberg@math.utah.edu), 155 S 1400 E, Department of Mathematics, University of Utah, Salt Lake City, UT 84112. *Compatibility conditions in dense lattices.* Preliminary report.

The paper deals with dense lattices where the number links exceed the number of degrees of freedom of the nodes. The lengths of the links in such lattices always satisfy additional compatibility conditions that are analogous to the compatibility conditions in continuum mechanics. We derive and analyze these conditions in a linear and nonlinear case and prove limiting theorems. The theory is applied to quantitive description of a state of a partially damaged lattice, providing a measure of the degree of a damage. (Received July 19, 2016)

81 ► Quantum theory

1121-81-30 **Zhenghan Wang*** (zhenghwa@microsoft.com), 2237 CNSI Bldg. Microsoft Station Q, UC Santa Barbara, Santa Barbara, CA 93106. *Hamiltonian realization of (3+1)-TQFTs.*

3D topological phases of matter are modeled by (3+1)-TQFTs in low energy. I will discuss the Hamiltonian realizations of (3+1)-TQFTs based on G-crossed braided fusion categories by S.-X. Cui in a joint work with D. Williamson. (Received July 01, 2016)

1121-81-103 **Nima Arkani-Hamed**, **Hugh Thomas*** (hugh.ross.thomas@gmail.com) and **Jaroslav Trnka**. *Defining the Amplituhedron.* Preliminary report.

Amplituhedra were introduced by Nima Arkani-Hamed and Jaroslav Trnka (arXiv:1312.2007) in the context of $\mathcal{N} = 4$ supersymmetric Yang-Mills theory. They include as special cases even-dimensional cyclic polytopes, but in general they are not polytopal. Rather, they are defined as the image of a map from one positive Grassmannian to another Grassmannian (also including entire postive Grassmannians as special cases). I will discuss a new definition for the amplituhedron, which gives a direct characterization of the points of the amplituhedron, without reference to a map from another positive Grassmannian. I will also discuss our progress towards proving that the two definitions agree. (Received July 14, 2016)

1121-81-114 **Ramis Movassagh*** (q.eigenman@gmail.com), 1101 route 134 Kitchawan Rd., Room 32-244, Yorktown Heights, NY 10598. *Generic Local Hamiltonians are Gapless.*

The gap, which is the positive difference of the smallest two distinct energies of a quantum system, is fundamental in quantum many-body physics. Often in physics, gapless systems are very special; they require high symmetry such as Goldstone modes and continuous symmetry breaking, or they require emergent gauge structure like in gapless quantum spin liquids. From a complexity perspective, the gap problem is formidable– just deciding whether the gap goes to zero or not is provably undecidable. Here we prove that the lack of an energy gap is a completely generic property. Specifically we prove that quantum local Hamiltonians, whose local terms are independent matrices from standard random matrix ensembles or certain random projectors, are gapless. The Hamiltonian can be on a lattice in any spatial dimension or on a graph with a bounded maximum vertex degree. The proofs combine quantum information techniques with ideas from analysis, probability and random matrix theories to explicitly construct gapless examples with dense open neighborhoods. Gapped systems are expected to be less resourceful. Therefore, in addition to pushing the undecidable subset into a low-dimensional corner, our results suggest that quantum Hamiltonians are typically richer than expected. (Received July 14, 2016)

1121-81-146 **John I Haas*** (haasji@missouri.edu). *Two families of weighted complex projective 2-designs.*

Weighted complex projective 2-designs are valuable because they provide optimal state determination in quantum experiments involving fixed numbers of outcomes. Two examples of such objects with equal weights are *maximals sets of mutually unbiased bases*, which are known to exist whenever the dimension of the underlying Hilbert space is a prime power, and *maximal sets of equiangular lines*, which are believed to exist in all dimensions but have only been verified in a finite number of cases.

In this talk, we consider the the case of unequal weights. By generalizing known constructions of 1-designs based on difference sets, we construct two infinite families of weighted complex projective 2-designs. Whenever the dimension M of the underlying Hilbert space is a prime power plus one, we obtain complex projective 2-designs of $M^2 + 1$ points, and whenever M is a prime power, we obtain complex projective 2-designs of $N = M^2 + M - 1$ points. In addition, we show that our examples achieve the orthoplex bound and therefore correspond to Grassmannian frames. (Received July 17, 2016)

1121-81-187 **Eric C Rowell*** (rowell@math.tamu.edu), Mathematics Department, Ms 3368, Texas A&M University, College Station, TX 77843. *The role of quantum dimension in quantum information.*

I will discuss quantum dimension as a statistic for anyons and its use in detecting properties such as universality, locality and non-abelian-ness. (Received July 18, 2016)

1121-81-227 **Colleen Delaney***, cdelaney@math.ucsb.edu. *Topological quantum computation with symmetry defects.*

A topological quantum computer would operate by braiding and measurement of anyons, particle-like excitations of a 2+1 dimensional topological phase of matter. In the presence of a global symmetry group G of the phase, extrinsic defects associated with the elements of G can also be used to perform computation. The algebraic theory of these symmetry defects is given by a G-crossed braided tensor category, which extends the unitary modular tensor category modeling the anyons. The computational power of anyon models can be enhanced by incorporating symmetry defects, so it is of practical importance to analyze the quantum gates that can be built from a G-crossed braided tensor category. (Received July 18, 2016)

1121-81-252 **Jon Yard*** (jtyard@gmail.com). *Arithmetic aspects of topological phases.*

This talk presents joint work with several people exploring various arithmetic aspects of $2 + 1$-dimensional topological phases. I will first show that abelian topological phases with boundary are classified by equivalence classes of integral quadratic forms, whereas the corresponding bulk topological phases are classified by a weaker invarient of quadratic forms known as the genus, characterized by equivalence over the p-adic integers $\mathbb{Z}_p$ for all primes p. I will also discuss potential physical interpretations of an intermediate invariant of quadratic forms known as the spinor genus. Finally, I will show that the image of the braid group representation associated to a qubit encoded among Fibonacci anyons is S-arithmetic. (Received July 19, 2016)

91 ► Game theory, economics, social and behavioral sciences

1121-91-65 **Michael Ludkovski** (ludkovski@pstat.ucsb.edu) and **Xuwei Yang*** (xyang4@wpi.edu), Department of Mathematical Sciences, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609. *Mean field game approach to production and exploration of exhaustible commodities.*

We employ mean field game approach to study energy markets characterized by a continuum of producers with exhaustible resources such as oil. Each producer chooses production and exploration strategies in order to maximize profit. We aim to study the Nash equilibrium of all producers' production and exploration strategies and the resulting total production, market price, and reserves distribution. (Received July 09, 2016)

1121-91-194 **Cody Hyndman*** (cody.hyndman@concordia.ca), Concordia University, Department of Mathematics and Statistics, 1455 De Maisonneuve Blvd West, Montreal, Quebec H3G1M8, Canada, and **Anastasis Kratsios**. *Manifold learning algorithms for arbitrage-free low-dimensional nonlinear model selection.* Preliminary report.

We introduce new manifold learning-based algorithms for selecting an arbitrage-free model for financial data in a parsimonious and computationally efficient manner. These geometric methods are data-dependent and fit naturally into the theoretical framework of several areas of mathematical finance. We show that these algorithms lead to models with lower MSE and improved prediction compared to Euclidean methods. (Received July 18, 2016)

1121-91-273 **Maxim Bichuch**, **Agostino Capponi** and **Stephan Sturm*** (ssturm@wpi.edu), Worcester Polytechnic Instute, Dept. of Mathematical Sciences, 100 Institute Road, Worcester, MA 02111. *Robust XVA for Credit Default Swaps.* Preliminary report.

Since the credit crisis of 2008 the inclusion of credit risk as well as differential funding rates have become standard in derivatives pricing. Value adjustments to the price due to this are calculated and added as surcharge. In the present paper we consider the total value adjustment (XVA) to the price of a credit default swap (CDS). As default intensities are notoriously hard to estimate, we propose here a robust approach where the intensity is assumed uncertain in given bounds. (Received July 19, 2016)

1121-91-281 **Agostino Capponi*** (ac3827@columbia.edu), New York, NY 10027. *Systemic risk under heterogeneous beliefs.* Preliminary report.

We consider an interbank network of bilateral exposures, where each bank only knows its own exposures but not the exposures between other pairs of banks. Defaults are costly and may lead to contagious defaults that spread through the network. We model this spread of insolvency as a dynamic game, where banks have the ability to intervene and join a rescue consortium to save the insolvent banks. Banks will do so only if an intervention is incentive compatible given their beliefs on the network, that is, their share of the bailout costs is believed to be smaller than their losses due to future defaults in the system. We analyze the set of sequential equilibria in games with heterogeneous beliefs and contrast the results to the equilibrium outcomes with complete information. We identify conditions on the network state under which incomplete information results in a better outcome, but also show that incomplete information may lead to a failure of coordination and a systemic default may occur in situations where it could have been avoided under complete information. (Received July 20, 2016)

92 ► Biology and other natural sciences

1121-92-10 **Carrie Diaz Eaton*** (ceaton@unity.edu). *The effect of second order interactions on stochastic bipartite networks.*

Bipartite networks between species are constructed in ecological settings as a result of relationships such as mutualism or antagonism. Here, I discuss a coevolving mutualistic network, in which the node values change stochastically and dependent on the values of its partner nodes. I prove that in cases where only the direct connections are considered, the network contracts. However, when indirect connections are considered, the network can maintain diversity. This is an important result in coevolutionary ecology, where mutualism between two species should cause traits to evolve trait matching, but entire networks such as plant-pollinator networks allow for diversity to coexist. Therefore, second order interactions should be considered when simulating large ecological networks. (Received June 15, 2016)

1121-92-170 **Stephanie R. Taylor*** (srtaylor@colby.edu), Dept. of Computer Science, Mayflower Hill, Colby College, Waterville, ME 04901, and **Thomas J. Wang**, **Daniel Granados-Fuentes** and **Erik D. Herzog**. *Using Augmented Phase-Amplitude Oscillators to Infer Directed Connections between Regions of the Mouse Circadian Clock.* Preliminary report.

The master clock that controls the daily rhythms in mouse behavior is a multi-oscillator composed of thousands of individual oscillators that synchronize via intercellular communication. The oscillators can be separated into two regions – the shell and core. The network which links oscillators within the regions and between the regions is the subject of ongoing study. Data are too sparse to infer connections between individual oscillators, but, with the aid of mathematical modeling, are not too sparse to infer the direction of connections between the two regions. We augmented a traditional phase-amplitude oscillator model to simulate experiments in which the communication network of a mouse circadian clock was destroyed and restored. Using experimental evidence and simulations of the dynamics upon restoration, we infer that the core entrains the shell. In this talk, we describe the model, why the augmentation was necessary, and our results. (Received July 18, 2016)

1121-92-218 **Matthew J Leventhal*** (mleventh@bowdoin.edu), 536 Smith Union, Brunswick, ME 04011. *Improving the efficiency of statistical analysis of cancer genomes through the development of cloud-based software.* Preliminary report.

Early detection of tumors is a key step in effectively treating cancer. One can determine if a patient is at risk for developing cancers by detecting regions of genetic aberrations or point mutations characteristic of tumor cell lines. We have can detect cancer-causing mutations early enough for effective treatment through statistical genomic analysis. The Pan Cancer analysis of Whole Genomes (PCAWG) project has developed a pipeline that aligns the tumor and normal cell genes, calculates differences in expression data and determines and annotates intervals of mutation in somatic cells that could lead to cancer, and initiates these tests all at once. However, a large quantity of computing power is necessary to run these tests efficiently. In order to reduce reliance on large virtual machines or supercomputers, we can use cloud-computing engines that allow investigators overcome hardware limitations. We re-built the PCAWG Pipeline on a Google Cloud platform called Firecloud using the Docker application. We tested the pipeline using genomic data from chromosome twenty-two and whole-exome data to successfully show that the pipeline could identify the presence of cancer-causing mutations and calculate expression data on a cloud-computing platform. (Received July 18, 2016)

1121-92-226 **Kathryn J Montovan*** (kmontovan@bennington.edu), 1 college drive, Bennington, VT 05201. *Understanding Colorado Potato Beetle behavior and the potential effectiveness of biological control measures using optimal control theory.* Preliminary report.

The Colorado Potato Beetle is a voracious pest that does significant damage to crops and has evolved resistance to the pesticides typically used to control it. Research to assess the potential effectiveness of utilizing predators to control the potato beetle population has shown that Colorado Potato Beetle larvae often cannibalize their egg-bound siblings and that cannibals exhibit stronger predator avoidance behaviors than non-cannibals. We use optimal control theory to understand whether the improved nutritional condition, due to cannibalism, is enough to explain the difference in behavior when a predator is present. We use the results to create a population model to explain the overall effectiveness of biological control measures on the population size and the implications of predator density for the population dynamics. (Received July 18, 2016)

93 ► Systems theory; control

1121-93-133 **Peter E. Caines*** (peterc@cim.mcgill.ca), Department of Electrical and Computer, Engineering, McGill University, 3480 University Street, Montreal, QC H3A 2A7, Canada, and **Dena Firoozi**. *The Execution Problem in Finance: A Partially Observed Mean Field Game Formulation.* Preliminary report.

Partially observed mean field game (PO MFG) theory was introduced and developed in (Caines and Kizilkale, 2013, 2014, Sen and Caines 2014, 2015), where it is assumed a major agent's state is partially observed by each minor agent, and the major agent completely observes its own state. Accordingly, each minor agent can recursively estimate the major agent's state, compute the system's mean field and thence generate the feedback control which yields an ϵ-Nash property. This theory was further extended in recent work (Firoozi and Caines, 2015, 2016) for major-minor LQG systems in which both the major agent and the minor agents partially observe the major agent's state. In this work we formulate the optimal execution problem with partial observations within the mean field game framework. Then, through the utilization of the results of PO LQG MFG theory,

the best rate of trading for each agent to maximize its utility function in the Nash equilibrium sense is obtained. (Received July 16, 2016)

1121-93-274 **Minyi Huang*** (mhuang@math.carleton.ca), School of Mathematics and Statistics, Ottawa, Ontario K1S 5B6, Canada, and **Son L. Nguyen** (sonluu.nguyen@upr.edu), Department of Mathematics, San Juan, PR 00936. *Mean Field Stochastic Growth with Relative Utility.*

We consider continuous time stochastic growth-consumption optimization in a mean field game setting. The individual capital stock evolution is determined by a Cobb-Douglas production function, consumption and stochastic depreciation. The individual utility functional uses a product of an own utility and a relative utility with respect to the population. The fixed point equation of the mean field game is derived with the aid of some ordinary differential equations. Due to the particular utility functional, the individual strategy takes the form of linear state feedback and its numerical solution does not need to solve the Fokker-Planck equation of the state process. (Received July 19, 2016)

94 ► Information and communication, circuits

1121-94-163 **Andreas Klappenecker*** (klappi@cse.tamu.edu), College Station, TX 77843-3112. *Quantum Codes and Fault-Tolerant Quantum Operations over Finite Frobenius Rings.*

The idealized model of quantum computation promises for certain problems a considerable speed-up over classical computation. However, protecting quantum information requires a considerable effort. We discuss the construction of quantum codes over finite Frobenius rings and the construction of fault-tolerant operations acting on such codes. (Received July 18, 2016)

00 ► General

1122-00-247 **Yuji Kodama*** (kodama.1@osu.edu), Department of Mathematics, The Ohio State University, 231 West 18th Ave, Columbus, OH 43210. *Triangulation and soliton graph.* Preliminary report.

I will report on an interesting connection between triangulations of a point set on the plane and soliton graphs in two-dimension. A soliton graph of two-dimensional integrable system is defined as a tropical (or ultra-discrete) limit of the contour plot of the soliton solution. Then the dual graph of the soliton graph gives a triangulation of a point set determined by the spectral parameters of the solution. Each soliton graph is generated by a point of the multi-time space of the hierarchy of the soliton equation. (Received August 15, 2016)

03 ► Mathematical logic and foundations

1122-03-30 **Jeremy F. Alm**, **Robin Hirsch** and **Roger D. Maddux*** (maddux@iastate.edu). *There is no finite-variable equational axiomatization of representable relation algebras over weakly representable relation algebras.*

Any equational basis that defines representable relation algebras over weakly representable relation algebras must contain infinitely many variables. The proof uses a construction, for every positive integer n, of finite relation algebras that are not representable but do have weak representations on finite sets, and whose n-generated subalgebras are representable. This includes the smallest known example (with 7 atoms) of a non-representable relation algebra that has a weak representation on a finite set. (Received July 26, 2016)

1122-03-40 **Jeremy F Alm*** (alm.academic@gmail.com), 1101 W. College Ave., Jacksonville, IL 62650. *Results and speculations in the neighborhood of the flexible atom conjecture.* Preliminary report.

The flexible atom conjecture states that a finite integral relation algebra with a flexible atom (i.e., an atom not involved in any forbidden diversity cycle) is representable on a finite set. While there is not yet a proof of this conjecture, several special cases have been established. In this talk, we survey what is known, and prove some new special cases as well as exhibiting some "nearby" examples, i.e., finite representations of algebras with "few" forbidden cycles. We conclude with some speculations about how a more general proof might come about. (Received August 01, 2016)

1122-03-63 **Alexander S Kechris*** (kechris@caltech.edu), Department of Mathematics, Caltech, Pasadena, CA 91125. *Borel equivalence relations and cardinal algebras.*

We show that Tarski's concept of cardinal algebra appears naturally in the context of the current theory of Borel equivalence relations. As a result one can apply Tarski's theory to discover a number of interesting laws governing the structure of Borel equivalence relations, which, in retrospect rather surprisingly, have not been realized before. (This is joint work with H.L.Macdonald.) (Received August 06, 2016)

1122-03-68 **Iian B Smythe*** (ismythe@math.cornell.edu), Department of Mathematics, Cornell University, Ithaca, NY 14853. *A local Ramsey theory for block sequences.*

Gowers proved an approximate Ramsey theorem for analytic partitions of the space of block sequences in a Banach space. Exact, discretized, versions of this result were later given by Rosendal. We isolate the combinatorial properties of the space of block sequences which enable these constructions, and prove that they can be carried out within certain subfamilies, analogous to selective coideals and the role they play in Mathias' local form of Silver's theorem for analytic partitions of $[\mathbb{N}]^\infty$. We consider applications of these results to understanding the combinatorial structure of projections in Calkin algebra. Under large cardinal assumptions, these results are extended to partitions in $\mathbf{L}(\mathbb{R})$. (Received August 06, 2016)

1122-03-84 **Andrzej Roslanowski*** (roslanow@member.ams.org), Department of Mathematics, University of Nebraska at Omaha, 6001 Dodge Street, Omaha, NE 68182-0243, and **Saharon Shelah** (shelah@math.huji.ac.il), Institute of Mathematics, The Hebrew University of Jerusalem, 91904 Jerusalem, Israel. *Around Borel hulls.*

Let $\mathcal{S}$ be a family of subsets of $\mathbb{R}$ with the Baire property. *A Borel hull* on $\mathcal{S}$ is a mapping $\psi : \mathcal{S} \longrightarrow \mathrm{Borel}(\mathbb{R})$ such that for each $A \in \mathcal{S}$ we have

$$A \subseteq \psi(A) \quad \text{and} \quad \psi(A) \setminus A \text{ is meager.}$$

Similarly we define Borel hulls on families of Lebesgue measurable sets (replacing "meager" with "null"). If the hull ψ satisfies

$(\circledast)^{\mathrm{monot}}$ for all $A, B \in \mathcal{S}$ such that $A \subseteq B$ we have $\psi(A) \subseteq \psi(B)$,

then we call it a monotone Borel hull. If ψ satisfies

$(\circledast)^{\mathrm{trans}}$ for every $A \in \mathcal{S}$ and a real number r we have $\psi(A + r) = \psi(A) + r$,

then we say ψ is transitive.

We are interested in monotone and/or transitive Borel hulls on the null and meager ideals, as well as on the families of all measurable sets (in the respective senses). In relation to transitive hulls we will point out a strange asymmetry: there exists (in ZFC) a null non-meager subgroup of $(\mathbb{R}, +)$ but consistently there is no meager non-null such subgroup. (Received August 08, 2016)

1122-03-97 **Sam van Gool*** (samvangool@me.com), City College of New York, Dept. of Mathematics, Convent Ave at 138th St, New York, NY 10031, and **Benjamin Steinberg** (bsteinberg@ccny.cuny.edu), City College of New York, Dept. of Mathematics, Convent Ave at 138th St, New York, NY 10031. *Stone duality and model theory.*

In recent joint work with Steinberg (presented in the special session on Recent Trends in Semigroup Theory at this meeting), we are studying the free proaperiodic monoid using model theory. In particular, we show that the free proaperiodic monoid is the Stone dual of the Lindenbaum-Tarski algebra of a certain first-order theory. The multiplication of this monoid corresponds through Stone duality to residuated structure on the Lindenbaum-Tarski algebra, that can also be described more directly in the first-order syntax. Moreover, while looking for applications of this duality result, we were led to consider saturated models and type spaces, which also have natural and useful algebraic and topological interpretations through duality.

In this talk I will try to give a somewhat more general perspective on what is going on, hoping it will also spark the interest of algebraic logicians who may not necessarily be interested in proaperiodic monoids per se. (Received August 09, 2016)

1122-03-106 **Yuan Yuan Zheng*** (yyz22@math.utoronto.ca). *Selective ultrafilters on FIN and those in $\mathcal{R}_\alpha$.*

We prove that selective ultrafilters on the set FIN of all finite nonempty subsets of $\mathbb{N}$ is preserved by side-by-side Sacks forcing. With a parametrized theorem, we obtain a similar result for the ultrafilters $\mathcal{U}_\alpha$ in the topological Ramsey spaces $\mathcal{R}_\alpha$ constructed by Dobrinen and Todorcevic. (Received August 10, 2016)

1122-03-107 **David J Fernández-Bretón*** (djfernan@umich.edu), 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109, and **Assaf Rinot** (rinotas@macs.biu.ac.il), Department of Mathematics, Bar-Ilan University, 52900 Ramat-Gan, Israel. *Strong failures of Hindman's Theorem for uncountable FS-sets.*

I will present some results showing that certain analogs of Hindman's Theorem fail, in a very strong sense, when one attempts to obtain uncountable monochromatic sets. Specifically, there is a proper class of cardinals κ satisfying the following statement (which we ad-hoc denote by $\circledast_\kappa$): whenever G is a commutative cancellative semigroup G of cardinality κ, there exists a colouring $c : G \longrightarrow \kappa$ such that, for every $X \subseteq G$ of cardinality κ, every colour $\alpha < \kappa$, and every $n < \omega$, there exist distinct $x_0, \ldots, x_n \in X$ such that $c(x_1 + \cdots + x_n) = \alpha$. Additionally, it is consistent with ZFC that $\circledast_\kappa$ holds for every regular uncountable cardinal κ. (Received August 10, 2016)

1122-03-136 **Paul B. Larson*** (larsonpb@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056. *Real games and the Hausdorff extension.*

We will present a partial result (joint with Dilip Raghavan) on the question of whether the Axiom of Real Determinacy ($\mathrm{AD}_{\mathbb{R}}$) implies that there are no tall semiselective coideals on the integers and use this to prove a covering theorem for forcing extensions of models of $\mathrm{AD}_{\mathbb{R}}$ by the partial order $\mathcal{P}(\omega)/Fin$. (Received August 11, 2016)

1122-03-153 **J. Michael Dunn*** (dunn@indiana.edu), IN. *Algebraic Logic Applied to Relevance Logic – From De Morgan Monoids to to Generalized Galois Logics.* Preliminary report.

Algebraic logic goes back at least to Boole (1847)** and the birth of modern "classical" logic. Through the course of next 100 years, algebra was applied to various "non-classical" logics, including many valued, intuitionistic, and modal logics. An early application to "substructural logics" was in Dunn's (1966) dissertation *The Algebra of Intensional Logics*, where a "De Morgan monoid" was introduced as the algebraic analog of the logic R of relevant implication. A De Morgan monoid is a De Morgan lattice-ordered, commutative monoid, that is *square increasing*, i.e., $a \leq a \circ a$. It was shown that De Morgan monoids are a kind of residuated monoid in the sense of Ward and Dilworth (1939), and so are a fusion of De Morgan lattices and residuated monoids. Meyer and Routley (1972) showed that a number of related logics may be obtained by playing with the postulates of a De Morgan monoid. I shall give a very brief survey of this and other "relevant" algebraic logic and how it led to generalized Galois logics (Dunn 1991, 1995a).

** All references can be found in R. G. Wolf's bibliography for Anderson, Belnap, and Dunn's *Entailment: The Logic of Relevance and Necessity*, vol. 2, Princeton Univ. Press, 1992.

(Received August 11, 2016)

1122-03-165 **Andreas R. Blass*** (ablass@umich.edu), Mathematics Dept., University of Michigan, Ann Arbor, MI 48109-1043. *Partitions and ultrafilters.* Preliminary report.

I plan to describe and compare the partition properties of several sorts of ultrafilters on ω. If time permits, I'll discuss selective ultrafilters, their sums and products, "the next best thing to a P-point", and stable ordered-union ultrafilters. (Received August 12, 2016)

1122-03-182 **Clinton T. Conley***, Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213. *Borel and measurable chromatic numbers of hyperfinite graphs.*

The study of how the chromatic number of a graph changes with various measurability constraints placed on the coloring function has garnered much attention of late. We survey several recent results, highlighting connections between these chromatic numbers and hyperfiniteness of the graph being considered. This talk includes joint work with Jackson, Kechris, Marks, Miller, Seward, and Tucker-Drob. (Received August 12, 2016)

1122-03-215 **Jose G Mijares*** (jose.mijarespalacios@ucdenver.edu), 1201 Larimer Street, Suite 4000, Denver, CO 80204. *Ultrailter limits in uniform spaces.*

Fix an uniform space $(X,\mathcal{U})$ and an ultrafilter $p \in \beta\mathbb{N}$. If $(x_n)_{n\in\mathbb{N}}$ is a sequence in X, we write $y = p - \lim_n x_n$ if for every neighborhood $V \in \mathcal{U}$, $\{n \in \mathbb{N} : (x_n, y) \in V\} \in p$.

Given a function $f : X \longrightarrow X$, uniformly continuous with respect to $\mathcal{U}$, define $f^p : X \longrightarrow X$ as follows:

$$\forall x \in X, f^p(x) = p - \lim_n f^n(x).$$

We study the continuity of the iteration f^p and discuss possible applications. (Received August 16, 2016)

1122-03-230 **Alessandra Palmigiano*** (a.palmigiano@tudelft.nl), van Breestraat 131, 1071ZL Amsterdam, Netherlands. *Linear Logic Properly Displayed.*

We introduce *proper* display calculi for Intuitionistic and Classical Linear Logic which are sound, complete, conservative, and enjoy cut-elimination and subformula property. Properness (i.e. closure under uniform substitution of all parametric parts in rules) is the main interest and added value of the present proposal, and allows for the smoothest Belnap-style proof of cut-elimination. Our proposal builds on an algebraic and order-theoretic analysis of the semantic environment of linear logic, and applies the guidelines of the multi-type methodology in the design of display calculi. (Received August 15, 2016)

1122-03-262 **James Cummings*** (jcumming@andrew.cmu.edu) and **Charles Morgan**. *Dowker filters.* Preliminary report.

A *Dowker filter* is a filter on a set X satisfying certain partition properties. The existence of such filters was first shown to be consistent with ZFC by Balogh and Gruenhage, although Freiling and Payne had earlier shown that the existence of *super-Dowker filters* with stronger partition properties is consistent with ZF. We give a simpler argument for the consistency of Dowker filters, and also show that the existence of super-Dowker filters is consistent with ZFC. (Received August 15, 2016)

1122-03-291 **Timothy O Trujillo*** (trujillo@mines.edu). *Parametrizing by the Ellentuck space.* Preliminary report.

We introduce a new construct that can be used to parametrize a topological Ramsey space by the collection of infinite subsets of natural numbers. We show that these parametrized spaces are topological Ramsey spaces.

Then we use these spaces to prove some parametrized perfect set theorems. We conclude with a discussion of how to extend the results to the abstract setting and open questions related to applying the results to the Tukey theory of ultrafilters. (Received August 15, 2016)

1122-03-310 **Sonia Navarro-Flores*** (sonianavarroflores91@gmail.com). *Pseudointersection numbers for topological Ramsey spaces.*

The pseudointersection number $\mathfrak{p}$ is the smallest cardinality of any family $\mathcal{F} \subseteq [\omega]^\omega$ which has the strong finite intersection property but which does not have a pseudointersection. It is known that $\omega_1 \leq \mathfrak{p} \leq \mathfrak{c}$ and it is consistent that $\mathfrak{p} = \mathfrak{c}$. Since topological Ramsey spaces are an abstraction of Ellentuck spaces, each topological Ramsey space has its own notion of a pseudointersection number, when partially ordered by almost reduction as defined by Mijares. Dobrinen asked whether the pseudointersection number of each topological Ramsey space is equal to $\mathfrak{p}$, or if not, what the relationships between them are. We show that pseudointersection number of some Ramsey spaces is equal to $\mathfrak{p}$ but there is a Ramsey space which has pseudointersection number equal to ω_1. The goal of this talk is to present this results. (Received August 15, 2016)

1122-03-352 **George F McNulty*** (mcnulty@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 20208. *Algebraic logic and models of set theory: a challenge.* Preliminary report.

As early as 1941 Alfred Tarski constructed an algebraic rendition of set theory. It was based on early work of Charles Sanders Peirce and Ernst Schroeder on the calculus of binary relations. Tarski's approach was primarily syntactic but by the 1970's with the work of Roger Maddux and Steve Givant it seemed to take on more model theoretic aspect. Meawhile Paul J. Cohen revolutionized work in set theory with his method of forcing. Like Tarski's work, Cohen's could be construed as primarily syntactic, although the method was soon elaborately developed along model theoretic lines. The task laid out in this talk is to do the same with Tarski's relation algebra approach. (Received August 16, 2016)

1122-03-371 **Vaughan R Pratt*** (pratt@cs.stanford.edu). *Algebras and bialgebras via categories with distinguished objects.*

We define a multisorted algebra A as an object of a category with distinguished objects s1, s2, ... serving as sorts, and a homomorphism thereof as a morphism between them. An element of A of sort s is a morphism from s to A. Homomorphisms act on algebras by composition with their elements, and are equivalent when they have the same action. We propose this definition as simpler than other ways of defining algebras and their homorphisms.

The base J of such a category C is the full subcategory of C comprised of the distinguished objects. The Yoneda embedding provides a category-theoretic interpretation of such structures.

Algebras generalize to bialgebras as a multisorted version of how sets generalize to Chu spaces, involving a second kind of distinguished object each identified with a property p. As with algebras, bialgebras and their bimorphisms are simply the objects and morphisms of such a category. A p-state of bialgebra A is a morphism from A to p. Bimorphisms h act on bialgebras as for algebras, and act dually by composition of the p-states of the target with the bimorphism to yield a p-state of the source.

We pose the problem of identifying an abstract class of bialgebras on a given base corresponding to the notion of topos for algebras. (Received August 16, 2016)

1122-03-376 **Taylor McMillan***, 1229 12th St, Greeley, CO 80631, and **Oscar Levin**. *Effective labelings of infinite graphs.* Preliminary report.

A *graph labeling* assigns integers to vertices, edges, or both, subject to certain conditions. For example, a labeling is *graceful* if the difference of labels on adjacent vertices is distinct for all edges, while a labeling is *edge-magic* if the sum of the labels on an edge and its incident vertices is constant for all edges. Graph labelings are usually studied for finite graphs, but some work has been done to extend these to infinite cases. In this talk we will consider the computable analogues to some results for graceful, edge-magic, and related labelings of infinite graphs. Using ideas from computability theory, we will explore the connection between the complexity of a graph's presentation and the complexity of its labelings.
(Received August 16, 2016)

1122-03-387 **Jose Gil-Ferez*** (jose.gil-ferez@vanderbilt.edu), Department of Mathematics, Vanderbilt University, 1323 Stevenson Center, Nashville, TN 37240, and **Stefano Bonzio**, **Francesco Paoli** and **Luisa Peruzzi**. *On Paraconsistent Weak Kleene Logic and Involutive Bisemilattices.*

Paraconsistent Weak Kleene logic (PWK) is the 3-valued logic with two designated values defined through the weak Kleene tables. This is a first attempt to investigate PWK within the perspective and methods of Abstract

Algebraic Logic. We give a Hilbert-style system for PWK and prove a normal form theorem. We examine some algebraic structures for PWK, called *involutive bisemilattices*, showing that they are distributive as bisemilattices and that they form a variety, $\mathcal{IBSL}$, generated by the 3-element algebra **WK**; we also prove that every involutive bisemilattice is representable as the Płonka sum over a direct system of Boolean algebras. We study PWK from the viewpoint of AAL, and show that $\mathcal{IBSL}$ is not the equivalent algebraic semantics of any algebraizable logic and that PWK is neither protoalgebraic nor selfextensional, not assertional, but it is truth-equational. We characterize the deductive filters of PWK on members of $\mathcal{IBSL}$ and its reduced matrix models. Finally, we investigate PWK with the methods of second-order AAL—we describe the class Alg(PWK) of PWK-algebras, showing that they coincide with the quasivariety generated by **WK**—which differs from $\mathcal{IBSL}$—and explicitly providing a quasiequational basis for it. (Received August 17, 2016)

05 ► Combinatorics

1122-05-17 **William G. Faris*** (faris@math.arizona.edu). *Rooted tree graphs and transformation groups.*

Series solutions of ordinary differential equations are indexed by rooted tree graphs. It was discovered by Butcher that there is an infinite-dimensional transformation group associated with rooted tree graphs. His discovery was in the context of numerical analysis of ordinary differential equations, but the same group emerges in the Connes-Kreimer approach to renormalization in quantum field theory. This talk will explore the combinatorial background to this subject. (Received June 25, 2016)

1122-05-21 **Ferdinand Ihringer*** (ferdinand.ihringer@gmail.com). *A Switching for the Collinearity Graphs of Polar Spaces.*

Consider the n-dimensional vector space over a finite field of order q: $\mathbb{F}_q^n$. Let s be a non-degenerate reflexive sesquilinear form on $\mathbb{F}_q^n$. We define a graph Γ as follows. The points are the 1-dimensional subspaces that vanish on s. Two points x and y are adjacent if $s(x,y)=0$. It is well-known that Γ is a strongly regular graph. Recently, triggered by a result by Abiad and Haemers, several new strongly regular graphs with the same parameters were constructed for $q=2$ and sufficiently large n (e.g. $n \geq 6$ for Abiad et al.). Here all the results use Godsil-McKay switching sets. We will present a generalization of one of these constructions that works for all q. Particularly, this implies that a strongly regular graph $srg(v,k,\lambda,\mu)$ with the same parameters as the collinearity graph of a finite classical polar space of rank at least 3 is not determined by its parameters v,k,λ and μ. (Received July 07, 2016)

1122-05-22 **Yun Fan**, Wuhan,, 430079, Peoples Rep of China, and **Bangteng Xu*** (bangteng.xu@eku.edu), 521 Lancaster Avenue, Richmond, KY 40475. *Nonlinear functions and difference sets on group actions.*

Let G be a finite abelian group acting on a finite set X. G-bent functions on X and G-difference sets of X are generalizations of bent functions on G and difference sets of G, respectively. We introduce the notion of a G-dual set $\widehat{X}$ of X, which plays a role similar to the dual group $\widehat{G}$ of G. For any T-valued function f on X, where T is the unit circle in the complex plane, we define the Fourier transform $\widehat{f}$ of f as a function on $\widehat{X}$. Then we characterize a G-bent function f in terms of its Fourier transform $\widehat{f}$, and a G-difference set of X by a normalized G-dual set. Constructions of G-bent functions and G-perfect nonlinear functions will also be discussed. (Received July 14, 2016)

1122-05-54 **Rani Hod**, Cambridge, MA 02138, **An Huang*** (anhuang@brandeis.edu), Waltham, MA 02453, **Mark Kempton**, Cambridge, MA 02138, and **Shing-Tung Yau**, Cambridge, MA 02138. *Strong embeddings and 2-isomorphism.* Preliminary report.

We present two conjectures related to strong embeddings of a graph into surfaces. The first conjecture relates 2-isomorphism of 2-connected graphs, with strong embeddings of these graphs. The second conjecture, motivated by ideas from physics and number theory, predicts a nonzero lower bound on the number of strong embeddings of a 2-connected graph. (Received August 03, 2016)

1122-05-69 **Boris Brimkov*** (bb19@rice.edu), Houston, TX 77005. *Structural and Extremal Results on Connected Zero Forcing.*

Zero forcing is a dynamic graph coloring process whereby a colored vertex with a single uncolored neighbor forces that neighbor to be colored. Zero forcing has applications in coding theory, power network monitoring, modeling propagation in social networks, and in approximating certain linear algebraic parameters. This talk introduces a variant of zero forcing in which the initially colored set of vertices induces a connected subgraph. A related

parameter of interest is the connected zero forcing number - the cardinality of the smallest initially colored connected vertex set which forces the entire graph to be colored. We discuss the complexity of computing this parameter, present closed formulas for it in specific families of graphs, and characterize graphs with extremal connected zero forcing numbers. (Received August 07, 2016)

1122-05-73 **Sinan Aksoy***, Department of Mathematics, 9500 Gilman Drive #0112, La Jolla, CA 92093, and **Fan Chung** and **Xing Peng**. *Extreme values of the stationary distribution of random walks on directed graphs.*

The *principal ratio* of a random walk on a directed graph is the ratio of maximum to minimum values of vertices in the stationary distribution. The principal ratio can be regarded as a metric for graph irregularity and plays a role in bounding the rate of convergence of a random walk on a digraph. Improving upon previous bounds, we prove a sharp upper bound for this ratio over all strongly connected graphs on n vertices, characterize all graphs achieving the upper bound, and give explicit constructions for these extremal graphs. (Received August 08, 2016)

1122-05-86 **Ronald J. Gould*** (rg@mathcs.emory.edu), Dept. of Math and Computer Science, Emory University, Atlanta, GA 30322. *On Saturation Spectrum.*

Given graphs G and H, we say that G is H-saturated if G does not contain a copy of H as a subgraph, but the addition of any edge $e \notin E(G)$ produces at least one copy of H in $G \cup e$. Given a positive integer n, the saturation number $sat(H, n)$ is the minimum number of edges on n vertices for which there exists an H-saurated graph. The well-studied extremal number, $ext(H, n)$, is the maximum number of edges on n vertices for which there exists an H-saturated graph. One question is for a fixed integer n, for what values m, $sat(H, n) \leq m \leq ext(H, n)$ does there exist an h-saturated graph. In this talk we explore what is known on this concept, called the saturation sectrum of H. (Received August 08, 2016)

1122-05-99 **John Engbers*** (john.engbers@marquette.edu). *Maximizing colorings of graphs.*

Given a family of graphs, which graph in the family has the most number of H-colorings (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.

What if we impose various connectedness requirements within the family? Doing so 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 August 09, 2016)

1122-05-100 **Brian G. Kronenthal*** (kronenthal@kutztown.edu), **Felix Lazebnik** and **Jason Williford**. *On the uniqueness of some girth eight algebraically defined graphs.*

In this talk, we will discuss algebraically defined bipartite graphs. Indeed, let $\mathbb{F}$ denote a field, and consider the bipartite graph with partite sets $P = \mathbb{F}^3 = L$ such that $(p_1, p_2, p_3) \in P$ and $[\ell_1, \ell_2, \ell_3] \in L$ are adjacent if and only if $p_2 + \ell_2 = p_1\ell_1$ and $p_3 + \ell_3 = p_1\ell_1^2$. This graph has girth eight, and of particular interest is whether it is possible to alter these equations by replacing $p_1\ell_1$ and $p_1\ell_1^2$ with other bivariate polynomials to create a nonisomorphic girth eight graph. In addition to discussing some results related to this question, we will also explain the connection between algebraically defined graphs and the point-line incidence graphs of generalized quadrangles, which partially motivates the study of the objects in this talk. (Received August 10, 2016)

1122-05-114 **Austin Parker**, **Kelly Yancey** and **Matthew Yancey*** (mpyance@super.org). *Regular Language Distance and Entropy.*

A language is a subset of words. A language L is regular if an arbitrary word w can be detected as belonging to L while using only a finite amount of memory as the individual characters of w stream by. We address the problem of determining the distance between two regular languages. We will show how to expand Jaccard distance, which works on finite sets, to potentially-infinite regular languages. This includes addressing issues that have required previous authors to rely on the upper limit of Shannon's traditional formulation of entropy, because its limit does not always exist. The theoretical work will involve counting walks in a directed graph that is **not** strongly connected. (Received August 10, 2016)

1122-05-118 **Stefaan De Winter*** (sgdewint@mtu.edu), Michigan Technological University, 1400 Townsend Drive, Fisher Hall, Houghton, MI 49931, and **Zeying Wang**. *Local multiplier results for Paley type partial difference sets.* Preliminary report.

Let $\mathcal{D}$ be a (v, k, λ, μ)-partial difference set in an Abelian group. Assume its parameters $\Delta = (\lambda - \mu)^2 + 4(k - \mu)$ is a perfect square. Recently a local version of a multiplier theorem for such partial difference sets has proven to be very useful in proving both non-existence and classification results. In this talk I will discuss a version in case the parameter Δ is not a perfect square. (Received August 11, 2016)

1122-05-127 **Virgil U Pierce*** (virgil.pierce@utrgv.edu), 1201 W University Drive, Edinburg, TX 78542. *Dispersionless Limits of the DKP Equations for Enumerating Mobius Graphs.* Preliminary report.

The partition functions of the orthogonal and symplectic ensembles of random matrices are tau functions of the Pfaff lattice hierarchy, and are solutions of the D-Type Kadomtsev-Petviashvili (DKP) hierarchy of equations. These partition functions for a special choice of initial conditions have combinatoric content in the limit as the size of the matrices goes to infinity: the asymptotic expansion of the log partition function in the matrix size parameter gives the enumeration of Mobius graphs partitioned by the Euler characteristic of the graph. This large matrix limit corresponds to a particular dispersionless limit of the DKP hierarchy (and its higher order corrections) and philosophically a continuum limit of the Pfaff lattice hierarchy. This is a work in progress. (Received August 10, 2016)

1122-05-138 **Kirsten Hogenson*** (kirsten.hogenson@coloradocollege.edu), Colorado Springs, CO 80903. *(4,2)-choosability of planar graphs with forbidden structures.*

All planar graphs are 4-colorable and 5-choosable, while some planar graphs are not 4-choosable. Determining which properties guarantee that a planar graph can be colored using lists of size four has received significant attention. In terms of constraining the structure of the graph, for any $\ell \in \{3, 4, 5, 6, 7\}$, a planar graph is 4-choosable if it is ℓ-cycle-free. In terms of constraining the list assignment, one refinement of k-choosability is choosability with separation. A graph is (k,s)-choosable if the graph is colorable from lists of size k where adjacent vertices have at most s common colors in their lists. Every planar graph is (4,1)-choosable, but there exist planar graphs that are not (4,3)-choosable. It is an open question whether planar graphs are always (4,2)-choosable. A chorded ℓ-cycle is an ℓ-cycle with one additional edge. In this talk, I will discuss a new result which states that a planar graph is (4,2)-choosable if it does not contain a chorded 6-cycle. This research was conducted during the 2014 Iowa State University discrete mathematics working seminar. (Received August 11, 2016)

1122-05-142 **Edward Hanson*** (hansone@newpaltz.edu). *New Characterizations of Leonard Pairs.*

Roughly speaking, a Leonard pair can be thought of as an algebraic generalization of a Q-polynomial distance-regular graph. Because of this connection, there are sequences of parameters associated with Leonard pairs that generalize the intersection numbers of a distance-regular graph. In this talk, we will discuss two new characterizations of Leonard pairs using these parameter sequences. (Received August 11, 2016)

1122-05-146 **Stefaan G. De Winter** and **Zeying Wang*** (zeying@mtu.edu), Michigan Technological University, Houghton, MI 49931. *Classification of PDS in Abelian groups of order $4p^2$.*

Recently we proved a theorem for strongly regular graphs that provides numerical restrictions on the number of fixed vertices and the number of vertices mapped to adjacent vertices under an automorphism. We then used this result to develop a new technique to study regular partial difference sets in Abelian groups. As a application we here provide a complete classification of partial difference sets in Abelian groups of order $4p^2$, p an odd prime. It turns that the known examples are the only examples. These are, up to complements, the trivial examples, the PCP examples, and a sporadic example in $\mathbb{Z}_2^2 \times \mathbb{Z}_3^2$.

In this talk I will present the main ideas used in our proof. I will conclude the talk with some ongoing research and ideas for future research. (Received August 11, 2016)

1122-05-159 **Allen Herman*** (allen.herman@uregina.ca), Department of Mathematics and Statistics, University of Regina, Regina, SK S4S 0A2, Canada. *The recognition problem for table algebras.*

We will discuss aspects of the table algebra recognition problem. Which semisimple algebras with involution have table algebra bases? If there is a table algebra basis, does it have an integral one? An interesting example is the 5-dimensional noncommutative semisimple algebra with conjugate transpose involution over $\mathbb{C}$, for which only non-integral table algebra bases exist. Other issues for recognition which I will raise are algorithms for deciding when a given element of the algebra belongs to a table algebra basis, and computational methods for

describing all standard integral table algebra bases for a given algebra. I will present preliminary results on these issues in dimensions up to 5. The results have been obtained in joint work with Mikhael Muzychuk and Bangteng Xu. (Received August 12, 2016)

1122-05-163 **Eric Swartz*** (easwartz@wm.edu), Department of Mathematics, College of William and Mary, P.O. Box 8795, Williamsburg, VA 23187-8795. *2-arc-transitive graphs of order kp^n.*

In recent years, there has been great interested in classifying graphs with a given amount of symmetry (e.g., 2-arc-transitive, arc-transitive, vertex-transitive) of a specific order (e.g., $4p$, where p is a prime). Many of these results follow a familiar pattern, and, in this spirit, we prove the following result: there exist functions c and g such that, if k, n and d are positive integers with $d > g(n)$ and Γ is a d-valent 2-arc-transitive graph of order kp^n with p a prime, then $p \leqslant kc(d)$. In other words, there are only finitely many d-valent 2-arc-transitive graphs of order kp^n with $d > g(n)$ and p prime, generalizing a recent result of Conder, Li and Potočnik. This is joint work with Luke Morgan and Gabriel Verret. (Received August 12, 2016)

1122-05-172 **Michael Tait*** (mtait@cmu.edu), Pittsburgh, PA 15224, and **Craig Timmons**. *Polarity graphs coming from planar polynomials.*

Given a planar polynomial one may construct a projective plane. If this plane admits a polarity, one may construct the corresponding polarity graph. We study the independence and chromatic numbers of such polarity graphs. This work recovers theorems about the independence and chromatic numbers of the Erdős-Renyi orthogonal polarity graph, but also applies to many other polarity graphs, including graphs coming from non-desarguesian planes and graphs where the polarity is neither orthogonal nor unitary. (Received August 12, 2016)

1122-05-173 **Michael Tait*** (mtait@cmu.edu), Pittsburgh, PA 15224, and **Josh Tobin**. *4 conjectures in extremal spectral graph theory.*

Extremal graph theory seeks to optimize a graph invariant over a family of graphs. We discuss how to prove 4 conjectures along these lines where the invariant in question is determined by the eigenvalues or eigenvectors of the adjacency matrix of the graph. All of the proofs follow a similar template, and we will end the talk with various problems to which one might try to apply our method. (Received August 12, 2016)

1122-05-174 **Michelle Delcourt**, **Bernard Lidický*** (lidicky@iastate.edu) and **Luke Postle**. *Decomposing random d-regular graphs into stars.* Preliminary report.

In 2006 Barat and Thomassen conjectured that every planar 4-regular 4-edge-connected graph has an edge decomposition into claws; shortly after, Lai constructed a counterexample. Recently, Delcourt and Postle showed that a random 4-regular graph has an edge decomposition into claws a.a.s.. We generalize the result to decomposition of d-regular graphs into stars for some d. We use the small subgraph conditioning method of Robinson and Wormald. (Received August 12, 2016)

1122-05-178 **Felix Lazebnik*** (fellaz@udel.edu), Department of Mathematical Sciences, University of Delaware, Newark, DE 19716, and **Shuying Sun** (shuying@udel.edu), Department of Mathematical Sciences, University of Delaware, Newark, DE 19716. *The Girth of Some Algebraically Defined Graphs.*

Let q be a prime power and k be an integer greater than 1. Bipartite graphs $D(k, q)$ were introduced by Lazebnik and Ustimenko in 1995, and found many applications. It is known that their girth (the length of a shortest cycle) is at least $k + 5$ for k odd, and at least $k + 4$ for k even. It is conjectured that these lower bounds are the exact values. In this talk we discuss the recent progress on this conjecture. (Received August 12, 2016)

1122-05-186 **Sung Y Song*** (sysong@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011. *Construction of partial geometric designs over finite fields.* Preliminary report.

We study a class of (q-analog) t-designs over finite fields and their intersection numbers. We use these to construct non-trivial partial geometric designs over finite fields. (Received August 12, 2016)

1122-05-190 **Paul M Terwilliger*** (terwilli@math.wisc.edu), U. Wisconsin Math Department, 480 Lincoln Drive, Madison, WI 53706. *Tridiagonal pairs of q-Racah type, the Bockting operator ψ, and L-operators for $U_q(L(\mathfrak{sl}_2))$.*

Tridiagonal pairs are used to describe the irreducible modules for the subconstituent algebra of a Q-polynomial distance-regular graph. Associated with any tridiagonal pair is a certain operator ψ due to Sarah Bockting-Conrad. We describe ψ for a tridiagonal pair of q-Racah type, in terms of a certain L-operator for the quantum loop algebra $U_q(L(\mathfrak{sl}_2))$. (Received August 13, 2016)

1122-05-198 **Yuqing Chen*** (yuqing.chen@wright.edu), 3640 Colonoel Glenn Hwy., Dayton, OH 45435. *A quadratic perfect non-linear function for many abelian 2-groups.* Preliminary report.

In this talk we present a quadratic function over a finite field of even characteristic which is perfect non-linear for all abelian 2-groups of a fixed order and of exponent no larger than 4. We will also discuss its connections with certain distance regular graphs and strongly regular graphs. (Received August 13, 2016)

1122-05-201 **Jianmin Ma*** (jianminma@yahoo.com), Department of Mathematics, Colorado State University, fort collins, CO 80523. *Nonexistence of certain distance regular graphs.* Preliminary report.

In this talk, we discuss how to eliminate several open parameter sets of distance-regular graphs. (Received August 13, 2016)

1122-05-231 **Aysel Erey*** (aysel.erey@gmail.com). *An extremal problem on the chromatic polynomial.*

Let $\mathcal{C}_k(n)$ be the family of all connected k-chromatic graphs of order n. We discuss recent results on the following problem: given a natural number $x \geq k$, what is the maximum number of x-colorings among graphs in $\mathcal{C}_k(n)$? (Received August 15, 2016)

1122-05-243 **Sarah Loeb*** (sloeb2@illinois.edu) and **Douglas B. West**. *Fractional Separation Dimension.*

Given a linear ordering σ of $V(G)$, say that a pair of nonincident edges is *separated* by σ if both vertices of one edge precede both vertices of the other. The *separation dimension* $\pi(G)$ of a graph G is the minimum size of a set of vertex orderings such that every pair of nonincident edges is separated in some ordering. The *fractional separation dimension* $\pi_f(G)$ is the infimum of $|\mathcal{F}|/l$ over all $l \in \mathbb{N}$ and all lists $\mathcal{F}$ of vertex orderings such that every pair of nonincident edges is separated in at least l orderings in $\mathcal{F}$.

We show that $\pi_f(G) \leq 3$ for every graph G, with equality if and only if $K_4 \subseteq G$. On the other hand, there is no sharper upper bound even for triangle-free graphs; we show $\pi_f(K_{m,m}) = \frac{3m}{m+1}$. (Received August 15, 2016)

1122-05-244 **Jae-Ho Lee*** (jhlee.math@gmail.com), 6-3-09 Aramaic-Aza-Aoba, Aoba-ku, Graduate School of Information Sciences, Tohoku University, Sendai, 980-8579, Japan. *The generalized Terwilliger algebra of dual polar graphs.*

Let Γ denote a dual polar graph contanning a Delsarte clique. Fix a vertex x in C and partition vertex set of Γ using x and C. This partition gives a vector space W that is a module for the algebra generated by the Terwilliger algebra $T(x)$ and the Terwilliger algebra $T(C)$. In this talk, we give a detailed description of the space W. (Received August 15, 2016)

1122-05-266 **Martin Rolek*** (mrolek@knights.ucf.edu), Orlando, FL 32817, and **Zi-Xia Song** (zixia.song@ucf.edu). *Cliques and Clique Minors in Double-Critical Graphs.*

A connected graph G is said to be double-critical if for any edge uv, $\chi(G-u-v) = \chi(G)-2$. A long-standing conjecture of Erdös and Lovász claims that the only double-critical t-chromatic graph is the complete graph K_t for all t. This has been shown to hold for $t \leq 5$, but remains open for $t \geq 6$. A recent weakening of this conjecture by Kawarabayashi, Pedersen, and Toft asserts that all double-critical t-chromatic graphs contain a K_t minor. In the same paper, they showed their conjecture to be true for $t \leq 7$. Albar and Gonçalves recently gave a long, computer-assisted proof for the case $t = 8$. Here, we give a much shorter, computer-free proof for the case $t = 8$, and extend the result to show that the weakened conjecture is true for $t = 9$, albeit with a computer-assisted lemma in this last case. We further examine claw-free double-critical t-chromatic graphs and show that the only such graph is the complete graph for $t = 6, 7$. We also improve some known properties of double-critical graphs: We show that any minimum separating set of size 6 must induce a subgraph of $K_{2,2,2}$ or $K_{3,3}$, and that any vertex of degree $t+1$ cannot be adjacent to a vertex of degree $t+2$. This is joint work with Zi-Xia Song. (Received August 15, 2016)

1122-05-270 **Gavin D King*** (gking3@uwyo.edu). *Searching for Schurian Balanced Sets.* Preliminary report.

Let S be a set of vectors on the unit sphere in $\mathbb{R}^d$ coming from a primitive idempotent of a symmetric association scheme. For some vectors $u, v \in S$ and constants $x, y \in \mathbb{R}$, let $R_{x,y}(u,v)$ be the sum of all vectors $s \in S$ such that $\langle s, u\rangle = x$ and $\langle s, v\rangle = y$. Such a set S is said to have the *balanced set property* of Terwilliger if for all $u, v \in S$ and $x, y \in \mathbb{R}$,

$$R_{x,y}(u,v) - R_{y,x}(u,v) \parallel y - x$$

Balanced sets arise naturally in the study of association schemes, where an association scheme gives rise to a balanced set if and only the *representation diagram* of that idempotent is a tree. If the representation diagram

is a path, we say that it has the Q-polynomial property; several examples of these schemes are known. Only one non-degenerate scheme is known whose representation diagram is a non-path tree: the 4-dimensional polytope known as the 600-cell. One special subcategory of association schemes is Schurian schemes, which arise from the orbitals of generously transitive permutation groups. In this talk, we describe the search for Schurian schemes giving balanced sets, both in the much more abundant Q-polynomial case and the much more poorly understood "Q-tree" case. (Received August 15, 2016)

1122-05-279 **Sarah R. Bockting-Conrad*** (sarah.bockting@depaul.edu). *Connections between the ψ, Δ, and $\mathcal{M}$ operators for a thin tridiagonal pair.*

Let $\mathbb{K}$ denote an algebraically closed field and let V denote a vector space over $\mathbb{K}$ with finite positive dimension. Let A, A^* denote a tridiagonal pair on V which has q-Racah type. In an earlier talk, we introduced the linear transformations $\psi : V \to V$, $\Delta : V \to V$, and $\mathcal{M} : V \to V$, each of which acts on the split decompositions of V in an attractive way. In this talk we focus on the situation when the tridiagonal pair A, A^* is thin. For this case, we will describe the relationship between these transformations in detail. (Received August 15, 2016)

1122-05-286 **Anne Schilling*** (anne@math.ucdavis.edu), Department of Mathematics, University of California, One Shields Avenue, 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 August 15, 2016)

1122-05-303 **Mark Kempton*** (mkempton@cmsa.fas.harvard.edu). *Quantum Tunneling on Graphs.* Preliminary report.

Given a graph G, the discrete Schrodinger equation on G is given by

$$H\phi_t = -i\frac{d}{dt}\phi_t,$$

and describes the evolution of the quantum state of a particle on a graph. Here, $H = \Delta - V$ where Δ is the graph Laplacian, and V is a diagonal matrix giving a potential at each vertex of G. It has been observed that solutions to the discrete Schrodinger equation sometimes exhibit the unexpected phenomenon that, if ϕ_0 is a characteristic function on a single vertex u of G, then at some time T, the solution ϕ_T is concentrated on a single different vertex v of G. When this happens, we say that tunneling occurs from u to v. In the absence of the potential V, this is sometimes also called perfect state transfer. We will give an overview of known results on quantum tunneling on graphs, and present some new directions based on recent work. (Received August 15, 2016)

1122-05-305 **Jason S Williford*** (jwillif1@uwyo.edu). *Q-polynomial association schemes with at most five classes.*

An association scheme can be thought of as a combinatorial generalization of a transitive finite permutation group. In the 1973 thesis of Philippe Delsarte, the author identified two special classes of association schemes: the so-called P-polynomial and Q-polynomial schemes. The schemes that are P-polynomial are precisely those generated by a distance-regular graph. However, the Q-polynomial schemes have no analogous combinatorial definition. In this talk, we will discuss what is known about primitive 3-class Q-polynomial schemes, and imprimitive Q-polynomial schemes with at most 5 classes. (Received August 15, 2016)

1122-05-307 **William J Martin*** (martin@wpi.edu), Department of Mathematical Sciences, 100 Institute Road, Worcester Polytechnic Institute, Worcester, MA 01609. *Scaffolds: A graph-based system for computations in Bose-Mesner algebras.* Preliminary report.

Let $(X, \mathcal{R})$ be an association scheme with Bose-Mesner algebra $\mathbb{A}$. Suppose we are given

- a (di)graph $G = (V(G), E(G))$
- a subset $R \subseteq V(G)$ of "red" nodes
- a map from edges of G to matrices in our Bose-Mesner algebra: $w : E(G) \to \mathbb{A}$ (edge weights), and

- a subset $F \subseteq V(G)$ of nodes and a function $\psi : F \to X$.

The *scaffold* $\mathsf{S}(G; R, F, \psi, w)$ is defined as the quantity

$$\mathsf{S}(G; R, F, \psi, w) = \sum_{\substack{\varphi: V(G) \to X \\ (\forall a \in F)(\varphi(a) = \psi(a))}} \prod_{\substack{e \in E(G) \\ e=(a,b)}} w(e)_{\varphi(a),\varphi(b)} \bigotimes_{r \in R} \widehat{\varphi(r)}.$$

When G is small, these are naturally encoded as simple diagrams and operations on these diagrams naturally represent certain transformations on scaffolds. Following work of Terwilliger, Dickie and Suzuki, we explore the known results on association schemes obtained using this language and offer a unified set of rules and lemmas along with several new results which utilize this technology. (Received August 15, 2016)

1122-05-317 **Kevin P Costello*** (costello@math.ucr.edu), Department of Mathematics, 900 University Avenue, Riverside, CA 92521. *On the Frequency of Integral Graphs.*

Call a graph *integral* if all of the eigenvalues of its adjacency matrix are integers. Although many families of integral graphs are known, there is no known general classfication, or even a precise estimate of their frequency.

I will discuss joint work with Parker Williams in which we give an upper bound on the number of such graphs (or, equivalently, the probability that a random symmetric matrix has purely integral spectrum). (Received August 16, 2016)

1122-05-320 **Zhanar Berikkyzy***, zhanarb@iastate.edu, and **Alex Schulte** and **Michael Young**. *Anti-van der Waerden numbers of 3-term arithmetic progressions.* Preliminary report.

The anti-van der Waerden number, denoted by $\mathrm{aw}([n], k)$, is the smallest r such that every exact r-coloring of $[n]$ contains a rainbow k-term arithmetic progression. Butler et. al. showed that $\lceil \log_3 n \rceil + 2 \leq \mathrm{aw}([n], 3) \leq \lceil \log_2 n \rceil + 1$, and conjectured that there exists a constant C such that $\mathrm{aw}([n], 3) \leq \lceil \log_3 n \rceil + C$. We show that this conjecture is true by determining $\mathrm{aw}([n], 3)$ for all n. This is joint work with Alex Schulte and Michael Young. (Received August 16, 2016)

1122-05-338 **Ron Gould**, **Paul Horn**, **Michael Jacobson** and **Brent Thomas*** (brent.thomas@usu.edu). *Gaps In The Saturation Spectrum Of Trees.* Preliminary report.

A graph G is H-saturated if H is not a subgraph of G but the addition of any edge from $\overline{G}$ to G results in a copy of H. The number of edges in a graph G is called the *size* of G. The minimum size of an H-saturated graph on n vertices is called the saturation number for H and is denoted $\mathbf{sat}(n, H)$; the maximum size is the extremal number, $\mathbf{ex}(n, H)$. Historically, the primary focus of the study of graph saturation was aimed at understanding the structure of H-saturated graphs with sizes close to the thresholds, $\mathbf{sat}(n, H)$ and $\mathbf{ex}(n, H)$, with the ultimate goal of determining these values. The saturation spectrum for a graph H is the set of sizes of H-saturated graphs between $\mathbf{sat}(n, H)$ and $\mathbf{ex}(n, H)$.

For large families of trees we give a bound on the maximum average degree of a connected H-saturated graph that is not a complete graph. One of the consequences of this bound is that the saturation spectrum has a gap immediately preceding $\mathbf{ex}(n, H)$. The proof used to give this bound and hence the gap in the saturation spectrum is not dependent on the structure of the tree, hence the proof establishes a general technique that could be applied to a broad families of trees. (Received August 16, 2016)

1122-05-342 **Jeno Lehel*** (lyency@gmail.com), 10401 Christina Crt., Louisville, KY 40223. *Path-pairability of Cartesian products.*

A graph G is *k-path-pairable*, if for any set of k disjoint pairs of vertices called *terminals*, s_i, t_i, $1 \leq i \leq k$, there exist pairwise edge-disjoint s_i, t_i-paths in G. Let $pp(G) = \max\{k \mid G \text{ is } k\text{-path-pairable}\}$ be the *path-pairability number* of G. A k-path pairable graph of order $2k$ is called *path-pairable*.

Trivial path-pairable graphs are the cliques and the stars of even order. It is known that path-pairable graphs can be obtained as the Cartesian product of cliques. This is not true for the product of stars, actually we determined the exact value $pp(K_{1,a} \square K_{1,b}) = \lceil (a+b)/2 \rceil$, for $a, b \geq 3$.

A sample of results and problems on the path-pairability number of the Cartesian product of trees and cliques will be presented. /Joint work with A.Jobson, A.Kézdy, G.Mészáros./ (Received August 16, 2016)

1122-05-350 **Michael Ferrara**, **Ellen Gethner**, **Stephen Hartke**, **Derrick Stolee** and **Paul S. Wenger*** (pswsma@rit.edu). *Precoloring Extension for Distinguishing Colorings.*

The *distinguishing number* of a graph G, denoted $D(G)$, is the minimum number of colors needed to color the vertices of G so that there are no nontrivial color-preserving automorphisms. In this talk we study how many vertices of a graph need to be left uncolored so that we can extend any partial precoloring of G with $D(G)$ colors to a distinguishing coloring. We will go beyond graphs, also studying this parameter for the unit circle

and the real line. This is joint work with Michael Ferrara, Ellen Gethner, Stephen Hartke, and Derrick Stolee. (Received August 16, 2016)

1122-05-358 **Jill Faudree*** (jrfaudree@alaska.edu), Department of Mathematics and Statistics, Fairbanks, AK 99709, and **Ron Gould**, **Michael Jacobson** and **Brent Thomas**. *Saturation Number and Saturation Spectrum of Brooms.*

Let H be a graph. A graph G is *H-saturated* if G contains no copy of H as a subgraph, but for each edge e in $\overline{G}$, the graph $G+e$ contains a copy of H. The saturation number of H, written $sat(n,H)$, is the minimum number of edges in an H-saturated graph with n vertices (assuming $n \geq |V(H)|$). A broom, $B_{s,t}$, is a tree on $s+t$ vertices formed by identifying the end vertex of a path on s vertices with the center vertex of a $K_{1,t}$. We determine $sat(n, B_{s,t})$ for all brooms such that $t \geq 6$.

The *saturation spectrum* for a graph H, which is denoted $spec(n,H)$, is the set of sizes of H-saturated graphs between $sat(n,H)$ and $ex(n,H)$, the extremal number of H. We prove that the saturation spectrum for a broom contains every integer from $sat(n,H)$ to within a constant of $ex(n,H)$. Additionally, we determine completely the saturation spectrum for a number of small brooms.

Some interesting examples and open problems will be presented.

This is joint work with Ron Gould, Mike Jacobson, and Brent Thomas. (Received August 16, 2016)

1122-05-364 **Dániel Gerbner**, **Balázs Keszegh**, **Cory Palmer*** (cory.palmer@umontana.edu) and **Balázs Patkós**. *On the number of cycles in a graph with restricted cycle lengths.*

Let L be a set of integers, each at least 3. We call a (directed) graph G an *L-cycle graph* if all cycle lengths in G belong to L. Let $c(L,n)$ be the maximum number of cycles possible in an n-vertex L-cycle graph (we use $\vec{c}(L,n)$ for the number of cycles in directed graphs). In the undirected case we show that for any fixed set L, we have $c(L,n) = \Theta_L(n^{\lfloor k/\ell \rfloor})$ where k is the largest element of L and 2ℓ is the smallest even element of L (if L contains only odd elements, then $c(L,n) = \Theta_L(n)$ holds.) We also give a characterization of L-cycle graphs when L is a single element.

In the directed case we prove that for any fixed set L we have $\vec{c}(L,n) = (1+o(1))(\frac{n-1}{k-1})^{k-1}$, where k is the largest element of L. We determine the exact value of $\vec{c}(\{k\},n)$ for every pair $k \leq n$ and characterize all graphs attaining this maximum. (Received August 16, 2016)

1122-05-366 **Andrzej Grzesik**, Krakow, Poland, **Ping Hu**, Coventry, CV47AL, United Kingdom, and **Jan Volec*** (honza@ucw.cz), 8050 Zurich, Switzerland. *Minimum number of edges that occur in odd cycles.*

If an n-vertex graph has more than $n^2/4$ edges, then G contains a copy of a cycle of length $2k+1$. Can we guarantee something stronger than just a single copy? In 1992, Erdos, Faudree and Rousseau showed that the number of edges that occur in a triangle in G is at least $n+1-(n \mod 2)$ and this bound is tight. They also showed that the number of edges in G that occur in a copy of $(2k+1)$-cycle, where $k>1$ is fixed, suddenly starts being quadratic in n, and it is asymptotically at least $11n^2/144$. However, they conjectured that the graph G must contain at least $(2/9+o(1))n^2$ such edges. Very recently, Furedi and Maleki showed that the conjecture is false in the case of 5-cycles by constructing n-vertex graphs with $n^2/4+1$ edges such that only $(2+\sqrt{2}+o(1))n^2/16 < 0.214n^2$ edges occur in 5-cycles, and proved an asymptotically correct lower bound on the number of such edges under the additional assumption that G has $(1/4+\epsilon)n^2$ edges. In this talk, we use a flag algebra approach to tackle this problem and show that every n-vertex graph with more than $n^2/4$ edges contains $(2+\sqrt{2}-o(1))n^2/16$ edges that occur in 5-cycles, which settles a conjecture of Furedi and Maleki. Moreover, we obtain the corresponding stability result and discuss analogous results for longer odd cycles. (Received August 16, 2016)

06 ► Order, lattices, ordered algebraic structures

1122-06-18 **Gezahagne Mulat Addis*** (buttu412@yahoo.com), Zobil Akababi, 196 Gondar, Amhara, Ethiopia. *Construction of an RCDL-Vector Spaces.*

In this paper we characterize relatively complemented distributive lattices with least element 0 (some authors call it a Generalized Boolean Algebra) which is a Boolean algebra not containing the largest element 1) and we prove the duality between relatively complemented distributive lattices with least element 0 and Boolean rings

(not containing the unity element 1). Moreover, we introduce the notion of an RCDL-Vector space; that is, a vector space over a relatively complemented distributive lattice with least element 0 (over a generalized boolean algebra). In the case such that, this lattice has the largest element 1, this vector space becomes a Boolean Vector space introduced by N. V. Subrahmanyam (1964). The norm and distance functions on an RCDL-Vector space are also discussed. (Received August 15, 2016)

1122-06-79 **Clifford Bergman*** (cbergman@iastate.edu). *Varieties of Boolean Semilattices.*

A *Boolean semilattice* is a Boolean algebra with a single normal binary operator that is associative, commutative and square-increasing. Boolean semilattices have a rich structure and representation theory as well as relationships to other objects in algebraic logic. In this talk I will survey what little is known about the lattice of subvarieties of Boolean semilattices, and pose some interesting open problems. (Received August 08, 2016)

1122-06-90 **George Metcalfe*** (george.metcalfe@math.unibe.ch). *Partial Orders on Free Groups and the Word Problem for Free Lattice-Ordered Groups.*

The aim of this talk will be to demonstrate the equivalence of two decision problems from the theory of ordered groups: namely, the problem of deciding whether a finitely generated partial right order on a free group extends to a total right order and the word problem for free lattice-ordered groups. A reward for establishing this equivalence is that various algorithms used to decide one problem can be used also to decide the other. Time permitting, the connection with proof theory for lattice-ordered groups and a similar equivalence for partial orders on free groups and deciding equations in ordered groups will be discussed. (Received August 09, 2016)

1122-06-98 **John Harding*** (jharding@nmsu.edu), Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003. *Algebras in type 2 fuzzy sets.*

Type 2 fuzzy sets are a generalization of fuzzy sets allowing a distribution $f : [0,1] \to [0,1]$ as a degree of membership rather than simply a single value. The truth value algebra for type 2 fuzzy sets is the collection M of all functions $f : [0,1] \to [0,1]$ equipped with operations introduced by Zadeh that are essentially convolutions of operations on the unit interval. The study of the algebra M, and its application in fuzzy control, involves a number of ordered algebraic structures including Birkhoff systems, de Morgan algebras, complex algebras, and quantales. These lead to interesting problems in universal algebra and to connections to current lines of research. (Received August 09, 2016)

1122-06-188 **Alasdair Urquhart*** (urquhart@cs.toronto.edu), Department of Computer Science, Sandford Fleming Building, University of Toronto, Toronto, Ontario M5S 3G4, Canada. *The Geometry of Relevant Implication.*

The logic **KR** is the result of adding the axiom $(A \wedge \neg A) \to B$ to the relevant logic **R**. This paper is a continuation of earlier work by the author on the connection between the logic **KR** and projective geometry. It contains a new, simplified construction of **KR** model structures; as a consequence, it extends the previous results to a much more extensive class of projective spaces and the corresponding modular lattices. (Received August 13, 2016)

1122-06-205 **Vincenzo Marra*** (vincenzo.marra@unimi.it), Dipartimento di Matematica *F. Enriques*, Università degli Studi di Milano, via Cesare Saldini 50, 20133 Milan, Italy. *Separability for lattice-ordered Abelian groups and MV-algebras: a characterisation theorem.*

This is joint work with Matias Menni (CONICET, Argentina). The classical notion of separable algebra has been abstracted to any category satisfying certain assumptions. See A. Carboni and G. Janelidze, J. Pure and Applied Algebra, 110(1996) no. 3, 219–240. This leads to a notion of separable lattice-ordered Abelian group with a strong unit, or equivalently, separable MV-algebra. Theorem: An MV-algebra is separable if, and only if, it is (isomorphic to) a finite product of subalgebra of $[0,1] \cap \mathbb{Q}$, the MV-algebra of rational numbers. The proof of this purely algebraic result is substantial; I will sketch it in the available time. Motivation: The result provides foundations for the current programme of extending the algebraic geometry of Baker-Beynon duality from coefficients in $\mathbb{Z}$ (lattice-groups, or MV-algebras) to coefficients in an arbitrary ordered subring of the reals, i.e. in a simple extension of $\mathbb{Z}$. The largest possible such extension, the reals, corresponds to vector lattices. The result presented here identifies simple separable extensions of $\mathbb{Z}$ amongst all extensions as precisely the rational ones. (Received August 14, 2016)

1122-06-208 **Wesley Fussner*** (wesley.fussner@du.edu) and **Nick Galatos**. *Esakia duality for Sugihara monoids.*

Sugihara monoids are idempotent, distributive, involutive commutative residuated lattices. They form the equivalent algebraic semantics for the well-studied relevance logic **R**-mingle as formulated with Ackermann constants, and have recently been shown to have a connection to certain expansions of subvarieties of Heyting

algebras. Exploiting this connection, we provide an Esakia-style duality for the category of Sugihara monoids in two ways: First, as a variation on well-known dualities for Heyting algebras equipped with nuclei, and second, as specialized from the Davey-Werner natural duality for Kleene algebras and its analogue for algebras without bounds in the signature. The latter characterization places this duality in a relationship to the Davey-Werner duality in a way directly analogous to that of the Esakia duality to Priestley's duality for bounded distributive lattices. (Received August 16, 2016)

1122-06-211 **Guram Bezhanishvili*** (guram@math.nmsu.edu), Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003, and **John Harding** (jharding@nmsu.edu), Department of Mathematical Sciences, New Mexico State University, Las Cruces, NM 88003. *On the proof that compact Hausdorff Boolean algebras are powersets.*

It is a well known result of Papert Strauss (1968) that a compact Hausdorff topological Boolean algebra is a powerset algebra. Her proof uses Pontryagin duality. An elementary proof of this result is surprisingly challenging. We give one such proof that relies on a version of Bogolyubov's lemma.

Papert Strauss' result is no longer true for distributive lattices. However, we show that it remains true for Heyting algebras. (Received August 14, 2016)

1122-06-246 **Benoit Larose** and **Ross Willard*** (ross.willard@uwaterloo.ca). *Series-parallel posets having a near-unanimity polymorphism.* Preliminary report.

A finite poset $\mathbb{P}$ is *series-parallel* if it can be constructed from one-element posets via disjoint unions and linear sums – equivalently, if it has no subposet isomorphic to the N-poset (the 4-crown with one comparability removed). Series-parallel posets are interesting because they are relatively uncomplicated and provide a good sandbox in which to play.

A *polymorphism* of $\mathbb{P}$ is a homomorphism $h : \mathbb{P}^n \to \mathbb{P}$ from some finite power of $\mathbb{P}$ to $\mathbb{P}$. It is a *near-unanimity* polymorphism if $n \geq 3$ and

$$h(a, \ldots, a, b, a, \ldots, a) = a$$

for all $a, b \in P$ and all positions of the lone b.

Dalmau, Krokhin and Larose (*Discrete Math.* **308** (2008), 2104–2114) gave several characterizations of series-parallel posets having a Taylor polymorphism. We give some characterizations of series-parallel posets with a near-unanimity polymorphism. (Received August 15, 2016)

1122-06-293 **John Rhodes*** (rhodes@math.berkeley.edu) and **Pedro V. Silva** (pvsilva@fc.up.pt). *Boolean Representations of Simplicial Complexes: Beyond Matroids.*

I will give a "crash course" on finite simplicial complexes admitting Boolean representations. Arbitrary finite matroids arise as a particular case. Zur Izhakian and I invented the theory of Boolean representations of simplicial complexes in 2008, and Pedro Silva and I later developed and matured the theory (see reference). Stuart Margolis has recently made contributions to the theory. We emphasize geometric, topological and combinatorial sides of the theory.

Reference: Boolean Representations of Simplicial Complexes and Matroids, by Rhodes and Silva, Springer Monographs in Mathematics, 2015 (Received August 15, 2016)

1122-06-311 **M. Andrew Moshier*** (moshier@chapman.edu), Mathematics, Physics and Computation, Chapman University, Orange, CA 92867. *Duality for Arbitrary Bounded Lattices.* Preliminary report.

Bounded lattices are not obviously amenable to representation by natural duality. On the other hand, Birkhof's notion of a *polarity* provides the structural part of a duality for complete lattices by giving a general method for specifying closure operators on powersets by generalized negation. This is not truly a duality because it only provides representation of the structures, not the morphisms. Nevertheless, various authors have proposed ways to wed polarity to topology, obtaining dual representations of general bounded lattices. In all the foregoing attempts, however, morphisms are restricted. So the dualities obtained are not full for bounded lattices and bounded lattice morphisms.

In this talk we make an honest marriage of polarity to topology by taking the natural topological duals of the meet semilattice and join semilattice reducts of a lattice L together with a polarity ($\not\leq$) between these spaces. This gives rise to a category of *spectral polarities* and a dual reflection of spectral polarities in bounded lattices. We also characterize those spectral polarities that are in the image of this reflection, thus obtaining a dual categorical equivalence between stable spectral polarities and bounded lattices. (Received August 15, 2016)

1122-06-353 **Gavin St. John*** (gavin.stjohn@du.edu). *Undecidability for certain subvarieties of commutative residuated lattices.*

The decidability of the equational and quasi-equational theories for commutative residuated lattices (**CRL**'s) axiomatized by $\{\cdot, 1, \leq\}$-inequalities has been fully classified (e.g. quasi-equational theories axiomatized by knotted rules of the form $x^n \leq x^m$, $n \neq m$, are decidable). We show that subvarieties of **CRL**'s axiomatized by rules from a certain class $\mathcal{D}$ of $\{\cdot, 1, \vee\}$-inequalities have an undecidable quasi-equational theory, and rules from a certain subset of $\mathcal{D}$ have an undecidable equational theory (e.g. inequalities such as $x \leq x^3 \vee x^2 \vee 1$ and $xy \leq x^2y^3 \vee x^3y^4$ yield undecidable quasi-equational theories, while $x \leq x^3 \vee x^2$ and $xy \leq x^2y^3 \vee x^3y^4$ have undecidable equational theories). Explicitly, for each $\mathbf{d} \in D$, there exists $R_{\mathbf{d}} \in \mathbf{CRL}$ such that $R_{\mathbf{d}} \in \mathcal{V}$ implies $\mathcal{V}$ has an undecidable quasi-equational theory, for any variety $\mathcal{V} \subseteq \mathbf{CRL}$. (Received August 16, 2016)

1122-06-382 **Clifford Bergman** and **William DeMeo*** (williamdemeo@gmail.com). *Some Algebraic Methods for CSP: with applications to commutative idempotent binars.*

We present some recently discovered algebraic methods for proving that certain classes of constraint satisfaction problems are tractable. We demonstrate how to apply these methods to a class of finite algebras known as commutative idempotent binars, and we prove that every such algebra of cardinality at most 4 yields a tractable constraint satisfaction problem. (Received August 16, 2016)

08 ► General algebraic systems

1122-08-204 **Andrei Bulatov**, **Peter Mayr** and **Agnes Szendrei*** (agnes.szendrei@colorado.edu). *The complexity of comparing subalgebras given by generators.* Preliminary report.

Let $\mathbf{A}$ be a fixed finite algebra. Given generating sets for two subalgebras of a finite power of $\mathbf{A}$, how difficult is it to determine whether one of the subalgebras is contained in the other? A polynomial time equivalent computational problem is the subpower membership problem for $\mathbf{A}$, which inputs finitely many tuples $a_1, \ldots, a_k$ and b from a finite power of $\mathbf{A}$, and asks whether b lies in the subalgebra generated by $a_1, \ldots, a_k$. We will discuss sufficient conditions on $\mathbf{A}$ such that there exist polynomial time algorithms for these decision problems. (Received August 14, 2016)

1122-08-314 **Keith A Kearnes*** (keith.kearnes@colorado.edu) and **Agnes Szendrei**. *Cube term blockers without finiteness.*

A new and natural Maltsev class was discovered about ten years ago, which generalizes both the class of congruence permutable varieties and the class of near unanimity varieties: it is the class of varieties with a cube term. I will discuss how to determine if an idempotent variety has a cube term. (Received August 16, 2016)

11 ► Number theory

1122-11-294 **Miranda C.N. Cheng** and **John F.R. Duncan*** (john.duncan@emory.edu), Dept. of Math and C.S., Emory University, 400 Dowman Dr, W401, Atlanta, GA 30322. *Genus Zero Groups in Moonshine.*

Genus zero groups of isometries of the hyperbolic plane play an important role in monstrous moonshine. In this talk we describe joint work with Miranda Cheng which classifies the mock modular forms with minimal growth whose coefficients are algebraic. This reveals a fundamental role for genus zero groups in umbral moonshine, and points to new paths for the future development of the theory. (Received August 15, 2016)

13 ► Commutative rings and algebras

1122-13-180 **Josh Stangle*** (jjstangl@syr.edu), 215 Carnegie Building, Syracuse University, NY 13244. *Orders and Non-commutative Crepant Resolutions.*

In 2004, Van den Bergh defined a non-commutative (crepant) resolution (NCCR) of singularities for a Gorenstein normal domain, R. The definition leads to many strong theorems and connections between commutative algebra and algebraic geometry. Additionally, theorems of Auslander give a constructive analog: NCCRs can be realized as endomorphism rings over R which are maximal Cohen-Macaulay R-modules and have finite global dimension. One goal of current research is to find a definition in the case of Cohen-Macaulay normal domains which replicates

some of these strong results and possesses a constructive analog. We will discuss the Gorenstein case and introduce some possible definitions (and obstructions) in the non-Gorenstein case. (Received August 12, 2016)

14 ► Algebraic geometry

1122-14-31 **Derek Tomlin*** (derek.tomlin@mavs.uta.edu), Dept. of Mathematics, P.O. Box 19408, Arlington, TX 76019, and **Michaela Vancliff**. *On the Line Scheme of $\mathcal{A}(\alpha)$.*

Inspired by the work of Artin, Tate, and Van den Bergh, geometric methods via schemes of *d-linear* modules have been developed by various researchers in an attempt to further the classification of regular algebras of global dimension four, so-called quantum $\mathbb{P}^3$s. In this talk, we discuss the one-dimensional line scheme of a certain family of algebras whose generic member is a candidate for a generic quadratic quantum $\mathbb{P}^3$. In particular, we examine the curves in $\mathbb{P}^5$ that comprise the line scheme, and we describe the lines in $\mathbb{P}^3$ parametrized by them. (Received July 28, 2016)

1122-14-50 **Alisa Knizel*** (alisik@mit.edu). *Moduli spaces of q-connections and gap probabilities.*

We will talk about a generalized q-analogue of methods introduced by Arinkin and Borodin. In particular we will explain how the one-interval gap probability for the q-Hahn orthogonal polynomial ensemble can be expressed through a solution of the asymmetric q-Painlevé V equation, which requires a new derivation of a q-difference equation of Sakai's hierarchy of type $A_2^{(1)}$. (Received August 02, 2016)

1122-14-113 **Vladimir Dragovic***, 800 West Campbell Rd., Mail Station FO 35, Richardson, TX 75080, and **Vasilisa Shramchenko**, 2500, boul. de l'Universite, Sherbrooke, Quebec J1K 2R1, Canada. *Algebro-geometric solutions to Schlesinger systems II: hyperelliptic case.*

Abstract. For a hyperelliptic curve a differential of third kind is constructed. The initial data for construction of the meromorphic differential include a point in the Jacobian of the curve, under the assumption that this point has nonvariable coordinates with respect to the lattice of the Jacobian while the branch points vary. The corresponding solutions of the rank two Schlesinger systems associated with hyperelliptic curves are constructed in terms of this differential. It appears that the cases where the coordinates of the point are rational correspond to periodic trajectories of the billiard ordered games associated with g confocal quadrics in (g+1)-dimensional space. This is a generalization of a situation studied by Hitchin. The research is partially supported by the NSF grant 1444147 and NSERC discovery grant. (Received August 10, 2016)

1122-14-120 **Anton Leykin*** (leykin@math.gatech.edu) and **Frank Sottile**. *Trace test.*

We give a brief derivation of the trace test to verify completeness of a partial witness set of an irreducible variety in affine or projective space. We also demonstrate how to apply the trace test for subvarieties of products of projective spaces working with multihomogeneous witness sets and using local coordinates. (Received August 10, 2016)

1122-14-137 **Jonathan Hauenstein** (hauenstein@nd.edu) and **Jose Israel Rodriguez*** (joisro@uchicago.edu), Department of Statistics, Chicago, IL 60657, and **Frank Sottile** (sottile@math.tamu.edu). *Numerical computation of Galois groups.*

The Galois/monodromy group of a family of equations (or of a geometric problem) is a subtle invariant that encodes the structure of the solutions. In this talk, we will use numerical algebraic geometry to compute Galois groups. Our algorithm computes a witness set for the critical points of our family of equations. With this witness set, we use homotopy continuation to construct a generating set for the Galois group. Examples from optimization will be stated (maximum likelihood estimation and formation shape control). (Received August 11, 2016)

1122-14-181 **Bong H Lian*** (lian@brandeis.edu). *D-modules, period integrals and invariants.* Preliminary report.

I will give an overview of some recent work on theory of period integrals, and its connections to D-modules and invariant theory. (Received August 12, 2016)

1122-14-226 **Daniel Brake*** (dbrake@nd.edu), 153 Hurley Building, Notre Dame, IN 46556. *Desingularizing cells of numerical real decompositions.* Preliminary report.

Real algebraic components are computable by a variety of methods, including Cylindrical Algebraic Decomposition, ray tracing, and the numerical cellular decomposition. Bertini_real implements the numerical method, which uses a combination of homotopy continuation and symbolics such as isosingular deflation to decompose

real curves and surfaces in any reasonable ambient dimension. Using linear projection values as parameters for the implicit function theorem, Bertini_real's output is a set of cells consisting of lower-dimensional boundary and generic cells, and a homotopy connecting them. This talk will discuss desingularization of the cell homotopy for 1- and 2-cells of numerical real decompositions. (Received August 14, 2016)

1122-14-233 **Dan Bates*** (bates@math.colostate.edu), **Eric Hanson**, **Jonathan Hauenstein**, **Alan Liddell** and **Charles Wampler**. *Finding exceptional sets with fiber products.*

Given a parameterized polynomial system, the dimension of the solution set is the same for almost all points in the parameter space. Points at which that dimension is higher than the usual dimension form exceptional sets. Exceptional sets are of interest both within mathematics and in various application areas, especially mechanism design.

This talk begins with a very brief recap of the general setup of the 2008 Sommese-Wampler technique for computing exceptional sets with fiber products. The bulk of the talk then focuses on our recent work in computing fiber products more efficiently, replacing massive *ab initio* solves with a fairly intricate sequence of homotopies. While this technique goes a bit beyond the foundations of numerical algebraic geometry, this talk will demonstrate the value of several foundational methods. (Received August 15, 2016)

1122-14-269 **Timothy E Hodges*** (hodges@math.colostate.edu). *Extending Bertini 2.0 for your own purposes.*

With the current redevelopment of Bertini as open source software hosted on Github, users have the opportunity to directly extend the capabilities of Bertini for their own purposes. In this talk, we introduce some of the high-level structures and paradigms of Bertini 2.0 and describe how to develop new code in the Bertini 2.0 environment. (Received August 15, 2016)

1122-14-284 **Daniel J. Bates**, **Brent Davis** and **Elizabeth Gross*** (elizabeth.gross@sjsu.edu), San Jose, CA 95192, and **Kenneth 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 August 15, 2016)

1122-14-340 **Brent R Davis*** (davisb@math.colostate.edu), 1874 Campus Delivery, Fort Collins, CO 80523-1874. *Numerical algebraic geometry for model selection.* Preliminary report.

Researchers working with mathematical models are often confronted by the related problems of parameter estimation, model validation, and model selection. These are all optimization problems, well-known to be challenging due to non-linearity, non-convexity and multiple local optima. Furthermore, the challenges are compounded when only partial data is available. Here, we consider polynomial models (e.g., mass-action chemical reaction networks at steady state) and describe a framework for their analysis based on optimization using numerical algebraic geometry. Our approach exploits the geometric structures relating models and data, and we demonstrate its utility on examples from the life sciences. (Received August 16, 2016)

1122-14-343 **Nathan R Bliss***, 851 S. Morgan Street (m/c 249), Chicago, IL 60607, and **Jan Verschelde**. *Computing all Space Curve Solutions of Polynomial Systems by Polyhedral Methods.*

A polyhedral method to solve a system of polynomial equations exploits its sparse structure via the Newton polytopes of the polynomials. We propose a hybrid symbolic-numeric method to compute a Puiseux series expansion for every space curve that is a solution of a polynomial system. Our focus here concerns the difficult case when the leading powers of the Puiseux series of the space curve are contained in the relative interior of a higher dimensional cone of the tropical prevariety. We show that this difficult case does not occur for polynomials with generic coefficients. To resolve this case, we propose to apply polyhedral end games to recover tropisms hidden in the tropical prevariety. (Received August 16, 2016)

1122-14-373 **Adrian Stefan Carstea** and **Anton Dzhamay*** (adzham@unco.edu), School of Mathematical Sciences, University of Northern Colorado, 501 20th Street, Greeley, CO 80639, and **Tomoyuki Takenawa**. *Deautonomization and Elliptic Difference Painlevé Equations with Special Symmetry Groups.*

Historically, many examples of discrete Painlevé equations were obtained as an application of the singularity confinement techniques to deautonomized versions of some autonomous maps, particularly the QRT-type maps, in the works of B. Grammaticos, A. Ramani, and their collaborators. This approach was primarily focused on explicit equations. We outline how one can do deautonomization in a systematic way using the geometric ideas of Sakai's theory. Starting with a birational two-dimensional mapping preserving a rational elliptic fibration (such as a QRT mapping), we choose a fiber and construct the deautonomized version of the mapping that preserves the type of the chosen fiber. We also explain some factorization techniques that allow us to obtain the explicit formulae for the deautonomized mappings. As an application we obtain new and simple elliptic difference Painlevé equations whose symmetry groups do not appear explicitly in Sakai's classification scheme, since these are special constrained cases. (Received August 16, 2016)

1122-14-374 **Nickolas Hein*** (nhein@benedictine.edu) and **Frank Sottile** (sottile@math.tamu.edu). *Liason pruning for certifiable Schubert calculus in geometry of type-C.* Preliminary report.

Square formulations for intersections in classical (type-A) Schubert calculus obtained via duality or by lifting to a more refined flag manifold generalize to other types, but the generalization may not be square. This is problematic for applications that require certification of solutions.

We will see a square formulation for a variety *containing* the solutions to a Schubert problem in a Lagrangian (type-C) Grassmannian. That is, we have a square system defining $X \cup Y$ where X is the set of solutions to the Schubert problem, and Y is another variety, which may be formulated using another square system. If we have numerical solutions to the square system for $X \cup Y$, we use the liason between X and Y to indirectly certify the approximate points of X. The strategy is to certify the points of $X \cup Y$, then certify the points of Y, then take the difference. Combinatorial rules from Schubert calculus indicate whether the number of point remaining, after the points of Y have been pruned, is the degree of X. When this occurs, we have indirectly obtained a certificate for the approximate solutions of X. (Received August 16, 2016)

1122-14-375 **Taylor Brysiewicz*** (tbrysiewicz@math.tamu.edu). *Computing Newton Polytopes via Numerical Algebraic Geometry.*

Although computing the defining polynomial of a hypersurface coming from a projection is often computationally infeasible, computing its Newton polytope is not. In 2012, Hauenstein and Sottile gave a numerical algorithm which provides what is known as an *oracle representation* for such a polytope. Using this oracle, we can retrieve the vertices of the polytope by an algorithm called beneath-beyond. In this talk, I will discuss both algorithms and present my most recent implementations of them. (Received August 16, 2016)

1122-14-378 **Matthew Niemerg*** (matthewniemerg@us.ibm.com) and **Martin Helmer** (martin.hemler@berkeley.edu). *Illuminating the Shadow of the Blowup.*

Any variety V can be written as the union of its irreducible components. A numerical irreducible decomposition consists of a *witness set* for each irreducible component of V. Once a numerical irreducible decomposition is computed, one can then compute projections onto a subset of the coordinates. The degree of this projection is intimately related to the multiprojective degree of a variety that lies in a product of projective spaces. Current methods for finding the numerical irreducible decomposition of a variety that lies in such a multiprojective space do not always use the multiprojective structure and those that do are not adapted for computing degree of the projection, also known as the shadow of the blowup. In this talk, I will present a new algorithm, Illumination, that computes the shadow of the blowup and, with careful book-keeping, the numerical irreducible decomposition of V. This is joint work with Martin Helmer. (Received August 16, 2016)

15 ► Linear and multilinear algebra; matrix theory

1122-15-83 **James B Wilson*** (james.wilson@colostate.edu), Department of Mathematics, Colorado State University, Fort Collins, CO 80523. *We should never have tensored with rings; Lie algebra tensors are universal.*

Representations on tensor products seem unmanageable in part because the dimensions grow exponentially. But there is now a different tensor product taken over Lie algebras rather than rings and which we prove is the universally smallest tensor product. To illustrate the impact, the 512-dimensional tensor space containing the

octonions is actually 1-dimensional over its Lie algebra, and the 19,683-dimensional tensor space containing the exceptional Jordan algebra collapses to a 5-dimensional space. The list goes on including all simple Lie algebras and simple modules. Because of the universality, each representation of groups or algebras on these tensor spaces condenses in a manner similar to Morita equivalence.

The main tool is a family of Galois connections between operators and tensor spaces, each parameterized by an affine scheme. This reports on individual and joint work with U. First and J. Maglione. (Received August 08, 2016)

1122-15-111 **Kristin E Heysse*** (keheysse@iastate.edu), 396 Carver Hall, 411 Morrill Road, Ames, IA 50011. *Constructions for distance cospectral graphs.*

The distance matrix of a connected graph is the symmetric matrix with columns and rows indexed by the vertices and entries that are the pairwise distances between the corresponding vertices. We give a construction for graphs which differ in their edge counts yet are cospectral with respect to the distance matrix. Further, we identify a subgraph switching behavior which constructs additional distance cospectral graphs. The proofs for both constructions rely on a perturbation of (most of) the distance eigenvectors of one graph to yield the distance eigenvectors of the other. (Received August 10, 2016)

16 ► Associative rings and algebras

1122-16-28 **Jason Gaddis*** (gaddisjd@wfu.edu), **Ellen Kirkman** (kirkman@wfu.edu) and **W. Frank Moore** (moorewf@wfu.edu). *On the discriminant of twisted tensor products.*

Automorphism groups of commutative and noncommutative algebras can be notoriously difficult to compute. The work of Ceken, Palmieri, Wang, and Zhang shows how one can approach this problem using the discriminant. In work with Ellen Kirkman and Frank Moore, we provide formulas for computing the discriminant of noncommutative algebras over central subalgebras in the case of Ore extensions and skew group extensions. The formulas follow from a more general result regarding the discriminants of certain twisted tensor products. (Received July 26, 2016)

1122-16-47 **Milen Yakimov*** (yakimov@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70808, and **Jesse Levitt** (jlevit3@lsu.edu), Department of Mathematics, University of Southern California, Los Angeles, CA 90089. *Rigidity of quadratic Poisson tori.*

We will describe a general theorem for rigidity of the automorphism groups of completed quadratic Poisson tori in characteristic 0. It gives a way to compute explicitly the automorphism groups of N-graded connected cluster algebras with respect to the Gekhtman-Shapiro-Vainshtein Poisson structure. As an application we will describe the automorphism groups of the coordinate rings of the Schubert cells of all symmetrizable Kac-Moody groups for the standard Poisson structures on their flag varieties. (Received August 02, 2016)

1122-16-49 **Michael Ben-Zvi**, Tufts University, **Alexander Ma**, University of Minnesota, and **Manuel L. Reyes*** (reyes@bowdoin.edu), Bowdoin College, Department of Mathematics, 8600 College Station, Brunswick, ME 04011-8486. *Quantum colorings of idempotent integer matrices.*

A Kochen-Specker (KS) coloring of a set S of idempotent $n \times n$ matrices over a ring R is an assignment of 0 and 1 to all elements of S such that, if $I_n = \sum E_i$ is a sum of orthogonal idempotents in S, then one of the E_i is assigned 1 and the rest are assigned 0. In their investigations into the foundations of quantum physics, Kochen and Specker proved that there is no KS coloring of the symmetric idempotent real matrices, establishing that there is no non-contextual hidden variable theory for quantum mechanics.

The KS theorem was recently applied in noncommutative geometry to show that every extension of the Zariski spectrum functor from commutative to noncommutative rings must assign the empty space to $\mathbb{M}_3(R)$ for every complex algebra R. Seeking to extend this result to all rings R, we are led to ask whether there is a version of the Kochen-Specker theorem for integer matrices.

By considering symmetric and non-symmetric matrices over various commutative rings, we show that the set of symmetric idempotent 3×3 integer matrices has a KS coloring, but that the set of all idempotent integer 3×3 matrices has no KS coloring. We apply this result to show that the spectrum obstruction above extends to all rings R. (Received August 02, 2016)

1122-16-64 **Yanhua Wang*** (yhw@mail.shufe.edu.cn), School of Mathematics, Shanghai University of Finance and Economics, Shanghai, 200433, Peoples Rep of China. *Invariant theory for quantum Weyl algebras under finite group action.*

This is a joint work with S. Ceken, J. H. Palmieri and J. J. Zhang. We study the invariant theory of a class of quantum Weyl algebras under group actions. It is proved that the fixed subrings are always Gorenstein. The Tits alternative for the automorphism groups of these quantum Weyl algebras was verified. (Received August 06, 2016)

1122-16-116 **Robert Won*** (wonrj@wfu.edu). *The noncommutative schemes of generalized Weyl algebras.*

The first Weyl algebra, A_1, admits a natural $\mathbb{Z}$-grading. Paul Smith showed that gr-A_1, the category of graded A_1-modules, is equivalent to the category of quasicoherent sheaves on a certain quotient stack. Using autoequivalences of gr-A_1, Smith constructed a commutative ring C, graded by finite subsets of the integers and proved that gr-C is equivalent to gr-A_1. Here, we generalize results of Smith by using autoequivalences of a graded module category to construct rings with equivalent graded module categories. For certain generalized Weyl algebras, we use autoequivalences defined in a so that these constructions yield commutative rings. (Received August 10, 2016)

1122-16-122 **Cris Negron*** (negronc@mit.edu) and **Richard Ng** (rng@math.lsu.edu). *Gauge invariants from the antipode for Hopf algebras with the Chevalley property.* Preliminary report.

By results of Larson and Radford, we know that the antipode of any finite dimensional Hopf algebra has finite order, and that such a Hopf algebra is semisimple if and only if the antipode is an involution (in characteristic 0). From this one can conclude immediately that if two semisimple Hopf algebras are gauge equivalent, i.e. if their categories of representations are monoidally equivalent, then their antipodes must have the same order. In this talk we will discuss invariance of the order of the antipode, and traces of the powers of the antipode, under gauge equivalence for non-semisimple Hopf algebras. In particular, we will see that these values are gauge invariants for Hopf algebras with the Chevalley property (e.g. Taft algebras and duals of pointed Hopf algebras). Some consequences for the indicators of non-semisimple Hopf algebras will be mentioned. (Received August 10, 2016)

1122-16-141 **Jianmin Chen*** (chenjianmin@xmu.edu.cn). *Equivariantization and Weighted Projective Lines of Tubular Type.*

By proving some general results on the equivariantization of an abelian category with respect to a finite group action, we deduce two equivalences between the category of (equivariant) coherent sheaves on a weighted projective line of tubular type and that on an elliptic curve, where the acting groups are cyclic and the two equivalences are adjoint to each other. This is a joint work with Xiao-Wu Chen and Zhenqiang Zhou. (Received August 11, 2016)

1122-16-143 **Manuel Reyes** (reyes@bwodoin.edu) and **Daniel Rogalski*** (drogalski@ucsd.edu). *Twisted Calabi-Yau and Artin-Schelter regular conditions for locally finite graded algebras.*

For connected graded algebras, the notion of a twisted (or skew) Calabi-Yau algebra is known to be equivalent to the older notion of an Artin-Schelter regular algebra. For graded locally finite but not necessarily connected algebras, several different possible definitions of Artin-Schelter regular have been proposed. We show that in most cases, these are all equivalent to the notion of twisted Calabi-Yau algebra. As an application of our homological methods, we show that any graded locally finite twisted Calabi-Yau algebra of global dimension 2 with finite GK-dimension is necessarily noetherian. (Received August 11, 2016)

1122-16-151 **Van C. Nguyen*** (v.nguyen@northeastern.edu), Northeastern University, Department of Mathematics, Boston, MA 02115. *On Classification of Quantum p-Groups via Primitive Deformations.*

Our goal is to study the structures of finite-dimensional connected Hopf algebras, to which we refer as finite quantum p-groups, over an algebraically closed field k of prime characteristic p. In particular, we introduce a concept, called Primitive Deformation, to provide a structured technique to classify all p^{n+1}-dimensional connected Hopf algebras whose primitive space is an abelian restricted Lie algebra of dimension n. As an application for case $n = 2$, this work helps us to complete the classification of p^i-dimensional, where $i \leq 3$, connected Hopf algebras over k. All necessary definitions will be given. This is a joint work with Linhong Wang and Xingting Wang. (Received August 11, 2016)

1122-16-152 **Jiafeng Lu** (jiafenglv@zjnu.edu.cn), Zhejiang Normal University, Hangzhou, **Xingting Wang*** (xingting@temple.edu), Temple University, PA , and **Guangbin Zhuang** (gzhuang@usc.edu), University of Southern California, CA. *Homological unimodularity and Calabi-Yau condition for Poisson algebras.*

We show that the twisted Poincaré duality between Poisson homology and cohomology can be derived from Serre invertible bimodule appeared in Serre duality. This gives us another definition of unimodularity of Poisson algebras in terms of its Picard group. We also achieve twisted Poincaré duality for Hochschild (co)homology of Poisson bimodules using dualizing complex introduced in Grothendieck duality. As a consequence, several equivalent conditions are established involving unimodularity of A and Calabi-Yau property of the universal enveloping algebra of A provided the underlining algebra A is the coordinate ring of an affine smooth variety with trivial canonical bundle. This work is joint with Jiafeng Lü and Guangbin Zhuang. (Received August 11, 2016)

1122-16-164 **D. S. Keeler*** (keelerds@miamioh.edu) and **K. Retert** (retertk@gmail.com). *Noncommutative ampleness from finite endomorphisms.*

Let X be a projective integral scheme with endomorphism σ, where σ is finite, but not an automorphism. We examine noncommutative ampleness of bimodules defined by σ. In contrast to the automorphism case, one-sided ampleness is possible. We also find that rings and bimodule algebras associated with σ are not noetherian. (Received August 12, 2016)

1122-16-214 **Jonathan D.H. Smith*** (jdhsmith@iastate.edu). *Quantum quasigroups, Belousov's Theorem, Yang-Baxter, and bimagma isotopy.*

Quantum quasigroups are self-dual objects that provide a general framework for the nonassociative extension of quantum group techniques. In this talk, it will be shown how the classical theorem of Belousov on the isotopy of distributive quasigroups and commutative Moufang loops may be reinterpreted to yield new solutions of the quantum Yang-Baxter equation. In particular, a novel concept of principal bimagma isotopy is introduced. (Received August 14, 2016)

1122-16-251 **Maria D. Vega*** (maria.vega@usma.edu), Department of Mathematical Sciences, United States Military Academy, West Point, NY 10996. *Hopf automorphisms and twisted extensions.*

I will describe some applications of a Hopf algebra constructed from a group acting on another Hopf algebra A as Hopf automorphisms, namely Molnar's smash coproduct Hopf algebra. I will also describe connections between the exponent and Frobenius–Schur indicators of a smash coproduct and the twisted exponents and twisted Frobenius–Schur indicators of the original Hopf algebra A. Joint work with S. Montgomery and S. Witherspoon. (Received August 15, 2016)

1122-16-302 **Harvey Blau** and **Angela Antonou*** (aantonou@stfrancis.edu). *Two-dimensional representations of reality-based algebras.* Preliminary report.

We study the extent to which a two-dimensional irreducible representation of a reality-based algebra is determined, up to equivalence, by the values and multiplicities of the characters afforded by the other irreducible representations. Methods of Herman, Muzychuk, and Xu are among those applied. (Received August 15, 2016)

1122-16-332 **Jonas T Hartwig*** (jth@iastate.edu) and **Vera Serganova**. *Some connections between Lie superalgebras and twisted generalized Weyl algebras.*

A construction will be given of a family of twisted generalized Weyl superalgebras that includes quotients of enveloping algebras of general linear and orthosymplectic Lie superalgebras. (Received August 16, 2016)

17 ► Nonassociative rings and algebras

1122-17-58 **Ching Hung Lam*** (chlam@math.sinica.edu.tw), 6F, Astronomy-Mathematics Building, No. 1, Sec. 4, Roosevelt Road, Taipei, 10617, Taiwan. *Reverse orbifold construction and classification of holomorphic VOAs of central charge 24.*

In 1993, Schellekens determined the possible Lie algebra structures for the weight one subspaces of holomorphic vertex operator algebras of central charge 24. There are 71 cases in his list but not all cases were constructed at that time. It was also conjectured that the VOA structure of a holomorphic VOA of central charge 24 is uniquely determined by the Lie algebra structure of its weight one subspace.

In this talk, we will report our recent work on the classification (with H. Shimakura, X.J. Lin and K. Kawasetsu). We will discuss the constructions of all 71 cases in Schellenkens' list. Moreover, we will show that the VOA structures of certain holomorphic VOAs of central charge 24 are uniquely determined by their weight one Lie algebras using a technique which we call "reverse orbifold construction". (Received August 04, 2016)

1122-17-59 **G Eric Moorhouse*** (moorhous@uwyo.edu), 1000 E Univ Ave, Dept 3036, Laramie, WY 82071. *On Cayley algebras over prime fields.* Preliminary report.

Denote by C_p the Cayley algebra (i.e. split octonion algebra) over the field of prime order $p > 2$. We highlight some interesting features of C_p not shared by Cayley algebras over more general finite fields. For starters, the p^8 elements of C_p form a connected Cayley graph of degree 240 under the translation group, where the adjacency relation is defined by the 240 roots. We investigate the spectrum of this graph.

Our primary interest is actually more geometric than graph-theoretic. Namely, an *ovoid* in C_p is a set of elements $v_i \in C_p$ for $i \in \{1, 2, \ldots, p^3 + 1\}$ such that $v_i \cdot v_j = 0$ iff $i = j$. (No set with the latter property can have size greater than $p^3 + 1$.) Note that the definition of ovoids requires only a nondegenerate bilinear form (of maximal Witt index) rather than the full structure of the Cayley algebra. But most known constructions of ovoids in 8 dimensions make essential use of additional structure which may be conveniently viewed as arising from the algebra product of C_p. We present a conjectured formula for the number of distinct ovoids in C_p constructible by the known Cayley construction. (Received August 04, 2016)

1122-17-62 **Geoffrey - Mason*** (gem@ucsc.edu), Department of Mathematics, University of California, Santa Cruz, CA 95064. *Pierce bundles of vertex rings.* Preliminary report.

Pierce sheaves and their corresponding etale bundles are special kinds of geometric structures over a Boolean base space that have proved useful for studying certain classes of associative rings. Pierce introduced and used them to study commutative von Neumann regular rings (vNr). We show that this theory extends to the category of vertex rings. For example, there is an equivalence of categories that says that every vertex ring is the space of global sections of a certain type of etale bundle over a Boolean base space. We define and characterize von Neumann regular vertex rings, which correspond to etale bundles of simple vertex rings. This generalizes Pierce's original theorem, which is the case when the vertex ring is a commutative vNr and the bundle is a bundle of fields. (Received August 05, 2016)

1122-17-76 **Thomas Creutzig**, **Shashank Kanade*** (kanade@ualberta.ca) and **Robert McRae**. *Tensor categories for vertex operator algebra extensions: Applications.* Preliminary report.

In this talk, I'll report on an ongoing joint work with Thomas Creutzig and Robert McRae, pertaining to tensor categories for vertex operator algebra extensions. I'll elucidate a few general tensor-categorical results with concrete applications regarding coset problems. (Received August 08, 2016)

1122-17-85 **Jonathan D. H. Smith** and **Stefanie G. Wang*** (sgwang@iastate.edu). *Isomorphism problems for linear quasigroups.*

For a commutative ring S, a quasigroup Q is said to be *S-linear* if Q has an S-module structure, with $x \cdot y = x^R + y^L$ for S-automorphisms R and L of Q. By definition, homomorphisms of S-linear quasigroups are module homomorphisms that respect the quasigroup structure.

Our primary concern is the isomorphism problem for finitely generated $\mathbb{Z}$-linear quasigroups. While finite-dimensional $\mathbb{C}$-linear quasigroups are classified up to isomorphism by ordinary characters, non-isomorphic finitely generated $\mathbb{Z}$-linear quasigroups may complexify to isomorphic $\mathbb{C}$-linear quasigroups. We present a subclass of $\mathbb{Z}$-linear quasigroups where isomorphic complexifications imply a permutational similarity of the $\mathbb{Z}$-linear quasigroups involved. (Received August 08, 2016)

1122-17-102 **Fatemeh Bagherzadeh-Golmakani** and **Murray R. Bremner***, bremner@math.usask.ca, and **Sara Madariaga**. *Jordan trialgebras and post-Jordan algebras.*

Lie (Jordan) algebras are defined by polynomial identities of low arity satisfied by the (anti)commutator in associative algebras. Loday discovered Lie dialgebras (Leibniz algebras) in the 1990's, together with diassociative algebras and the (anti)dicommutator; Jordan dialgebras arrived a decade later. Roughly speaking, Lie (Jordan) dialgebras are noncommutative analogues of Lie (Jordan) algebras. Loday and Ronco discovered dendriform algebras, governed by the Koszul dual of the diassociative operad; the (anti)dicommutator produces pre-Lie and pre-Jordan algebras. These results can be reformulated using Manin white and black products. Triassociative and tridendriform algebras came next, and then Lie trialgebras and post-Lie algebras. We study the Jordan side of the picture, and find the correct definitions of Jordan trialgebras and post-Jordan algebras. Lie (Jordan)

trialgebras combine Lie (Jordan) algebras and dialgebras into one structure. We use a computational approach to determine the identities of arities ≤ 4 for the anti(di)commutator in triassociative and tridendriform algebras. Our results complement the partial results of others using a more theoretical approach. (Joint work with postdoctoral fellows Fatemeh Bagherzadeh and Sara Madariaga.) (Received August 10, 2016)

1122-17-115 **Thomas Creutzig**, **Shashank Kanade** and **Robert McRae*** (robert.h.mcrae@vanderbilt.edu). *Tensor categories for vertex operator algebra extensions: Theory.* Preliminary report.

In a recent paper, Huang, Kirillov, and Lepowsky showed that under suitable conditions, an extension of vertex operator algebras is equivalent to a commutative associative algebra in the braided tensor category of modules for the smaller vertex operator algebra. Here, we relate a certain monoidal category of representations of a commutative associative algebra in a braided tensor category constructed by Kirillov and Ostrik to Huang-Lepowsky tensor category theory for modules for a vertex operator algebra. (Received August 10, 2016)

1122-17-155 **Jinwei Yang*** (jyang7@nd.edu), 255 Hurley building, University of Notre Dame, South Bend, IN 46556. *Twisted representations of vertex operator algebras associated to the affine Lie algebras.*

We prove that the categories of lower bounded twisted modules of positive integer levels for simple vertex operator algebras associated with affine Lie algebras and general automorphisms are semisimple, using the twisted generalization of Zhu's algebra for these vertex operator algebras, constructed by Y.-Z. Huang and myself. We also show that the category of lower bounded twisted modules for a general automorphism is equivalent to the category of lower bounded twisted modules for the corresponding diagram automorphism. (Received August 12, 2016)

1122-17-183 **Tevian Dray*** (tevian@math.oregonstate.edu), Dept of Mathematics, Oregon State University, Corvallis, OR 97331. *The octonionic eigenvalue problem.*

We consider the problem of finding the eigenvalues and eigenvectors of octonionic 3×3 Hermitian matrices, that is, elements of the exceptional Jordan algebra, also known as the Albert algebra. For real eigenvalues, most of the properties expected by analogy with the complex case still hold, provided they are reinterpreted to take into account of the lack of commutativity and associativity. There are nevertheless some interesting surprises along the way, related both to the properties of the primitive idempotents (the Cayley–Moufang plane), and to the existence of non-real eigenvalues. Possible applications to physics will be briefly discussed. (Received August 12, 2016)

1122-17-191 **Chongying Dong**, **Li Ren*** (renl@scu.edu.cn) and **Feng Xu**. *On orbifold theory.*

This talk will report our recent work on orbifold theory. Let V be a simple vertex operator algebra and G a finite automorphism group of V such that V^G is regular. It is proved that every irreducible V^G-module occurs in an irreducible g-twisted V-module for some $g \in G$. Moreover, the quantum dimensions of each irreducible V^G-module are determined and a global dimension formula for V in terms of twisted modules is obtained. (Received August 13, 2016)

1122-17-193 **Chongying Dong*** (dong@ucsc.edu) and **Li Ren** (renl@scu.edu.cn). *Modular framed vertex operator algebras.* Preliminary report.

We report our recent work on framed vertex operator algebras over algebraically closed fields of finite characteristics. In particular, the irreducible modules for modular code vertex operator algebras are constructed and classified. (Received August 13, 2016)

1122-17-203 **Bojko Bakalov*** (bojko_bakalov@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695. *Vertex operators in Gromov-Witten theory.* Preliminary report.

We first review the recent notion of a twisted logarithmic module of a vertex algebra, which provides an algebraic approach to the operator product expansion in logarithmic conformal field theory. Then we present a construction that associates such a module to any semisimple Frobenius manifold. The talk is based on a joint work in progress with Todor Milanov. (Received August 14, 2016)

1122-17-241 **Tomoyuki Arakawa*** (arakawa@kurims.kyoto-u.ac.jp). *Quasi-lisse vertex algebras.*

The lisse condition, or the C_2-cofiniteness condition, is an important finiteness condition of vertex algebras. Lisse vertex algebras satisfy various favorable properties including modular invariance. However, there are non-lisse vertex algebras, such as admissible affine vertex algebras, that still have some nice properties. In this talk we

introduce a notion of quasi-lisse vertex algebras and explain that admissible affine vertex algebras are quasi-lisse. Moreover, we show that quasi-lisse vertex algebras satisfy a certain modular invariance property. This is a joint work with Kazuya Kawasetsu. (Received August 15, 2016)

1122-17-256 **Michael Penn** and **Christopher Sadowski*** (csadowski@ursinus.edu), 601 E. Main Street, Collegeville, PA 19426. *Vertex-algebraic structure of principal subspaces of basic modules for twisted affine Lie algebras of type $A^{(2)}_{2n+1}, D^{(2)}_n, E^{(2)}_6$.*

Principal subspaces of standard modules for untwisted affine Lie algebras were introduced by Feigin and Stoyanovsky, and have since been further studied by many authors. In this talk, we discuss the vertex-algebraic structure of principal subspaces of basic modules for twisted affine Lie algebras of type $A^{(2)}_{2n+1}, D^{(2)}_n, E^{(2)}_6$. In particular, we use exact sequences to derive recursions satisfied by the multigraded dimensions of these principal subspaces. Solving these recursions, we obtain the multigraded dimensions of these principal subspaces. (Received August 15, 2016)

1122-17-277 **Antun Milas*** (antun.milas@gmail.com), SUNY-Albany, Albany, NY 12222. *Unrolled quantum groups and vertex algebras.*

We first introduce unrolled quantum groups and discuss a conjectural correspondence between them and certain vertex subalgebras of the Heisenberg vertex algebra. Then we focus on the simplest unrolled quantum group, $U_q^H(sl_2)$, $q = e^{\pi i/p}$, and the corresponding vertex algebra, called the $(1,p)$-singlet algebra. We show how to use deformable families of modules to efficiently compute tangle invariants colored with projective $U_q^H(sl_2)$-modules. We also discuss logarithmic open Hopf link invariants in connection to asymptotic (or quantum) dimensions of the singlet vertex algebra. In the last part, we present evidence for higher rank generalization of these results.

This talk is based on a joint project with T. Creutzig and, in part, also jointly with M. Rupert. (Received August 15, 2016)

1122-17-381 **Michael Penn*** (michael.penn@coloradocollege.edu), **Christopher Sadowski** and **Gautam Webb**. *Principal Subspaces of Twisted Modules of Lattice Vertex Operator Algebras.*

Given an even lattice, L, with a certain positivity condition, and an automorphism that fixes the principal subalgebra W_L of the lattice vertex algebra V_L, we explore the principal subspace of the associated twisted V_L-module. We describe this twisted module in terms of the quotient of a polynomial algebra by an ideal generated by certain quadratic relations. In addition, the graded dimensions are found. (Received August 16, 2016)

18 ► Category theory; homological algebra

1122-18-123 **Paul Bruillard**, **Julia Plavnik*** (julia@math.tamu.edu) and **Eric Rowell**. *Classification of weakly integral modular categories of dimension 8m, with m odd square-free integer.* Preliminary report.

In this talk, we will first introduce some basic definitions and properties of fusion, braided and modular categories, and we will also give some basic examples to help understanding this structures. We will present some classification results for modular categories of specific dimensions and we will explain some of the techniques that we found useful to push further the classification. (Received August 10, 2016)

1122-18-156 **Henry Tucker*** (henryjtucker@gmail.com), UCSD Mathematics, 9500 Gilman Drive # 0112, La Jolla, CA 92093-0112, and **Masaki Izumi**, Kyoto, Japan. *Non-commutative near-group fusion categories.*

Izumi classified the non-commutative near-group fusion categories, that is, fusion categories with one non-invertible simple object and a non-abelian group of invertible objects. He showed, in particular, that the groups of invertible simple objects must be extra-special two groups. I will discuss joint work with Izumi toward computing the Frobenius-Schur indicators for these categories. We also establish some realizations of these categories as representation categories for bi-crossed product quasi-Hopf algebras. (Received August 12, 2016)

19 ► K-theory

1122-19-257 **Shmuel Weinberger** and **Zhizhang Xie***, Department of Mathematics, Mailstop 3368, Texas A&M University, College Station, TX 77843, and **Guoliang Yu**. *Additivity of higher rho invariants and nonrigidity of topological manifolds.*

Let X be a closed oriented topological manifold of dimension n. A main purpose of this talk is to prove that the higher rho invariant is a group homomorphism from the structure group $\mathcal{S}^{\mathrm{TOP}}(X)$ of X to the analytic structure group $K_n(C^*_{L,0}(\widetilde{X})^\Gamma)$ of X. Here $\widetilde{X}$ is the universal cover of X, $\Gamma = \pi_1 X$, and $C^*_{L,0}(\widetilde{X})^\Gamma$ is a certain C^*-algebra. We then apply this result to study non-rigidity of topological manifolds. More precisely, we give a lower bound for the size of the *reduced* structure group of a closed oriented topological manifold, by the number of torsion elements in the fundamental group of the manifold. Furthermore, we introduce a notion of homological higher rho invariant, which can be used to detect nontrivial elements in the structure group of a closed oriented topological manifold, even when the fundamental group of the manifold is torsion free. The talk is based on joint work with Shmuel Weinberger and Guoliang Yu. (Received August 15, 2016)

20 ► Group theory and generalizations

1122-20-4 **Janusz Konieczny*** (jkoniecz@umw.edu). *A New Definition of Conjugacy for Semigroups.*

The conjugacy relation plays an important role in group theory. If a and b are elements of a group G, a is conjugate to b if $g^{-1}ag = b$ for some $g \in G$. The group conjugacy extends to inverse semigroups in a natural way: for a and b in an inverse semigroup S, a is conjugate to b if $g^{-1}ag = b$ and $gbg^{-1} = a$ for some $g \in S$.

I will define a conjugacy for an arbitrary semigroup S that reduces to the inverse semigroup conjugacy if S is an inverse semigroup. (None of the existing notions of conjugacy for general semigroups has this property.) Moreover, this conjugacy is close to the group conjugacy in the following sense. Every transformation on a set can be represented as a directed graph in a natural way. It is well known that in the symmetric group of permutations on a set, two elements are group conjugate if and only if their digraphs are isomorphic. Similar results hold for the new conjugacy in several important semigroups of transformations.

I will compare the new notion of conjugacy with existing definitions, characterize the conjugacy in basic semigroups of transformations on a set using the representation of transformations as directed graphs, and determine the number of conjugacy classes in these semigroups. (Received December 03, 2015)

1122-20-7 **Tuval Foguel*** (tfoguel@adelphi.edu), 66 Caroline Ave, Franklin Square, NY 11010. *Idempotent Quasigroups and Exponent Two Loops.*

In this paper we prove that there is a one to one correspondence between finite idempotent quasigroup and finite loops of exponent 2. And we will use this correspondence to study some interesting loops of exponent two and some interesting idempotent quasigroup. (Received April 28, 2016)

1122-20-11 **Paul A Cummings*** (pcummings@albany.edu), 20 Meadowlark Drive, Cohoes, NY 12047. *Annular Semigroup Conjugacy Diagrams.*

We will define and construct annular semigroup conjugacy diagrams and demonstrate how they model certain types of conjugacy in a semigroup. (Received May 17, 2016)

1122-20-14 **Luise-Charlotte Kappe*** (menger@math.binghamton.edu), Binghamton University, Department of Mathematical Sciences, Binghamton, NY 139026000. *A question of Paul Erdös and its answer in groups, loops, rings and semigroups.*

In 1975, Paul Erdös asked the question if there exists a finite bound on the cardinality of sets of pairwise noncommuting elements in a group provided every such set is finite. The question makes sense in loops, rings and semigroups as well. The short answer for groups and rings is yes and no in the case of loops and semigroups.

B.H. Neumann answered Erdös' question in the affirmative by showing that every such group is central-by-finite and that the converse also holds. A similar result holds for rings. In the case of groups and rings we present other conditions equivalent to central-by-finite. In the case of loops and semigroups we are looking for sufficient conditions on the structures assuring a finite bound on the sets of pairwise noncommuting elements. (Received June 16, 2016)

1122-20-19 **Z. Mesyan*** (zmesyan@uccs.edu), Department of Mathematics, University of Colorado, Colorado Springs, CO 80918, and **J. D. Mitchell**, **M. Morayne** and **Y. H. Péresse**. *Topological Graph Inverse Semigroups.*

To every directed graph E one can associate a *graph inverse semigroup* $G(E)$, where elements roughly correspond to possible paths in E. These semigroups generalize polycyclic monoids, and they arise in the study of various rings and C^*-algebras. We investigate topologies that turn $G(E)$ into a topological semigroup. For instance, we show that in any such topology that is Hausdorff, $G(E) \setminus \{0\}$ must be discrete for any directed graph E. On the other hand, $G(E)$ need not be discrete in a Hausdorff semigroup topology, and for certain graphs E, $G(E)$ admits a T_1 semigroup topology in which $G(E) \setminus \{0\}$ is not discrete. We also describe, in various situations, the algebraic structure and possible cardinality of the closure of $G(E)$ in larger topological semigroups. (Received July 05, 2016)

1122-20-35 **Alexandru Chirvasitu*** (chirva@uw.edu), Department of Mathematics, Seattle, WA 98195, and **Souleiman Omar Hoche** and **Pawel Kasprzak**. *Subgroup lattices of discrete and compact quantum groups.*

The lattice of subgroups of a discrete group is the subject of numerous results revolving around the central theme of decomposing the group into "chunks" (subquotients) that can then be compared to one another in various ways.

Examples of results in this class would be the Noether isomorphism theorems, Zassenhaus' butterfly lemma, the Schreier refinement theorem for subnormal series of subgroups, the Dedekind modularity law, and last but not least the Jordan-Holder theorem.

We discuss analogues of the above-mentioned results in the context of quantum groups of two flavors: compact (cast mathematically as objects dual to certain well-behaved cosemisimple Hopf algebras) and discrete, which are Pontryagin duals of the former. Time permitting, the talk will also touch on the difficulties of extending such results to the more general setting of locally compact quantum groups (which simultaneously generalizes the two cases).

(joint with Souleiman Omar Hoche and Pawel Kasprzak) (Received July 28, 2016)

1122-20-57 **Simon M. Goberstein*** (sgoberstein@csuchico.edu), Department of Mathematics and Statistics, California State University, Chico, 400 West First Street, Chico, CA 95929-0525. *Perfect congruences on simple inverse ω-semigroups.* Preliminary report.

A congruence ε on a semigroup S is perfect if for any congruence classes $x\varepsilon$ and $y\varepsilon$ their product as subsets of S coincides (as a set) with the congruence class $(xy)\varepsilon$. A semigroup is an ω-semigroup if its idempotents form a semilattice isomorphic to the semilattice of idempotents of the bicyclic semigroup. A complete description of perfect congruences on bisimple ω-semigroups has been recently obtained by the author and his students (see *Semigroup Forum*, 91:117-127, 2015). The purpose of this talk is to characterize perfect congruences on simple inverse ω-semigroups. (Received August 04, 2016)

1122-20-75 **Scott Andrews*** (scottandrews@boisestate.edu). *The unipotent modules of $GL_n(\mathbb{F}_q)$.*

The irreducible modules of the symmetric group S_n were constructed by James (1976) by considering the action of S_n on tableaux of size n. Often results about S_n can be generalized to $\mathrm{GL}_n(\mathbb{F}_q)$, the group of invertible matrices over the finite field $\mathbb{F}_q$. Although James has constructed the unipotent modules of $\mathrm{GL}_n(\mathbb{F}_q)$ (1984), his construction differs significantly from his tableaux-based one for S_n. Using new results of Andrews and Thiem (2016) about the generalized Gelfand–Graev representations, we construct the unipotent modules of $\mathrm{GL}_n(\mathbb{F}_q)$ from tableaux in a manner analogous to the S_n approach of James. (Received August 08, 2016)

1122-20-80 **Jay Taylor*** (jaytaylor@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N. Santa Rita Ave., Tucson, AZ 85721. *Action of Automorphisms on Irreducible Characters of Symplectic Groups.*

In recent years a new approach has been developed to several long standing conjectures in the representation theory of finite groups; such as the McKay conjecture. These conjectures are stated for all finite groups but the recent approach has reduced these conjectures to checking certain conditions on quasisimple finite groups (often referred to as inductive conditions). This, in theory, makes the conjecture more manageable thanks to the classification of finite simple groups. However, the downside to this is that one requires information about how automorphisms act on the irreducible characters of quasisimple finite groups. In this talk we present new results in this direction concerning the finite symplectic groups $\mathrm{Sp}_{2n}(q)$ where q is an odd prime power. Specifically we completely describe the action of the automorphism group on the ordinary irreducible characters of these groups. (Received August 08, 2016)

1122-20-88 **Franco V Saliola*** (saliola.franco@uqam.ca). *Symmetrized shuffling operators on left regular bands.*

This work developed from explorations of the algebraic properties of random walks on the minimal ideal of left regular bands (LRBs). This seminal theory was initiated by Bidigare, Hanlon and Rockmore (BHR) and further developed by Brown and Diaconis. It turns out that several important Markov chains are random walks on LRBs.

The talk will present results on symmetrized versions of these shuffling operators. These are obtained by composing a BHR operator with its "dual". Examples include the random-to-random shuffling operator, which describes the evolution of a deck of cards if someone repeatedly removes a card at random and puts it back in at a random position. This is a symmetrized BHR shuffle in that it can be thought of as sequentially applying a random-to-top shuffle (choose a card at random and move it to the top) and a top-to-random shuffle (move the top card to a random position) at each step.

This talk is based on collaborations with Ton Dieker, Vic Reiner and Volkmar Welker. (Received August 09, 2016)

1122-20-94 **Norman R Reilly*** (nreilly@sfu.ca), Department of Mathematics, Simon Fraser University, Burnaby, B.C. V5A 1S6, Canada. *Kernel Classes in The Lattice $\mathcal{L}(C\mathcal{R})$ of Varieties of Completely Regular Semigroups.* Preliminary report.

Several complete congruences on the lattice $\mathcal{L}(\mathcal{CR})$ of varieties of completely regular semigroups have been fundamental to studies of the structure of $\mathcal{L}(\mathcal{CR})$. These are the kernel relation K, the left trace relation T_ℓ and the right trace relation T_r. Despite the fact that these have proved to be powerful tools in the study of $\mathcal{L}(\mathcal{CR})$, until recently, very little was known regarding the detailed structure of individual K, T_ℓ, T_r-classes. For instance, the only K-class with a completely determined structure was the K-class of the trivial variety $\mathcal{T}$, where $\mathcal{T}K = \mathcal{L}(\mathcal{B})$, the sublattice consisting of all varieties of bands. In this talk, I will describe the detailed structure of a large family of other K-classes. (Received August 09, 2016)

1122-20-101 **Sam van Gool*** (samvangool@me.com), City College of New York, Dept. of Mathematics, Convent Ave at 138th St, New York, NY 10031, and **Benjamin Steinberg** (bsteinberg@ccny.cuny.edu), City College of New York, Dept. of Mathematics, Convent Ave at 138th St, New York, NY 10031. *Proaperiodic semigroups and model theory.*

We begin with the observation that the free profinite aperiodic monoid over a finite set A is isomorphic to the Stone dual space (spectrum) of the Boolean algebra of first-order definable sets of finite A-labelled linear orders ("A-words"). This means that elements of this monoid can be viewed as elementary equivalence classes of models of the first-order theory of finite A-words. From this perspective, the operations of multiplication and ω-power on proaperiodic monoids can be understood in a very concrete way. This point of view allows us to import methods from both topology and model theory, in particular saturated models, into the study of proaperiodic monoids. We use these methods to prove results about ω-terms in the free proaperiodic monoid and well-quasi-orders of factors in related proaperiodic monoids. (Received August 09, 2016)

1122-20-103 **Klaus Lux*** (klux@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N. Santa Rita Ave., Tucson, AZ 85721-0089. *The 13-modular character table of 2.Suz.2.* Preliminary report.

One of the open problems of the modular Atlas project (www.math.rwth-aachen.de/ MOC/work.html) is the determination of the 13-modular character table of 2.Suz.2. In this talk we describe how we determined this character table using theoretical and computation methods. The tools involved are the theory of blocks of cyclic defect, the GAP-package chop (implementing the MeatAxe), and the condensation method. This is joint work with A. Ryba, CUNY Queens College, N.Y. (Received August 10, 2016)

1122-20-105 **Christopher P French*** (frenchc@grinnell.edu), Noyce Science Center, 1116 8th Ave, Grinnell, IA 50112. *Noncommutative association schemes of rank 6 with affine subschemes.*

Since finite noncommutative association schemes must have rank at least six, it is natural to seek examples with rank exactly six. One method for conducting such a search is to impose some extra conditions, like requiring the existence of a symmetric subscheme of rank three. If one adds two other simplifying conditions, one finds that such a subscheme must correspond to a self-complementary strongly regular graph whose automorphism group acts transitively on the vertex set. Recently, Klin, Kriger, and Woldar demonstrated that one can obtain numerous examples of such graphs using the theory of affine schemes. In this talk, we consider these examples to see if they can be used to construct new noncommutative schemes of rank six. (Received August 10, 2016)

1122-20-117 **Joshua Maglione*** (maglione@math.colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523. *New tools for computing automorphism groups.*

We introduce a general method to make a series of isomorphism invariant subgroups. Even in the extreme case where the only classically known characteristic subgroup is the commutator, this method can produce maximal characteristic series. We prove that this can be computed efficiently, which lead to a test on a half billion 2-groups of class 2 – groups for which isomorphism invariants are least known. We succeeded in identifying new subgroups in about 97% of the groups we surveyed, and our approach can be adapted for further improvement. We report on individual and joint work with J.B. Wilson. (Received August 10, 2016)

1122-20-134 **Peter Mayr*** (peter.mayr@colorado.edu), CU Boulder, Boulder, CO , and **Nik Ruskuc**, University of St Andrews, St Andrews, United Kingdom. *Finite generation and presentations for subdirect products of loops.*

Recall that a subloop of a direct product of loops is a *subdirect product* if it projects onto each factor.

Like for groups, every direct product of two finitely generated loops is clearly finitely generated. But when is a subdirect product finitely generated? We show that this happens if the factors are finitely generated and, e.g., the projection kernels are finitely generated as normal subloops. This sufficient condition is also necessary if the factors are free (or more generally, finitely presented). A closer analysis leads to questions about finite presentations of loops.

We observe that, unlike for groups, a direct product of two infinite loops can never be finitely presented. The proof employs Evans' confluent rewriting systems for loops (1951).

Finally, using the commutator theory of universal algebra, we show that every subdirect product of three finitely generated loops is finitely generated if its projection on every two factors is the full direct product. (Received August 11, 2016)

1122-20-149 **Gerald Hoehn*** (gerald@monstrous-moonshine.de). *Fixed-point lattices of the Leech lattice and applications.*

I will first describe joint work with Geoffrey Mason on the classification of fixed-point lattices of the Leech lattice.

I will then discuss applications to the classification of vertex operator algebras, symplectic automorphisms of hyperkähler manifolds and symmetries of K3-sigma models. (Received August 11, 2016)

1122-20-157 **Markus Steindl*** (ma.steindl@gmail.com), Department of Mathematics, University of Colorado Boulder, Boulder, CO 80309-0395. *The subpower membership problem for semigroups.* Preliminary report.

We fix a finite semigroup S and let $a_1, \ldots, a_k, b$ be tuples in a direct power S^n. The *subpower membership problem* SMP(S) asks whether b is in the subsemigroup generated by $a_1, \ldots, a_k$. In other words, SMP(S) asks whether b can be written as some product in $a_1, \ldots, a_k$. Our goal is to answer how the semigroup S affects the computational complexity of SMP(S).

For groups S there is a polynomial time algorithm for SMP(S) using Sims' stabilizer chains. We show that the SMP for a commutative semigroup is either in P or NP-complete. We will also establish a P/NP-complete dichotomy for bands. A frequently studied semigroup is the 5-element Brandt semigroup. It is formed by all 2 by 2 matrices with at most one entry 1 and the rest 0. We show that its SMP is NP-complete. If we add the identity matrix, then the resulting Brandt monoid has PSPACE-complete SMP. This is joint work with A. Bulatov, M. Kozik, and P. Mayr. (Received August 12, 2016)

1122-20-158 **James D Mitchell*** (jdm3@st-andrews.ac.uk). *Computing maximal subsemigroups of a finite semigroup.*

In a paper of 1968, Graham, Graham, and Rhodes describe the possible forms that a maximal subsemigroup of a finite semigroup can take. In this talk, I will outline a new effective algorithm for determining the maximal subsemigroups of each type described by Graham, Graham, and Rhodes. We will see that certain cases reduce to other well-known problems, such as, for instance, finding all maximal cliques in a graph and computing the maximal subgroups in a group. (Received August 12, 2016)

1122-20-167 **Dan Rossi***, Dept. of Mathematics, University of Arizona, 617 N. Santa Rita Ave., Tucson, AZ 85721. *Rational Characters and Rational Conjugacy Classes in Finite Groups.*

Let G be a finite group. A character $\chi \in \mathrm{Irr}(G)$ is called *rational* if $\chi(g) \in \mathbb{Q}$ for every $g \in G$, and an element $g \in G$ is called *rational* if $\chi(g) \in \mathbb{Q}$ for every $\chi \in \mathrm{Irr}(G)$. If $g \in G$ is rational then we say the conjugacy class $cl_G(g)$ is rational. Write $\mathrm{Irr}_{\mathbb{Q}}(G)$ and $Cl_{\mathbb{Q}}(G)$, respectively, for the sets of rational irreducible characters and rational conjugacy classes of G. Extending work of Navarro-Tiep (2008) we show that when G is non-solvable

either $|\mathrm{Irr}_{\mathbb{Q}}(G)| = 3$ if and only if $|Cl_{\mathbb{Q}}(G)| = 3$ or else the composition factors of G are under very tight control. (Received August 12, 2016)

1122-20-171 **Bhama Srinivasan*** (srinivas@uic.edu), Department of Mathematics, University of Illinois at Chicago, Chicago, IL 60607. *Representation stability in finite general linear groups.*

The notion of representation stability for symmetric groups was introduced by Church and Farb. It has proved to be of importance in understanding how representations of a sequence of symmetric groups stabilize after a certain stage, in terms of multiplicities of irreducible representations. In a recent paper Wee Liang Gan and John Watterlond prove the stability of multiplicities of irreducible components of some permutation representations of finite general linear groups. In this talk we consider stability questions for Lusztig-induced representations of finite general linear groups. (Received August 12, 2016)

1122-20-194 **Spencer J Gerhardt*** (sgerhard@usc.edu), University of Southern California, Department of Mathematics, 3620 S. Vermont Avenue, Los Angeles, CA 90089-2532. *Topological generation of special linear algebraic groups.*

Let $G = SL_n(k)$ with k an uncountable algebraically closed field of characteristic $p \geq 0$. Let $C_1, .., C_e$ be conjugacy classes of G. In this talk we consider the following question: when do there exist elements $g_1, .., g_e \in C_1, \ldots, C_e$ such that $\langle g_1, \ldots, g_e \rangle$ is Zariski dense in G? Applications to random generation of finite groups of Lie type, and the representation theory of simple algebraic groups will also be discussed. (Received August 13, 2016)

1122-20-197 **Richard M. Green*** (rmg@colorado.edu), Department of Mathematics, University of Colorado Boulder, Boulder, CO 80309-0395, and **Ilia D. Mishev** and **Eric Stade**. *Coxeter group actions on hypergeometric series.*

There are certain linear combinations of Saalschützian ${}_4F_3(1)$ hypergeometric series that are invariant under the action of a simply laced finite Coxeter group. I will describe how relations among these series may be classified into types, given in terms of the orbits of the action of the group, and in terms of a natural metric on the set on which the group acts. (Received August 13, 2016)

1122-20-218 **Kenneth W Johnson*** (kwj1@psu.edu), PA. *S-rings associated to random walks on groups and sets with group actions.* Preliminary report.

A random walk on a finite group G may be described as a probability on G . The analysis is more straightforward if p is constant on conjugacy classes. The class algebra is an example of an S-ring. Recent work with Humphries has shown that this S-ring spits into S-rings S' which remain commutative and if p is constant on the classes of such S' the corresponding random walk is also relatively easy to analyse. Now consider a random walk on a set X acted on by a transitive group G. Usually a p is given on G which is constant on the cosets of H, the stabiliser of a point. The "easy" case is when p is constant on the double cosets of H. In some cases, for example the random walk on a cube or icosahedron, there is a regular subgroup K of G, and there is naturally an S-ring S on K, which gives rise to an equivalent analysis of the walk. In the spirit of the previous paragraph, there is an associated algebraic problem: given an S-ring S on a group K, obtain the commutative S-rings which arise from splitting the classes of S. (Received August 14, 2016)

1122-20-229 **E. A. O'Brien**, University of Auckland, and **Petr Vojtechovsky***, University of Denver, 2280 S Vine St, Denver, CO 80208. *Enumeration of code loops.* Preliminary report.

Code loops capture intersection properties of codewords in doubly even binary codes and they play an important role in the construction of local subgroups of sporadic groups. We describe theoretical and computational methods that we used to classify code loops (and thus also trilinear alternating forms) in dimension up to eight. (Received August 15, 2016)

1122-20-255 **Ian Biringer** and **Omer Tamuz*** (tamuz@caltech.edu). *Unimodularity of invariant random subgroups.*

An invariant random subgroup $H \leq G$ is a random closed subgroup whose law is invariant to conjugation by all elements of G. When G is locally compact and second countable, we show that for every invariant random subgroup $H \leq G$ there almost surely exists an invariant measure on G/H. Equivalently, the modular function of H is almost surely equal to the modular function of G, restricted to H.

We use this result to construct invariant measures on orbit equivalence relations of measure preserving actions. Additionally, we prove a mass transport principle for discrete or compact invariant random subgroups. (Received August 15, 2016)

1122-20-258 **Robert D Gray*** (robert.d.gray@uea.ac.uk), School of Mathematics, University of East Anglia, Norwich NR4 7TJ, Norwich, Norfolk NR4 7TJ, United Kingdom. *Investigating groups of units of special monoids using boundaries in Schützenberger graphs.*

A monoid presentation is called special of all of the relations are of the form $u = 1$. In a series of papers in the 90s Louxin Zhang proved several interesting structural and computational results about monoids defined by finite special presentations. In this theory he builds a certain infinite complete rewriting system and uses it to relate properties of the monoid to properties of its group of units. For example, his theory gives finite presentations for the units and right units of the monoid, and can be used to show that the monoid has decidable word problem if and only if its group of units has decidable word problem. In the case of one relator special monoids his theory gives a very neat alternative proof of Adjan's theorem that one-relator special monoids have decidable word problem. In this talk I will present some recent (and ongoing) joint work with Nik Ruskuc (St Andrews) which investigates, so-called, Cayley graph boundaries of the units and right units of monoids. I shall explain how our results can be used to give new simpler proofs of some of the results of Zhang for special monoids. Then I will give an account of the progress we have managed to make so far on extending these results to investigate properties of the groups of units of special inverse monoids. (Received August 15, 2016)

1122-20-260 **Alexander J Hulpke*** (hulpke@colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523. *Unravelling Primitivity.* Preliminary report.

Every 2-transitive group is primitive, but not every primitive group is 2-transitive. Recent combinatorial definitions allow for a better analysis of the area between these two definitions. I will look at some of these definitions and consider ways how to test for them. This is joint work with Peter Cameron and Joao Araujo (Received August 15, 2016)

1122-20-265 **Arvind Ayyer** and **Benjamin Steinberg*** (bsteinberg@ccny.cuny.edu). *Random walks on rings and modules.* Preliminary report.

We compute the eigenvalues for some natural models of random walks on finite commutative rings or, more generally, on finite modules over commutative rings. Our main technique is a mixture of group and semigroup representation theory. (Received August 15, 2016)

1122-20-271 **Nathaniel Thiem*** (thiemn@colorado.edu), Boulder, CO 80309. *Geometric p-groups.*

Despite being a high proportion of finite groups, general p-groups remain somewhat mysterious. As a family these groups have notoriously difficult representation theories, and can exhibit extremely odd behavior. In fact, a complete understanding of these groups may be hopeless. However, for some families of such groups we can use supercharacter theory to obtain startlingly nice combinatorics. This talk investigates a supercharacter theoretic approach to pattern groups that lead to geometric questions about integer polytopes. (Received August 15, 2016)

1122-20-278 **Hyereem Lee*** (hlee@math.arizona.edu). *Triples in Finite Groups and a Conjecture of Guralnick and Tiep.*

R. M. Guralnick and P. H. Tiep conjectured that a finite group G has a composition factor of order divisible by distinct odd primes p and q if and only if G contains a 2-element x, p-element y, and q-element z such that $xyz = 1 \neq x, y, z$. Using the classification of finite simple groups, this conjecture will be shown to be true. (Received August 15, 2016)

1122-20-282 **Jonathan I Hall*** (jhall@math.msu.edu), Department of Mathematics, Michigan State University, 619 Red Cedar Road, East Lansing, MI 48840. *Octonion multiplication groups and spin.*

In 2003 Nagy and Vojtěchovský noted that the identification of the multiplication group of the unit split octonions with the corresponding group of type D_4 was observed in the literature but rarely (if ever) proved before their paper. Here we reprove this as a special case of the multiplication group of unit octonions in general. We make reference to Freudenthal's version of triality and its relationship to spin groups in dimension 8. (Received August 15, 2016)

1122-20-287 **Rob Carman*** (wcarman@ucsc.edu), University of California, Santa Cruz, Department of Mathematics, 1156 High St, Santa Cruz, CA 95064. *Tensor Induction for Trivial Source Rings and their Ghost Rings.*

Given two finite groups G, H and a right-free (G, H)-biset, we define a tensor induction construction that gives a multiplicative functor from the category of FH-modules to the category of FG-modules, where F is a field of prime characteristic. We show how this induces a multiplicative function between the trivial source rings of

H and G over F, and then we show how to extend this function to the level of ghost rings of the trivial source rings. (Received August 15, 2016)

1122-20-296 **Peter R Jones*** (peter.jones@mu.edu). *Varieties of left restriction semigroups.* Preliminary report.

Left restriction semigroups are unary semigroups $(S, \cdot, ^+)$ that abstract semigroups of partial functions, the unary operation associating to a partial function its domain. We study the variety **B** of left restriction semigroups generated by Brandt semigroups. This exploration follows a similar study by the author for (two-sided) restriction semigroups, and previous work on the 'plain' semigroup varieties so generated. As in these situations, key roles are played by the five-element Brandt semigroup B_2, the subsemigroup B_0 obtained by dropping a nonzero idempotent and the further subsemigroup D obtained by dropping a nonzero idempotent. In the two-sided case, the author previously demonstrated pathological behaviour: B_0 (and thus also B_2) is inherently nonfinitely based. General arguments show that this cannot be the case here, but in fact in the one-sided case a single identity serves as a basis for B_2's identities. We also consider the structure of the lattice of subvarieties of **B** and show that, despite the contrast just enunciated, this lattice is rather similar to its counterpart in the two-sided case. (Received August 15, 2016)

1122-20-304 **Liudmila Sabinina*** (liudmila.sabinina@gmail.com), Cinc UAEM, 62360 Cuernavaca, Morelos, Mexico. *Half-Automorphisms of Cayley- Dickson loops.*

We study the groups of half-automorphisms of Cayley- Dickson loops. We introduce the concept of elementary mapping and show that for octonions the group of half-automorphisms is the product of the group, generated by elementary mappings and the group of automorphisms of the octonions. This talk is based on the joint work with P. Plaumann and M. L. Merlini Giuliani. (Received August 15, 2016)

1122-20-323 **Stephen J. Trefethen*** (sjtrefethen@wm.edu), 2605 Ayrshire Reach, Williamsburg, VA 23188. *The Structure of ℓ-Brauer m-Rational Groups.* Preliminary report.

For a fixed integer $m \geq 1$, a finite group G is said to be m-rational if $[\mathbb{Q}(\chi) : \mathbb{Q}] \mid m$ for all irreducible ordinary characters $\chi \in \mathrm{Irr}(G)$. Likewise, for a fixed prime $\ell \geq 2$, G is said to be ℓ-Brauer m-rational if $[\mathbb{Q}(\varphi) : \mathbb{Q}] \mid m$ for all irreducible ℓ-Brauer characters $\varphi \in \mathrm{IBr}_\ell(G)$. It is known that (for a fixed m) only finitely many groups of Lie type can occur as a composition factor of some m-rational group. In this talk, we show that an analogous statement holds in the ℓ-Brauer m-rational case, and give an explicit list of the possible non-abelian composition factors of ℓ-Brauer rational groups. (Received August 16, 2016)

1122-20-325 **Mark B. Greer*** (mgreer@una.edu), One Harrison Plaza, UNA Box 5051, Florence, AL 35632. *Γ-loops.*

Γ-loops where first discovered due to their deep connection to Bruck loops of odd order. Using the well known structure of Bruck loops of odd order, we derive the Odd Order, Lagrange and Cauchy Theorems for Γ-loops of odd order, as well as the nontriviality of the center of finite Γ-p-loops (p odd). More generally, we show Γ-loops are power-associative and if the Γ-loop has exponent 3, then the loop is a commutative Moufang loop. The correspondence between Bruck loops and Γ-loops uses a construction from Baer using nilpotent groups. We'll discuss some results and conjectures about the structure of the group and its corresponding Γ-loop. (Received August 16, 2016)

1122-20-336 **Adam M. Glesser*** (aglesser@fullerton.edu). *Representations of fusion systems.* Preliminary report.

One approach to the study of fusion systems is to mimic the development of the study of groups. In this vein, it makes sense to consider a representation theory (or character theory) of fusion systems. This talk contains some preliminary results on what seems to works and what is more problematic to translate. (Received August 16, 2016)

1122-20-344 **Michael Kinyon*** (mkinyon@du.edu), Department of Mathematics, 2280 S. Vine St., Denver, CO 80208, and **David Stanovsky**, Prague, Czech Rep. *The center of an inverse semigroup.*

For an inverse semigroup S, the traditional "center", $C(S) = \{a \in S \mid ax = xa, \quad \forall x \in S\}$, is an inverse subsemigroup, but is generally neither full nor self-conjugate, hence not normal, that is, not the kernel of a congruence. The purpose of this talk is to convince you that the correct definition of center is:

$$Z(S) = \{a \in S \mid axa^{-1}a = aa^{-1}xa, \quad \forall x \in S\}.$$

This is always a normal inverse subsemigroup. That $Z(S)$ is the true center is shown by Freese-McKenzie commutator theory in universal algebra. Like all universal algebras, an inverse semigroup S has a *central*

congruence $\zeta = \zeta(S)$ which is the largest congruence centralizing the universal relation over the identity relation. In general it is difficult to get a concrete description of ζ, but for inverse semigroups, the term condition which characterizes ζ is manageable and its kernel is precisely $Z(S)$. I will also discuss *central nilpotence*, defined by a terminating upper central series. For example, the Brandt semigroup of order 5 is centrally nilpotent of class 2. (Received August 16, 2016)

1122-20-349 **Kenneth W Johnson*** (kwj1@psu.edu). *Some algebraic problems connected to random walks on loops.* Preliminary report.

A random walk on a loop Q is associated to a probability p on Q. If at a given stage of the walk it is at the element x, the probability of moving to the point y is $p(z)$ where $xz = y$. If p is constant on the conjugacy classes of Q (the orbits of the stabiliser of e), the calculations become similar to those for a random walk on a group. It is easier to analyse the situation if there is a regular subgroup in the multiplication group of Q, whose class algebra is "compatible" with that of Q.

One algebraic question coming from this situation is the following: given a loop Q, find regular subgroups of the multiplication group of Q which are "compatible" with the class algebra of Q. Calculations on small Moufang loops suggest that this problem may be interesting. There is also a general question of classifying the S-rings on a loop, generalising work on S-rings over groups. (Received August 16, 2016)

1122-20-356 **Robert Boltje*** (boltje@ucsc.edu) and **Olcay Coskun**. *Fibred biset functors.*

In 1996 Serge Bouc introduced in a landmark paper the notion of a "biset functor", which builds on the notion of a Mackey functor and incorporates besides restriction and induction the additional operations of inflation and deflation in a unified functorial set-up. This setup uses actions of bisets. Most types of representation rings of finite groups are examples of biset functors. Since they allow besides biset operations also operations of fibred bisets (monomial bimodules), it is natural to introduce "fibred biset functors". In this talk we define the notion of a fibred biset functor, classify all simple functors and study some representation rings as such functors. (Received August 16, 2016)

1122-20-386 **Michael Kinyon** and **Izabella Stuhl***, izabella.stuhl@du.edu, and **Petr Vojtechovsky**. *On commutative automorphic loops of small order.*

We will present some new results on commutative automorphic loops of small order. (Received August 17, 2016)

22 ► Topological groups, Lie groups

1122-22-23 **Shiang Tang*** (tang@math.utah.edu), 1400 east, 155 south, Room 233, Salt Lake City, UT 84112. *Action of intertwining operators on pseudo-spherical K-types.*

In this paper, we give a concrete description of the two-fold cover of a simply connected, split real reductive group and its maximal compact subgroup as Chevalley groups. We study a small genuine representation of the maximal compact subgroup called pseudospherical representation, which appear with multiplicity one in the principal series representation. We introduce a family of canonically defined intertwining operators and compute the action of them on pseudospherical K-types, obtaining explicit formulas of the Harish-Chandra c-function. It has potential applications in the study of automorphic forms on metaplectic groups. (Received July 18, 2016)

28 ► Measure and integration

1122-28-38 **Dong Hyun Cho*** (j94385@kyonggi.ac.kr), Department of Mathematics, Kyonggi University, Suwon, Kyonggido , South Korea. *Change of scale formulas for conditional Fourier-Feynman transforms over continuous paths II.*

Let $C0,T]$ be a generalized Wiener space, that is, the space of real-valued continuous functions on $[0,T]$. Let $a \in C[0,T]$, $h \in L_2[0,T]$ with $h \neq 0$ a.e. and define $Z : C[0,T] \times [0,T] \to \mathbb{R}$ by

$$Z(x,t) = \int_0^t h(s)dx(s) + x(0) + a(t)$$

and define $Z_n : C[0,T] \to \mathbb{R}^{n+1}$ by

$$Z_n(x) = (Z(x,t_0), Z(x,t_1), \cdots, Z(x,t_n)),$$

where $0 = t_0 < t_1 < \cdots < t_n < T$ is a partition of $[0, T]$. Using a simple formula for conditional Wiener integrals given Z_n, we evaluate an analytic conditional Fourier-Feynman transform and a convolution product of the cylinder functions

$$F_r(x) = f\left(\int_0^t v_1(s)dZ(x,s), \cdots, \int_0^t v_r(s)dZ(x,s)\right)$$

for $x \in C[0,T]$, 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 investigate their relationships and establish various change of scale formulas for the transform. In these evaluation formulas we use a multivariate normal distribution so that the orthonormalization process of the projections $\mathcal{P}^{\perp}hv_1, \cdots, \mathcal{P}^{\perp}hv_r$ can be removed in the existing change of scale formulas. (Received July 30, 2016)

30 ► Functions of a complex variable

1122-30-5 **Hady K. Joumaa*** (hkj@alum.mit.edu). *On some functional properties of the Hurwitz-Euler eta function.*

We report on some essential functional properties associated with the Hurwtiz-Euler eta function $\eta(s,q)$. We first discuss the formulation of various theorems related to $\eta(s,q)$, its partial derivative, and its reflection relations for both rational and real q. The application of the Laplace transform and the Mellin transform on $\eta(s,q)$ generates two novel integral-sum relations for some logarithmic-based infinite series. The connection between $\eta(1,q)$ and the newly-introduced *alternating harmonic number* is generalized so that this number can be defined for arbitrary real coefficients. An asymptotic approximation for $\eta(s,q)$ at small s, based on the Abel-Plana formula, is constructed leading to the evaluation of some divergent η-associated series through Abel and Cesaro's sums. In addition, a geometric property for the extrema points of trigonometric integral functions is induced from the first derivative formula of $\eta(s,q)$. Finally, a Taylor series representing $\eta(s,q)$ is formed whereby a generalized relation expressed in an η-based power series is established. (Received February 22, 2016)

33 ► Special functions

1122-33-112 **Vladimir Dragovic** and **Vasilisa Shramchenko*** (vasilisa.shramchenko@usherbrooke.ca). *Algebro-geometric solutions to Schlesinger systems I: elliptic case.*

A method of constructing algebro-geometric solutions of rank two Schlesinger systems is presented. For an elliptic curve given as a ramified double covering of CP^1, a meromorphic differential is constructed with the following property: the common projection of its two zeros on the base of the covering, regarded as a function of the only moving branch point of the covering, is a solution of a Painleve VI equation. This differential provides an invariant formulation of a classical Okamoto transformation for the Painleve VI equations. This approach is motivated by an observation of Hitchin connecting algebraic solutions of a Painleve VI equation to the Poncelet polygons in the plane. The research is partially supported by the NSF grant 1444147 and NSERC discovery grant. (Received August 10, 2016)

1122-33-196 **Christopher M Ormerod*** (christopher.ormerod@maine.edu), 5752 Neville Hall, Room 333, Orono,, ME 04469, and **Eric M Rains** (rains@caltech.edu), 1200 California Blvd, Mathematics, MC 253-37, Pasadena, CA 91125. *Symmetric difference-differential Lax pairs for Painlevé equations.*

We present a new Lax pair for the sixth Painlevé equation arising as a continuous isomonodromic deformation of a system of linear difference equations with an additional symmetry structure. We call this a symmetric difference-differential Lax pair. We show how a discrete isomonodromic deformation of the associated linear problem may be expressed in terms of a discrete version of the fifth Painlevé equation. By considering degenerations we obtain symmetric difference-differential Lax pairs for the fifth Painlevé equation and the various degenerate versions of the third Painlevé equation. (Received August 13, 2016)

1122-33-237 **Marco Bertola*** (marco.bertola@concordia.ca), 1455 de Maisonneuve St. W, Montreal, QC H3G 1M8, Canada, and **Mattia Cafasso**, University of Angers, France. *The Airy (Kontsevich) and Bessel Matrix integrals and universality at the edges.*

We consider averages of products and ratios characteristic polynomials for unitary ensembles. In an appropriate scaling limit near the so called "soft" and "hard" edge of the spectrum, we show that these averages can be

expressed in turn as a matrix integral with external source that generalizes the Airy (soft-edge) and Bessel (hard-edge) functions. The connection to integrable systems of Painlevé type will be indicated. (Received August 15, 2016)

34 ► Ordinary differential equations

1122-34-148 **Alessandro Arsie*** (alessandro.arsie@utoledo.edu), 2800 W. Bancroft St, Toledo, OH 43606, and **Paolo Lorenzoni** (paolo.lorenzoni@unimib.it), Via Paolo Cozzi, 55, 20125 Milano, Italy. *F-manifolds, multi-flat structures and Painlevé transcendents.*

We study 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 that are related to the eventual identities for the multiple products involved. When the relevant distributions are integrable, we construct bi-flat F-manifolds in dimension 2 and 3, and tri-flat F-manifolds in dimensions 3 and 4. 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 the endomorphism $L = E\circ$. As a consequence, we have that confluences of P_{IV}, P_V and P_{VI} correspond to collisions of eigenvalues of L preserving the regularity. (Received August 11, 2016)

1122-34-315 **Sarbarish Chakravarty***, Department of Mathematics, University of Colorado, Colorado Springs, CO 80918. *Projective connection and Chazy equations.* Preliminary report.

A differential geometric interpretation of the Chazy-type equations is provided via the theory of affine connections in one-dimensional complex manifolds with a projective structure. The projective structure is determined a Schrödinger equation with a rational potential with parameters. It will be shown how different choices of these parameters of the potential lead to different parameterization of the Chazy XII equation. This work is motivated by B. Dubrovin's (Springer Lecture Notes in Mathematics Vol. 1620 (1996), pp.120–348) observations on this topic. (Received August 16, 2016)

1122-34-369 **Brenton J LeMesurier*** (lemesurierb@cofc.edu), Department of Mathematics, College of Charleston, Charleston, SC 29424. *Pulses in binary wave guide arrays and long wave PDE approximations.*

Binary waveguide arrays are linear arrays of optical waveguides with binary alternation of parameters, and have been of recent interest. They can be modeled by systems of nonlinear ODEs with forms related to the discrete nonlinear Schrödinger equation. Such systems can also arise in semi-classical molecular models of polymers with excitable states in each monomer and coupling between these.

An important class of solutions arises from an initially highly localized signal, such as input to a single element of the array. Simulations show that for a wide array of parameter values and of such initial data, a pulse is generated that travels approximately as a traveling wave. After a suitable phase shift in the variables, this pulse quickly develops a slow spatial variation, leading to a long-wave approximation by a system of coupled third order PDEs; one each for nodes of even and odd indices.

This system of PDEs is presented, and verified to quite accurately reproduce the pulse propagation seen in the ODE system. Further there is often a strong tendency for the behavior of the two PDE components to converge, with a corresponding convergence of the even and odd index parts of the ODE system solution. The PDE model gives some indication of why this occurs. (Received August 16, 2016)

35 ► Partial differential equations

1122-35-29 **Viktoria Savatorova***, viktoria.savatorova@unlv.edu, and **Aleksei Talonov**. *Modeling of Gas Transport in Organic-Rich Shales with Irregular Distribution of Pores.*

In this work, we perform multi-scale modeling of gas transport through the rigid heterogeneous solid having complex structure of pores. We assume that the solid consists of inorganic matrix with kegogen inclusions imbedded into it. 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. We assume that irregularities in porous structure can be characterized by their small deviations

from the regular distribution. We apply multi-scale analysis to mass balance equations, the equation of state for free gas, and an adsorption isotherm. As a result of upscaling, we get a macroscopic equation describing gas transport through an effective medium. It turns out that macroscale parameters characterizing fluid flow depend on diffusivity, permeability, and porosity of components of the system, the amount of inclusions and their spatial distribution. We investigate sensitivity of macroscale parameters to deviations in distributions of heterogeneities from their averaged values. We solve macroscopic problem and determine the distribution of fluid concentration in effective medium for the given initial and boundary conditions. (Received July 26, 2016)

1122-35-33 **Cornelis VAN DER MEE*** (cornelis110553@gmail.com), Viale Merello 92, 09123 Cagliari, Italy. *Exact Solutions of the Heisenberg Ferromagnetic Equation.*

In this talk the matrix triplet method is used to derive N-soliton and breather solutions of the Heisenberg ferromagnetic equation. The solutions obtained describe magnetic droplets. This equation can be obtained from the NLS equation by gauge transformation. (Received July 28, 2016)

1122-35-34 **Bernard Deconinck*** (deconinc@uw.edu), Department of Applied Mathematics, University of Washington, Seattle, WA 98195, and **Benjamin Segal** (bsegal@uw.edu), Department of Applied Mathematics, University of Washington, Seattle, WA 98195. *Analyzing the stability spectrum for elliptic solutions to the focusing NLS equation.*

The one-dimensional focusing cubic nonlinear Schroedinger (NLS) equation is one of the most important integrable equations, arising in a multitude of applications. The stability of the stationary periodic solutions of NLS is well studied, leading to, for instance, the iconic figure-eight spectrum for its cnoidal wave solutions. We present an explicit expression for the linear stability spectrum of both the trivial- and nontrivial-phase solutions. We use this expression to generate many explicit results about the spectrum. (Received July 28, 2016)

1122-35-44 **Tristan Buckmaster*** (buckmaster@cims.nyu.edu). *Onsager's Conjecture and Kolmogorov's Spectrum.*

In 1949, Lars Onsager in his famous note on statistical hydrodynamics conjectured that weak solutions to the Euler equation belonging to Hölder spaces with Hölder exponent greater than 1/3 conserve energy; conversely, he conjectured the existence of solutions belonging to any Hölder space with exponent less than 1/3 which dissipate energy.

The first part of this conjecture has since been confirmed (cf. Eyink 1994, Constantin, E and Titi 1994). During this talk we will discuss recent work related to resolving the second component of Onsager's conjecture. In particular, I will discuss a new result in the direction of a modern refinement of the conjecture related to Kolmogorov's famous scaling laws. (Received August 01, 2016)

1122-35-51 **Hakima Bessaih*** (bessaih@uwyo.edu), 1000 E. University Ave., Dept. 3036, Laramie, WY 82071, and **Yalchin Efendiev** and **Florian Maris**. *Homogenization of stochastic models in porous media.*

We study Brinkman's flows with microscale properties that are highly heterogeneous in space and time. The time variations are controlled by a stochastic differential equation (SDE). Our main results include the derivation of macroscale equations and showing that the macroscale equations are deterministic. 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 are generalized to some nonlinear diffusion equations with heterogeneous coefficients. (Received August 02, 2016)

1122-35-55 **Luigi C Berselli*** (luigi.carlo.berselli@unipi.it), Dipartimento di Matematica, Universita' di Pisa, Pisa, Italy. *On the local energy inequality for the Navier-Stokes equations.*

In this talk I will discuss the problem of approximations to the Navier-Stokes equations producing solutions, which are suitable in the sense of Scheffer and Caffarelli-Kohn-Nirenberg. This notion of solution is very relevant for partial regularity results, but also the local behavior of energy seems a natural request for numerical methods. I will present recent results on certain methods related with classical numerical methods. (Received August 04, 2016)

1122-35-56 **Eden Furtak-Cole*** (furtak@aggiemail.usu.edu), Animal Science, 3900 Old Main Hill, Logan, UT 84322, and **Aleksey S. Telyakovskiy** and **Clay A. Cooper**. *A Series Solution to the Porous Medium Equation.*

The porous medium equation (PME) is a generalization of the traditional Boussinesq equation when the diffusivity is a power-law function of hydraulic head. We analyze the power-law recharge of an initially dry, unconfined aquifer of semi-infinite extent. Similarity variables are introduced and the original problem is reduced to a boundary value problem for a nonlinear ODE. The position of the advancing front is not known ahead of time and is found in the process of solution. We present an analytical solution in the form of a power series, with the coefficients of the series given by a recurrence relation. The presented analytical solution compares favorably with a highly accurate numerical solution, and only a small number of terms of the series is needed to achieve high accuracy in our investigated scenarios. Our newly obtained analytical solution provides a good fit for the fluid profiles in a Hele-Shaw wedge experiment. (Received August 04, 2016)

1122-35-60 **Peter D. Miller*** (millerpd@umich.edu). *Semiclassical soliton ensembles for the three-wave resonant interaction equations.*

The three-wave resonant interaction equations are a fundamental asymptotic model for the weakly nonlinear non-dispersive interaction between three wave packets whose phases satisfy a triad resonance condition. This system has been known to be completely integrable since the 1970s due to contributions of Zakharov, Manakov, Kaup, and others. The Lax representation involves 3×3 matrices. I will describe joint work with Robert Buckingham and Robert Jenkins in which we study the Cauchy initial-value problem for certain generic initial data in the semiclassical limit. Our aim is to describe the stage of the evolution in which the packets are strongly interacting. I will explain how we construct a semiclassical soliton ensemble that approximates the dynamics in the semiclassical limit. (Received August 04, 2016)

1122-35-65 **B. M. Herbst*** (ben.herbst@gmail.com) and **C. P. Olivier** (colivier@sansa.org.za). *A numerical study of the large-period limit of a Zakharov–Shabat eigenvalue problem with periodic potentials.*

Deconinck and Kutz (2006 J. Comput. Phys. 219 296–321) developed an efficient algorithm for solving the Zakharov–Shabat eigenvalue problem with periodic potentials numerically. The same algorithm, using large periods, can be used to study non-periodic potentials (defined over the whole real line). It is shown that a particular choice of the Floquet exponent can produce accurate results for even moderately large periods of the potential. We use this to study the rather complex evolution of the spectrum from a periodic potential to the infinite line potential for the nonlinear Schroedinger equation. (Received August 06, 2016)

1122-35-67 **Bao-Feng Feng*** (baofeng.feng@utrgv.edu), 1201 W. Univ. Dr., Edinburg, TX 78541. *The geometric and algebraic aspects of a complex short pulse equation.*

In this talk, we are concerned with a complex short pulse (CSP) equation, which can be viewed as the analogue of the nonlinear Schrödinger (NLS) equation in the ultra-short pulse regime. We firstly derive the complex short pulse equation from the motion of space curves, and linked the CSP equation with a complex sine-Gordon equation, or the well-known Pohlmeyer-Lund-Regge system. Then we construct the multi-soliton solution for the CSP equation based on the reductions of two-component KP hierarchy. (Received August 06, 2016)

1122-35-71 **Eunhee Park*** (parkeh@indiana.edu), Indiana University, Department of Mathematics, 831 E 3rd St, Bloomington, IN 47405, and **C-Y Jung** (changyeoljung@gmail.com) and **Roger Temam**. *Boundary Layer Analysis of Nonlinear Reaction-Diffusion Equations in Polygonal Domains.*

We consider singularly perturbed nonlinear reaction-diffusion equations whose solutions display thin boundary layers near the boundary of the domain. We fully analyse the singular behaviours of the solutions at any given order with respect to the small parameter ϵ. It is noteworthy that we discuss boundary layer analysis which fits a domain with corners, especially a polygonal domain. The other key feature of this work is that we treat the nonlinear reaction terms at any given order which is novel along the singular perturbation analysis. We believe that the analysis can be suitably extended to other nonlinear problems. (Received August 07, 2016)

1122-35-74 **José Carrillo**, **Sabine Hittmeir**, **Bruno Volzone** and **Yao Yao*** (yaoyao@math.gatech.edu). *Long time behavior of solutions to the 2D Keller-Segel equation with degenerate diffusion.*

The Keller-Segel equation is a nonlocal PDE modeling the collective motion of cells attracted by a self-emitted chemical substance. When this equation is set up in 2D with a degenerate diffusion term, it is known that solutions exist globally in time, but their long-time behavior remains unclear. In a joint work with J.Carrillo,

S.Hittmeir and B.Volzone, we prove that all stationary solutions must be radially symmetric up to a translation, and use this to show convergence towards the stationary solution as the time goes to infinity. (Received August 08, 2016)

1122-35-96 **Jessica Lin***, 480 Lincoln Dr., Madison, WI 53706, and **Scott Armstrong**. *Optimal Error Estimates in the Stochastic Homogenization for Elliptic Equations in Nondivergence Form.*

I will present quantitative error estimates in the stochastic homogenization for uniformly elliptic equations in nondivergence form. Under strong independence assumptions on the environment, I will identify the typical (optimal) size of the fluctuations with stretched exponential-type bounds in probability. A key ingredient of our approach is to develop a regularity theory down to microscopic scale which is essentially inherited from the homogenized equation. (Received August 09, 2016)

1122-35-110 **Gino Biondini*** (biondini@buffalo.edu), State University of New York at Buffalo, Department of Mathematics, Buffalo, NY 14260. *Universal behavior of modulationally unstable media.*

I will begin by showing how modulational instability (MI) manifests itself within the inverse scattering transform for the focusing nonlinear Schrodinger (NLS) equation. Then 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. For long times, the xt-plane divides into three regions: 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. Finally, I will show that this kind of asymptotic behavior is not limited to the NLS equation, but is shared among a rather large class of models (including several PDEs, nonlocal systems and differential-difference equations) possessing modulational instability (Received August 10, 2016)

1122-35-121 **Ian Grooms*** (ian.grooms@colorado.edu), Boulder, CO 80309, **William Kleiber**, Boulder, CO 80309, and **William Barham**, Boulder, CO 80309. *Non-Gaussian stochastic multiscale models in geophysical fluid dynamics.*

Simulations of large-scale geophysical fluid dynamics require parameterizations of the effects of unresolved subgrid scale dynamics. Unresolved dynamics commonly effect the resolved large scales through their net momentum and tracer fluxes, which are quadratic products of subgrid-scale variables. These unresolved variables can be efficiently modeled as Gaussian random fields, leading to strongly non-Gaussian fluxes. This talk reports the development and simulation of stochastic PDE models for large-scale ocean dynamics forced by subgrid-scale fluxes that are products of Gaussian random fields. It also reports on the development and simulation of a system of five stochastic differential equations modeling the response of the large-scale ocean circulation to fluxes affected by products of fast Gaussian variables. (Received August 10, 2016)

1122-35-124 **Robert Buckingham*** (buckinrt@uc.edu), Department of Mathematics, University of Cincinnati, Cincinnati, OH 45221, and **Robert Jenkins** and **Peter Miller**. *Semiclassical phenomena in the three-wave resonant interaction equations.*

The three-wave resonant interaction equations are a completely integrable system modeling the evolution of three electrical pulses in a dispersive medium with quadratic linearity. Using WKB-approximated scattering data, we construct families of exact solutions to study the semiclassical behavior. Our results suggest the asymptotic approximation of solutions by modulated elliptic functions, similar to phenomena seen in other nonlinear wave equations such as the KdV, NLS, and sine-Gordon equations. This work is joint with Robert Jenkins and Peter Miller. Further details on our analytical results for semiclassical scattering data will be presented in the companion talk by Peter Miller. (Received August 10, 2016)

1122-35-133 **Gino Biondini** and **Dionyssios Mantzavinos*** (dmantzavinos@umass.edu), Department of Mathematics and Statistics, University of Massachusetts Amherst, Amherst, MA 01003-9305. *Long-time asymptotics for the focusing nonlinear Schrödinger equation with nonzero boundary conditions at infinity.*

The long-time asymptotic behavior of the focusing cubic nonlinear Schrödinger (NLS) equation on the line with nonzero boundary conditions at infinity is characterized via the Deift-Zhou nonlinear steepest descent method. First, employing the recently developed inverse scattering transform for the focusing NLS with nonzero boundary conditions, the solution of the NLS initial value problem is associated to a Riemann-Hilbert problem whose jumps involve exponentially growing terms. Then, using the Deift-Zhou method, these jumps are regularized via appropriate deformations of the jump contours in the spectral plane. Importantly, these deformations are

not the same everywhere on the xt-plane, and eventually decompose the xt-plane into two types of regions: 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 slowly modulated periodic oscillations. The expression of the asymptotics in the central region in terms of elliptic solutions of the focusing NLS equation is also explicitly discussed. This is joint work with Gino Biondini. (Received August 11, 2016)

1122-35-140 **Gro Hovhannisyan** and **Oliver Ruff***, Kent State University at Stark, 6000 Frank Ave NW, North Canton, OH 44720. *Darboux transformations on time-space scales.*

We extend the classical Darboux transformation to the setting of Hilger's time-scale calculus, and obtain a Crum-type formula valid on an arbitrary time-space scale and applicable to a variety of integrable non-linear dynamic equations. (Received August 11, 2016)

1122-35-145 **Ziad H Musslimani*** (musslimani@math.fsu.edu), Florida State University, Department of Mathematics, Tallahassee, FL 32306. *PT symmetry, nonlocal integrable evolution equations and application.*

A nonlocal nonlinear Schrödinger (NLS) equation was recently introduced in Phys.Rev.Lett. 110, 064105 (2013) and shown to be an integrable infinite dimensional Hamiltonian evolution equation. In this talk we present a detailed study of the inverse scattering transform of this nonlocal NLS equation. The direct and inverse scattering problems are analyzed. Key symmetries of the eigenfunctions and scattering data and conserved quantities are discussed. The inverse scattering theory is developed by using a novel left-right Riemann–Hilbert problem. The Cauchy problem for the nonlocal NLS equation is formulated and methods to find pure soliton solutions are presented; this leads to explicit time-periodic one and two soliton solutions. A detailed comparison with the classical NLS equation is given and brief remarks about nonlocal versions of the modified Korteweg–de Vries and sine-Gordon equations are made.

This is a joint work with Mark J. Ablowitz (Received August 11, 2016)

1122-35-170 **Akif Ibragimov*** (akif.ibraguimov@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Lubbock, TX 79409, **Alexander Grigoryan**, Fakultat fur Mathematik, Universit, Bielefeld, Germany, and **Alexander Nazarov**, St.-Petersburg Branch of Steklov Math. Instit, St.-Petersburg, Russia. *Mixed boundary value problem in unbounded domain for elliptic equation of second order.*

In this paper we will investigate regularity problem at infinity for solutions of elliptic equation of second order with respect to mixed Dirichlet and Neumann boundary conditions. We will show that under some assumption on Dirichlet and Neumann parts of the boundary solution is regular at infinity. First this type of test was obtained in breakthrough work by Vladimir Mazya for elliptic equations in divergent form in "An analogue of Wiener's criterion for the Zaremba problem in a cylindrical domain." Funktsional. Anal. i Prilozhen. 16 (1982), No. 4. In the current research both divergent and non-divergent equations will be considered. (Received August 12, 2016)

1122-35-179 **Susan Friedlander*** (susanfri@usc.edu), **Nathan Glatt-Holtz** and **Vlad Vicol**. *Inviscid limits for a stochastically forced shell model of turbulent flow.*

We establish the anomalous mean dissipation rate of energy in the inviscid limit for a stochastic shell model of turbulent flow. The proof relies on viscosity independent bounds for stationary solutions and on establishing ergodic and mixing properties for the viscous model. (Received August 12, 2016)

1122-35-195 **Anna L Mazzucato*** (alm24@psu.edu), **Victor Nistor** and **Siyan Zhang**. *On the solution semigroup for a degenerate Fokker-Planck equation.*

We discuss a degenerate Fokker-Planck equation which arises in a stochastic volatility model with mean reversion. By means of a certain operator splitting and commutator arguments, we prove that the solution operator forms a strongly continuous semigroup in exponentially weighted Sobolev spaces, which are natural for applications, and derive an exact formula for its distributional kernel. We exploit techniques from solvable Lie algebras. (Received August 13, 2016)

1122-35-216 **Vincent R Martinez*** (vmartin6@tulane.edu), Mathematics Department, 424 Gibson Hall, New Orleans, LA 70118, **Michael S Jolly** (msjolly@indiana.edu), IN , and **Edriss S Titi** (titi@math.tamu.edu), TX. *Analytical studies for a Data Assimilation Algorithm: Surface data, Higher-order synchronization, and Time-averaged measurements.*

This talk will discuss recent studies in a data assimilation algorithm proposed by Azouani, Olson, and Titi. The algorithm exploits the finite-dimensionality of the dynamics of certain dissipative equations for which "determining quantities" exist, e.g. knowledge of sufficiently many low Fourier modes of the solution for all time, determines all higher modes asymptotically in time. By collecting finitely many of such quantities, one can then use the algorithm to produce an approximating solution that converges to the reference solution corresponding to the collected data asymptotically in time and an exponential rate. In this talk, we will discuss several joint works with A. Biswas, M.S. Jolly, E.J. Olson, and E.S. Titi in which we investigate the topologies that the synchronization takes place, its ability to accommodate the more physical case of time-averaged observables, and studies that support the idea that for vertically-constrained flows, one need only assimilate data collected at the boundary to synchronize the approximating flow with the reference flow in the domain's interior. In these works, we use the 2D Navier-Stokes and 2D subcritical surface quasi-geostrophic equations as our main examples. (Received August 14, 2016)

1122-35-219 **Amnon J. Meir*** (ajmeir@smu.edu), Department of Mathematics, Southern Methodist University, PO Box 750156, Dallas, TX 75275. *On Some Constrained PDE.*

In this talk I will briefly describe some (nonstandard) constrained pde which arise from applications. In the problems of interest the pde are supplemented by integral constraints. I will describe some theoretical results and the finite element approximation of solutions of these equations.

This is based on joint work with D. Glotov, W. E. Hames, and S. Nagoma. (Received August 14, 2016)

1122-35-227 **Juraj Foldes*** (jfoldes@ulb.ac.be), 141 Cabell Drive, Kerchof Hall, Charlottesville, VA 22904, and **Vladimir Sverak**. *An analysis of Euler equation via statistical mechanics and variational methods.*

Two dimensional turbulent flows for large Reynold's numbers can be approximated by solutions of incompressible Euler's equation. As time increases, the solutions of Euler equation are increasing their disorder; however, at the same time, they are limited by the existence of infinitely many invariants. Hence, it is natural to assume that the limit profiles are functions which maximize an entropy given the values of conserved quantities. These profiles, described by methods of Statistical Mechanics, are solutions of non-usual variational problems with infinite number of constraints. We will show how to analyze the problem and we will derive symmetry properties of entropy maximizers on symmetric domains. This is a joint work with Vladimr Sverak (University of Minnesota). (Received August 14, 2016)

1122-35-275 **David Parker**, 1874 Campus Delivery, Fort Collins, CO 80523, **Barbara Shipman** (bshipman@uta.edu), Arlington, TX , and **Patrick Shipman*** (shipman@math.colostate.edu), Fort Collins, CO 80523-1874. *Weierstrass-Enneper Representations of Surfaces in Euclidean and Lorentz spaces – Part II.*

We continue the talk of B. Shipman by looking at isometric deformations of Euclidean, spacelike, and timelike surfaces given by general Weierstrass-Enneper representations. (Received August 15, 2016)

1122-35-280 **Jacob Bedrossian*** (jacob@cscamm.umd.edu), 1400 Irving St NW, Apt 947, Washington, DC 20010. *Nonlinear Echoes and Landau damping with insufficient regularity.*

In this talk, we will discuss recent advances towards understanding the regularity hypotheses in the theorem of Mouhot and Villani on Landau damping near equilibrium for the Vlasov-Poisson equations on $\mathbb{T}^d \times \mathbb{R}^d$. Specifically, we will discuss the recent proof that it cannot, in general, be extended to Sobolev spaces on $\mathbb{T} \times \mathbb{R}$. This is demonstrated by constructing a sequence of homogeneous background distributions and arbitrarily small perturbations in H^s which deviate arbitrarily far from free transport for long times. The density experiences a sequence of nonlinear oscillations that damp at a rate which is arbitrarily slow compared to the predictions of the linearized Vlasov equations. The nonlinear instability is due to the repeated re-excitation of a resonance known as a plasma echo. Connections with the stability of shear flows in the 2D and 3D Navier-Stokes equations may also be discussed if time permits. (Received August 15, 2016)

1122-35-289 **Frederico Furtado*** (furtado@uwyo.edu), Dept. of Mathematics, University of Wyoming, Laramie, WY 82071, and **Dan Marchesin** and **Pablo Castaneda**. *The displacement problem for immiscible three-phase flow in green reservoirs.*

We discuss the displacement problem for immiscible three-phase flow described by a system of two conservation laws with fluxes originating from Corey-type permeabilities. A mixture of water, gas, and oil is injected into a porous medium initially saturated with oil, which is partially displaced. The solutions of the resulting Riemann problems generically belong to two classes. Each class of solutions occurs for injection states in one of two regions of the state space, separated by a curve of states for which the interstitial velocities of water and gas are equal. This is a separatrix curve because on one side water appears at breakthrough, while gas appears for injection states on the other side. In other words, the behavior near breakthrough is flow of oil and of the dominant phase, either water or gas; the non-dominant phase is left behind. This description of the solutions is valid for any values of phase viscosities. The inevitable loss of strict hyperbolicity for such flow models seems to be the cause of this solution structure. (Received August 15, 2016)

1122-35-300 **Jesenko Vukadinovic*** (jesenko.vukadinovic@csi.cuny.edu), 365 Fifth Avenue, PhD Program in Mathematics, New York, NY 10016-4309. *Dissipation enhancement by flows whose Hamiltonians feature hyperbolic equilibrium points.*

This is an extension of author's work on dissipation enhancement by closed flows with Hamiltonians whose orbits are Jordan curves and feature only elliptic equilibrium points. Averaging along stream lines allows for reduction of the spectral problem for the 2D advection-diffusion equation to a 1D Schrödinger spectral problem featuring purely imaginary potentials. Dissipation enhancement is expressed as a power law with respect to diffusivity, with the power determined by the least power in the Taylor expansion of the frequency function about its end points and critical points. It has been conjectured that in the case of more complicated Hamiltonians featuring hyperbolic point, the dissipation enhancement is better than any power law. In this talk, the author will discuss how recent work by Bedrossian and Coti-Zelati using ideas from hypocoercivity can be extended to prove this conjecture. (Received August 15, 2016)

1122-35-306 **Igor Rumanov*** (igor.rumanov@colorado.edu), Dept. of Applied Mathematics, University of Colorado Boulder, 526 UCB, Boulder, CO 80309. *Quantum Painleve II (QPII).*

Quantum Painleve equations (QP) are Fokker-Planck (or non-stationary Schroedinger) equations in two independent variables ("time" and "space")with diffusion-drift operators being quantized Painleve Hamiltonians. They are satisfied by certain eigenvalue probabilities of beta ensembles of random matrices (a.k.a. Coulomb gases). Dyson index beta (beta/2) plays the role of (inverse) Planck constant. We construct classical integrable structure associated with QPII, more explicit in the case of even integer beta. However, the nonlinear PDEs derived from QPII possess Painleve PDE property for all values of beta. Their general solutions are related by a Cole-Hopf transform with two linearly independent solutions of QPII. (Received August 15, 2016)

1122-35-309 **Ning Ju*** (ning.ju@okstate.edu), 401 Mathematical Sciences, Oklahoma State University, Stillwater, OK 74078. *Global regularity and long-time behavior for the solutions to 2D Boussinesq equations.*

New results recently obtained by the speaker about global regularity and long-time behavior for solutions to 2D Boussinesq equations will be presented and discussed. (Received August 15, 2016)

1122-35-312 **Jessica Taylor** (jtaylor5@ucmerced.edu), Merced, CA 95343, and **Boaz Ilan*** (bilan@ucmerced.edu), Merced, CA 95343. *Band-edge solitons in the NLS equation with periodic PT-symmetric potentials.*

The bifurcation of nonlinear bound states from the spectral edges of the NLS equation with periodic parity-time (PT)-symmetric potentials is studied asymptotically and computationally. These modes undergo a transition near the breakdown point of the PT symmetry. The effective mass tensor and nonlinear coupling constants, which determine the structure of these modes, are analyzed in detail. The implication to collapse dynamics is discussed. (Received August 16, 2016)

1122-35-329 **Annalisa M Calini*** (calinia@cofc.edu), Department of Mathematics, College of Charleston, 66 George St, Charleston, SC 29424, and **Stephane Lafortune** and **Brenton J Lemesurier**. *A Lyapunov function for the Hasimoto Filament.* Preliminary report.

We investigate the nonlinear stability of the one-soliton solution of the Vortex Filament Equation (VFE) without making recourse to its well-known correspondence with the Nonlinear Schrödinger equation. After formulating the VFE as a Hamiltonian system that is invariant under a group of symmetries on a suitable space of curves,

we propose a Lyapunov functional for the Hasimoto filament and discuss its orbital stability. (Received August 16, 2016)

1122-35-334 **Gregory Lyng*** (glyng@uwyo.edu). *Eigenvalue perturbations and semiclassical soliton ensembles for the focusing nonlinear Schrödinger equation.*

Eigenvalues of the nonselfadjoint Zakharov–Shabat problem are a key building block in the analysis of the semiclassical (zero-dispersion) limit for the focusing nonlinear Schrödinger equation. However, in many cases, complete knowledge of the eigenvalues is not known. Because of this, it is typical to work with approximate eigenvalues, but this introduces an uncontrolled error into a system which features acute modulational instabilities in the limit of interest. In this talk, we describe recent and ongoing computational and analytical work with the ultimate goal of rigorously characterizing and controlling this error. (Received August 16, 2016)

1122-35-337 **Stephane Lafortune*** (lafortunes@cofc.edu), Dpartment of Mathematics, College of Chalreston, 175 Calhoun Street, RSS 339, Charleston, SC 29424, and **Annalisa Calini**, **Brenton LeMesurier** and **Thomas Ivey**. *Linear and Orbital Stability of Solutions to the VFE and the VFE Hierarchy.* Preliminary report.

By the term vortex filament, we mean a mass of whirling fluid or air (e.g. a whirlpool or whirlwind) concentrated along a slender tube. The most spectacular and well-known example of a vortex filament is a tornado. A waterspout and dust devil are other examples. In more technical applications, vortex filaments are seen and used in contexts such as superfluids and superconductivity. One system of equations used to describe the dynamics of vortex filaments is the Vortex Filament Equation (VFE). The VFE is a system giving the time evolution of the curve around which the vorticity is concentrated. In this talk, we develop a framework for studying the linear and orbital stability of VFE solutions, based on the correspondence between the VFE and the NLS provided by the Hasimoto map. This framework is applied to VFE solutions that take the form of soliton solutions or closed vortices. If time permits, we will also tackle the case of solutions to other members of the VFE hierarchy of integrable equations. (Received August 16, 2016)

1122-35-346 **David P Herzog*** (dherzog@iastate.edu), Department of Mathematics, Iowa State University, 396 Carver Hall, Ames, IA 50011. *Scalings and saturation in infinite-dimensional control problems with applications to stochastic partial differential equations.*

We discuss scaling methods which can be used to solve low mode control problems for nonlinear partial differential equations. These methods lead naturally to a infinite-dimensional generalization of the notion of saturation, originally due to Jurdjevic and Kupka in the finite-dimensional setting of ODEs. The methods will be highlighted by applying them to specific equations, including reaction-diffusion equations, the 2d/3d Euler/Navier-Stokes equations and the 2d Boussinesq equations. Applications to support properties of the laws solving randomly-forced versions of each of these equations will be noted. (Received August 16, 2016)

1122-35-347 **A. David Trubatch*** (david.trubatch@montclair.edu), Department of Mathematical Sciences, Montclair State University, Montclair, NJ 07043, and **Jeffrey Slepoi**. *Detection of Wave Breaking in the Short-Pulse Equation.*

The Short-Pulse Equation (SPE) is a model for ultra-short (pico- and femto-second) pulses in optical fibers with Kerr nonlinearity. Solutions of the SPE may undergo wave breaking (derivative catastrophe) in finite time. In particular, the pulse solution breaks in finite time when the shortness parameter exceeds a threshold value. The appearance of the break is associated with a qualitative change in the decay rate of the Fourier coefficients of the solution. This method of detecting wave breaking is also effective for detecting wave breaking numerical simulations of the SPE. For modified-Gaussian initial data, the parameter dependence of wave breaking cannot be completely determined analytically. Instead, in parameter space, there is a gap between a region of solutions that can be proven to exist for infinite time and solutions proven to break in finite time. However, by analysis of numerically simulated solutions with modified-Gaussian initial data, it is possible to identify threshold parameter values in the gap that separate breaking and non-breaking solutions. (Received August 16, 2016)

1122-35-351 **Magdalena Czubak*** (magda.czubak@colorado.edu). *Almost sure wellposedness for 2D wave equations with null forms.* Preliminary report.

The null condition was introduced by Klainerman. The nonlinearities exhibiting null structure appear in many systems including Wave Maps, Yang Mills, Maxwell-Klein-Gordon and the space-time Monopole equation. Two dimensions create obstacles towards low regularity wellposedness that are not present in higher dimensions. In this talk we describe recent progress on improving the wellposedness results by suitably randomizing the initial data. We discuss both a periodic and nonperiodic setting. (Received August 16, 2016)

1122-35-363 **Patrick Sprenger** and **Mark A Hoefer*** (hoefer@colorado.edu), Applied Mathematics, 526 UCB, Boulder, CO 80304. *Non-convex/Non-classical Dispersive Hydrodynamics.*

The fifth order Korteweg-de Vries (KdV) or Kawahara equation, is identified as a universal model of Eulerian hydrodynamics with higher order dispersive effects. Utilizing asymptotic methods and numerical computations, this work classifies the long-time behavior of solutions for step-like initial data. For convex linear dispersion, the result is a dispersive shock wave (DSW), bearing close resemblance to the classical KdV DSW. For non-convex dispersion, three distinct dynamic regimes are observed. For small amplitude jumps, a perturbed KdV DSW with positive polarity and orientation is generated, accompanied by small amplitude radiation from a solitary wave leading edge that is embedded in the linear spectrum, termed a radiating DSW or RDSW. For moderate jumps, a crossover regime is observed with finite amplitude waves propagating forward and backward from the sharp transition region. For jumps exceeding a critical threshold, a new type of DSW is observed termed a traveling DSW or TDSW. The TDSW consists of a traveling wave solution that connects a partial, non-monotonic, negative solitary wave at the trailing edge to an interior nonlinear periodic wave. Its speed, a generalized Rankine-Hugoniot jump condition, is determined by the far-field structure of the traveling wave. (Received August 16, 2016)

1122-35-390 **Yajie Zhang*** (wonderfulzyj@gmail.com), 715-2 W Cherry Ln, State College, PA 16803. *A Regularity Analysis of Parabolic Transmission Problem on Polygonal Domain.*

We study theoretical and practical issues for second order linear parabolic equation with jump discontinuities in its coefficients on a polygonal domain Ω that may have cracks or vertices that touch the boundary. We consider in particular the equation $-div(A\nabla u)+u_t = f$ with appropriate initial condition and mixed boundary/interface conditions, where the matrix A has variable, piecewise smooth coefficients. We establish some regularity results and, under some additional conditions, we also establish well-posedness in weighted Sobolev spaces in the cases when there are no Neumann boundary conditions imposed on adjacent sides of the polygonal domain. When Neumann boundary conditions are imposed on adjacent sides, we fail to have well-posedness according to the Lumer-Phillips Theorem. (Received August 17, 2016)

37 ► Dynamical systems and ergodic theory

1122-37-70 **Kelly B Yancey*** (kbyancey1@gmail.com). *Self-Similar Interval Exchange Transformations.*

During this talk we will discuss the class of self-similar 3-IETs and show that they satisfy Sarnak's conjecture. We will do this by appealing to the theory of joinings. Specifically we will show how to prove the property of minimal self-joinings for substitution systems (self-similar IETs can be thought of in this context). (Received August 07, 2016)

1122-37-130 **Terry Soo***, tsoo@ku.edu, and **Amanda Audrey Wilkens**. *Equivariant thinning.* Preliminary report.

We construct monotone entropy increasing factors in the context of a Bernoulli shift over the free group of rank at least two. (Received August 10, 2016)

1122-37-176 **Michael H. Schraudner*** (mschraudner@dim.uchile.cl), Beauchef 851, Torre Norte, Of. 709, 8370459 Santiago de Chile, RM, Chile, and **Álvaro M. Bustos**. *Projective subdynamics of subshifts of finite type on virtually cyclic groups.* Preliminary report.

Building on the notion of projective subdynamics, studied by R. Pavlov and M. Schraudner for $\mathbb{Z}^d$ subshifts of finite type (SFTs) the current work investigates the setting of G SFTs defined on (infinite) virtually cyclic groups G. Possible projective subdynamics are sofic and have to satisfy necessary conditions similar to the ones obtained in the $\mathbb{Z}^d$ context. Constructive realization results however depend on the structure and size of the complementary part of the infinite cyclic subgroup inside G and we are able to give tight bounds on the question for which virtually cyclic groups G certain sofic shifts do (or do not) occur as projective subdynamics. In addition we also prove some results relating the G SFT's entropy to the entropy of its projective subdynamics. (Joint work carried out during A. Bustos' master thesis.) (Received August 12, 2016)

1122-37-192 **Maria Isabel Cortez** (medynets@usna.edu), Annapolis, MD 21402, and **Kostya Medynets*** (medynets@usna.edu), 572C Holloway Road, Annapolis, MD 21402. *Orbit Equivalence Rigidity of Equicontinuous Systems.*

We establish that every equicontinuous system is topologically conjugate to a profinite action, where the finite-index subgroups are not necessarily normal. We then show that two profinite actions (X, G) and (Y, H) are

continuously orbit equivalent if and only if the groups G and H are virtually isomorphic and the isomorphism preserves the structure of the finite-index subgroups defining the actions. As a corollary, we obtain a dynamical classification of the restricted isomorphism between generalized Bunce-Deddens C^*-algebras. We show that for minimal equicontinuous $\mathbb{Z}^d$-systems continuous orbit equivalence implies that the systems are virtually piecewise conjugate. This result extends Boyle's flip-conjugacy theorem. (Received August 13, 2016)

1122-37-199 **Sergey Bezuglyi*** (sergii-bezuglyi@uiowa.edu), 14 MacLean Hall, Iowa City, IA 52242.
On some non-dynamical applications of Bratteli diagrams.

In my talk, I will discuss several applications of Bratteli diagrams in analysis. Firstly, Bratteli diagrams can serve as a source of highly nontrivial examples of harmonic functions of finite energy on weighted graphs. Secondly, stationary Bratteli diagrams naturally generate semibranching function systems which lead to representations of Cuntz-Krieger algebras. Thirdly, the path space of a random walk on an infinite graph can be represented as the path space of an "infinite dimensional" Bratteli diagram equipped with a Markov measure. (Received August 13, 2016)

1122-37-206 **Lori Alvin*** (lalvin@bradley.edu). *Homeomorphic restrictions of unimodal maps.*

In this talk we provide several symbolic characterizations of a class of unimodal maps whose restriction to the omega-limit set of the turning point is a minimal homeomorphism on a Cantor set. The first characterization is given in terms of the shift space generated by the kneading sequence of the unimodal map, and a second characterization relying only on the structure of the kneading sequence is also provided. The goal of this project is to develop an algorithm that can be used to generate the kneading sequences of unimodal maps with the desired homeomorphic restriction. (Received August 14, 2016)

1122-37-212 **Vaughn Climenhaga*** (climenha@math.uh.edu). *Specification and Markov properties in shift spaces.*

A classical result in thermodynamic formalism is that for a mixing subshift of finite type, the equilibrium states associated to Holder continuous potentials are unique and display strongly stochastic behaviour. There are two approaches, one via the specification property and one via the Markov structure of the shift. These have both been generalized to broader classes of shift spaces; I will describe results relating these generalizations to each other. (Received August 14, 2016)

1122-37-217 **Vadim Kaimanovich***, 585 King Edward, Ottawa, ON , Canada. *Invariance, quasi-invariance and unimodularity for random graphs.*

We interpret the probabilistic notion of unimodularity for measures on the space of rooted locally finite connected graphs in terms of the theory of measured equivalence relations. It turns out that the right framework for this consists in considering quasi-invariant (rather than just invariant) measures with respect to the root moving equivalence relation. We define a natural modular cocycle of this equivalence relation, and show that unimodular measures are precisely those quasi-invariant measures whose Radon–Nikodym cocycle coincides with the modular cocycle. This embeds the notion of unimodularity into the very general dynamical scheme of constructing and studying measures with a prescribed Radon–Nikodym cocycle. (Received August 14, 2016)

1122-37-261 **Oksana Bihun*** (obihun@uccs.edu). *Infinite Hierarchies of Solvable N-body Problems.*
Preliminary report.

We propose a new algebraic concept of infinite hierarchies of monic polynomials, such that the coefficients of the polynomials in the next generation of the hierarchy are the zeros of a polynomial in the current generation. Using this concept, we formulate a new method to construct solvable N-body problems. By assuming that the zero generation – seed – polynomial has time-dependent coefficients that evolve according to a known solvable N-body system, we describe the motion of the coefficients of the polynomials in the subsequent generations of the polynomial hierarchy. This way an infinite hierarchy of N-body problems is constructed. Each system in the last hierarchy is solvable: its solution evolves as the N zeros of a polynomial with time-dependent coefficients that themselves evolve as the zeros of another polynomial, from a previous generation in the polynomial hierarchy, and so on, until the seed polynomial is reached. Among the examples, we present a new solvable N-body problem that is a hybrid of the two famous Calogero-Moser and goldfish models. This is a joint work with Francesco Calogero. (Received August 15, 2016)

1122-37-267 **Jeannette Janssen** and **Anthony Quas***, Mathematics and Statistics, University of Victoria, Victoria, BC V8W2Y2, Canada, and **Reem Yassawi**. *On random infinite rank Bratteli diagrams.*

A Bratteli diagram is a graded directed graph with a single root and edges from vertices in one level to the level below. Vershik introduced a dynamical system on a Bratteli diagram equipped with a suitable order. In this talk, we discuss the question: given a fixed Bratteli diagram, what are the properties of the Vershik system if an order is selected at random? (Received August 15, 2016)

1122-37-292 **Lori Alvin** and **Drew D Ash*** (drash@davidson.edu), 215 N. Thompson St., Davidson, NC 28036, and **Nicholas S Ormes**. *Bounded Topological Speedups of Odometers and Primitive Substitution systems.*

Given a dynamical system (X, T) one can define a speedup of (X, T) as another dynamical system $S : X \to X$ where $x \mapsto T^{p(x)}(x)$ for some $p : X \to \mathbb{Z}^+$. 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 and is a topological analogue of a theorem of Arnoux, Ornstein, and Weiss. In this talk, we will focus on recent joint work with Lori Alvin and Nic Ormes on a strengthening of topological speedups, namely bounded topological speedups. In this case, we require that our "jump function" p be bounded and hence continuous. Here the motivating question is: what, if anything, can be preserved with the added structure of p being bounded? We will discuss two theorems which yield positive answers to this question. Specifically, a bounded speedup of an odometer is a conjugate odometer and a bounded speedup of an aperiodic, primitive substitution is again an aperiodic, primitive substitution, though is never conjugate to the original substitution system. (Received August 15, 2016)

1122-37-313 **James P Talisse*** (m176378@usna.edu). *The Centralizer Group of Toeplitz Systems Under Abelian Group Actions.*

Given a Cantor dynamical system (X, G), the centralizer group $C(G)$ consists of all homeomorphisms of X that commute with the action of the group G. In the talk, we briefly discuss what is known about the interplay between algebraic properties of $C(G)$ and dynamical properties of the underlying system (X, G). We then prove that if G is Abelian and (X, G) is a Toeplitz system, i.e., an almost one-to-one extension of an equicontinuous system, then $C(G)$ is Abelian. (Received August 16, 2016)

1122-37-322 **Kevin McGoff*** (kmcgoff1@uncc.edu) and **Andrew Nobel**. *Optimal tracking for dynamical systems.* Preliminary report.

This talk concerns recent joint work with Andrew Nobel in which we describe the limiting behavior of the average per-state cost when trajectories of a topological dynamical system are used to track a trajectory from an observed ergodic system. We establish a variational characterization of the limiting average cost in terms of the joinings of the two systems, and we show that the set of optimal joinings is convex and compact in the weak topology. Using these results, we establish a general convergence theorem for the limiting behavior of statistical inference procedures based on optimal tracking. (Received August 16, 2016)

1122-37-331 **Eugen Andrei Ghenciu*** (ghenciue@uwstout.edu), 1296 River Ridge Rd., River Falls, WI 54022, and **Simon Baker**. *Dynamical properties of S-gap shifts and other shift spaces.*

We study the dynamical properties of certain shift spaces. To help study these properties we introduce two new classes of shifts, namely boundedly supermultiplicative (BSM) shifts and balanced shifts. We also study the measure theoretic properties of balanced shifts. We show that a shift space admits a Gibbs state if and only if it is balanced. Restricting ourselves to S-gap shifts, we relate certain dynamical properties of an S-gap shift to combinatorial properties from expansions in non-integer bases. This identification allows us to use the machinery from expansions in non-integer bases to give straightforward constructions of S-gap shifts with certain desirable properties. (Received August 16, 2016)

1122-37-335 **Joel Moreira*** (moreira@math.ohio-state.edu), Evanston, IL 60208, and **Florian Karl Richter**. *Spectral aspects of multiple ergodic theorems.*

Furstenberg's ergodic proof of Szemerédi's theorem initiated the study of multi-correlation sequences, i.e., sequences of the form $\alpha(n) = \int_X f_0 \cdot T^n f_1 \cdots T^{kn} f_k d\mu$, where (X, μ, T) is a measure preserving system, $k \in \mathbb{N}$ and $f_0, \ldots, f_k \in L^\infty(X)$. The limiting behavior of multi-correlation sequences is closely connected with the subject of multiple recurrence and hence has interesting implications in combinatorial number theory. We investigate multi-correlation sequences arising from systems with some spectral restrictions, and in particular show that the set of prime numbers is a set of multiple recurrence for totally ergodic systems. (Received August 16, 2016)

1122-37-345 **Sarah Bailey Frick*** (sarah.frick@furman.edu), 3300 Poinsett Hwy, Greenville, SC 29613, **Karl Petersen**, Chapel Hill, and **Sandra Shields**. *An essentially faithful coding of adic systems on the Pascal graph.*

We consider arbitrary orderings of the edges entering each vertex of the (downward directed) Pascal graph. Each ordering determines an adic (Bratteli–Vershik) system, with a transformation that is defined on most of the space of infinite paths that begin at the root. We prove that for every ordering the coding of orbits according to the partition of the path space determined by the first three edges is essentially faithful, meaning that it is one-to-one on a set of paths that has full measure for every fully supported invariant probability measure. (Received August 16, 2016)

1122-37-348 **Van Cyr*** (van.cyr@bucknell.edu), Department of Mathematics, Bucknell University, 1 Dent Drive, Lewisburg, PA 17837, **Bryna Kra** (kra@math.northwestern.edu), Department of Mathematics, Northwestern University, 2033 Sheridan Road, Evanston, IL 60208, and **John Franks** (j-franks@northwestern.edu), Department of Mathematics, Northwestern University, 2033 Sheridan Road, Evanston, IL 60208. *Automorphisms of zero entropy dynamical systems.*

The symmetries of a dynamical system X form an interesting and often quite complicated group called its automorphism group. A celebrated result of Boyle, Lind, and Rudolph is that the automorphism group of even very easily described (but positive entropy) systems frequently contains isomorphic copies of all of the following (among many others): every finite group, the free group on two generators, and the direct sum of countably many copies of Z. By contrast, a number of strong algebraic results have been obtained recently for symbolic dynamical systems with zero entropy. In this talk I will discuss recent joint work with B. Kra and J. Franks in which we provide nontrivial examples of groups that cannot embed into the automorphism group of any zero entropy subshift. (Received August 16, 2016)

1122-37-355 **Thomas French***, Thomas.French@du.edu. *Follower and Extender Sets of β-Shifts.*

Given a word w in the language of a one-dimensional symbolic shift X, the follower set $F(w)$ of w is the set of all right-infinite sequences which may legally follow w in some point of X. The follower set sequence of a shift X is the sequence which records, for each length n, the number of distinct follower sets corresponding to words of length n in X. Extender sets are a generalization of follower sets and we define the extender set sequence similarly. This talk will use the classical β-shifts as examples to demonstrate that for a given shift X, the follower and extender set sequences of X may behave quite differently. In fact, we will see examples in which the follower set sequence grows as slowly as possible, while the extender set sequence grows exponentially. (Received August 16, 2016)

1122-37-362 **Mike Boyle*** (mmb@math.umd.edu) and **Scott Schmieding**. *Isolating zero dimensional dynamics on manifolds II.* Preliminary report.

This is joint work in progress with Scott Schmieding, and a Part II to his talk.

For a surface homeomorphism (F,M), we consider an isolated zero dimensional subsystem (X,f). When (X,f) is expansive, we provide the kind of very strong constraints on (X,f) provided by Jana and Federico Rodriguez Hertz for the case (X,f) is an expansive attractor (relying very heavily on their work), but also find some additional possibilities allowed. (X,f) could be a shift of finite type (of course); a special type of sofic shift; or a subshift derived from an interval exchange transformation. The key is to study the connected components of a point of X within its local stable and unstable sets for (F,M), an approach at the heart of the great work of Hiraide and Lewowicz on expansive surface homeomorphisms.

We also consider how these results generalize when (F,M) is a surface homeomorphism and the isolated subsystem is not necessary expansive or zero dimensional. (Received August 16, 2016)

1122-37-367 **Scott Schmieding*** (schmiedi@math.umd.edu) and **Mike Boyle** (mmb@math.umd.edu). *Isolating zero dimensional dynamics on manifolds I.* Preliminary report.

A compact invariant set for a homeomorphism is called isolated if it is the maximal invariant set of some neighborhood of itself, and strongly isolated if it also contains the non-wandering points in the isolating neighborhood. A homeomorphism of a compact metric space can be (strongly) isolated in dimension n if it is topologically conjugate to the restriction of a homeomorphism of an n-dimensional compact manifold to a (strongly) isolated set. We recall some previous results presented elsewhere, including the result that the restrictions of homeomorphisms in dimension n to compact invariant sets can be strongly isolated in dimension $n+1$. We present some new constructions of Cantor systems which can be strongly isolated in dimension 2. (Received August 16, 2016)

1122-37-370 **Mahsa Allahbakhshi**, **John Antonioli*** (john.antonioli@du.edu) and **Jisang Yoo**. *Relative Equilibrium States and Class Degree.*

For a shift of finite type X, functions with a broad range of regularity conditions are known to have unique equilibrium states. In the presence of a factor map $\pi : X \to Y$, simple examples show that there may be multiple equilibrium states when we restrict to the fiber over an ergodic invariant measure on Y. In previous work, the notion of degree for a finite-to-one factor map was extended to give a bound on the number of measures of relative maximal entropy in a fiber.

In this talk, we will discuss how the same bound may be extended to relative equilibrium states for functions with sufficient regularity. (Received August 16, 2016)

1122-37-380 **Liz Sattler*** (lsattler@carleton.edu). *Fractal dimension of subfractals induced by subshifts.* Preliminary report.

In this talk, we will discuss subfractals, which will be defined as the set of all points in a fractal which are associated with an allowable word from a subshift on the symbolic space. We will show that bounds exist for the Hausdorff and box dimensions for a subfractal induced by a sofic subshift. We will also discuss ongoing work with certain classes of subfractals induced by non-sofic subshifts, such as S-gap shifts and beta shifts. (Received August 16, 2016)

39 ► Difference and functional equations

1122-39-61 **Ralph Willox*** (willox@ms.u-tokyo.ac.jp), Graduate School of Mathematical Sciences, the University of Tokyo, 3-8-1 Komaba, Meguro-ku, Tokyo 153-8914. *Singularity confinement, anticonfinement and algebraic entropy.*

In this talk I will discuss a method, recently introduced by Rod Halburd and inspired by Nevanlinna theory, for calculating the exact degree growth of a map that enjoys the singularity confinement property. In particular, I will present a simplified version of the same algorithm which is sufficient for obtaining the exact algebraic entropy for a confining second order map, and I will explain the algebro-geometric underpinnings of this approach. If time permits, I will also discuss special non-confining — so-called anticonfining — maps and show how to obtain their algebraic entropy. (Received August 05, 2016)

1122-39-213 **Nicholas M. Ercolani***, Department of Mathematics, University of Arizona, Tucson, AZ 85721. *Combinatorics, Dynamics, Integrability and Entropy.* Preliminary report.

Recent developments in random matrix combinatorics have provided insights into combinatorial/probabilistic problems such as geodesic distance in random surfaces and super-Brownian excursions. This talk will outline how these insights can be related to, and better understood, from a dynamical systems perspective on integrable discrete dynamical systems and, time permitting, the notion of algebraic entropy introduced by V. Arnold. This is joint work with Tova Brown. (Received August 14, 2016)

1122-39-224 **Dylan Murphy*** (dmurphy@math.arizona.edu). *Geometry of Discrete Schrödinger Operators.* Preliminary report.

Discrete and continuous Schrödinger operators with periodic potentials have beautiful algebrogeometric underpinnings. In the continuous case, they are known as Hill's operators, and from such an operator one can construct an algebraic curve with some associated geometric data. Together the curve and data can be used to integrate the flows of the KdV hierarchy by linearizing the flow on the Jacobian variety of the curve, and using theta functions to map back into the space of operators. Mumford and van Moerbeke established a similar correspondence for periodic difference operators (including, but more general than, discrete Schrödinger operators), showing how to construct an algebraic curve and ancillary data from an operator, and how to recover the operator (modulo conjugation by a diagonal operator) from the curve.

In this talk, we will discuss some current work toward the construction of geometric data for discrete Schrödinger operators with non-periodic potentials, following a limiting construction used by Ercolani and McKean to construct a "curve" and associated geometric data for continuous Schrödinger operators of scattering class. (Received August 14, 2016)

41 ► Approximations and expansions

1122-41-240 **Hoang A Tran*** (tranha@ornl.gov), Oak Ridge National Laboratory, Oak Ridge, TN 37831. *Polynomial approximation via compressed sensing of high-dimensional functions on lower sets.*

This work proposes and analyzes a compressed sensing approach to polynomial approximation of complex-valued functions in high dimensions. Of particular interest is the setting where the target function is smooth, characterized by a rapidly decaying orthonormal expansion, whose most important terms are captured by a lower (or downward closed) set. By exploiting this fact, we present a novel weighted ℓ_1 minimization procedure with a precise choice of weights, and a new version of iterative hard thresholding method, for imposing the downward closed preference. Theoretical results reveal that our computational approaches possess a provably reduced sample complexity compared to existing compressed sensing techniques presented in the literature. In addition, the recovery of the corresponding best approximation using these methods is established through an improved bound for the restricted isometry property. Numerical examples are provided to support the theoretical results and demonstrate the computational efficiency of the new weighted ℓ_1 minimization strategy. This is the joint work with Abdellah Chkifa, Nick Dexter and Clayton Webster. (Received August 15, 2016)

45 ► Integral equations

1122-45-52 **P. A. Praveen Janantha**, **Mikhail Cherkasskii**, **Boris A. Kalinikos**, **Mark A. Hoefer** and **Mingzhong Wu*** (mwu@colostate.edu), Department of Physics, Colorado State University, Fort Collins, CO 80523. *Advances in Nonlinear Spin Waves – Dark Soliton Pairs, Dispersive Shock Waves, and Foldover.*

Spin waves in magnetic thin films provide a powerful and versatile test bed for the study of dynamics of nonlinear waves. This presentation will report three of our recent studies on nonlinear spin waves in Y3Fe5O12 (YIG) thin films. We will first report the use of surface spin waves in YIG films to demonstrate for the first time the opposite phase jumps of dark soliton pairs. This phase property is expected theoretically but has never been demonstrated experimentally. Then, we will report the observation of envelope dispersive shock waves (DSWs) for surface spin waves. The nonlinear schrödinger equation predicts that an initial, steep increase in the amplitude of a carrier wave with repulsive nonlinearity can develop into an envelope DSW that consists of oscillations with both amplitude and width increasing from the front to the back and is terminated by a dark soliton. Such predictions have never been demonstrated before and will be reported in this presentation. Finally, we will report a foldover effect for nonlinear forward volume spin waves in a YIG strip-based feedback ring system. (Received August 03, 2016)

46 ► Functional analysis

1122-46-82 **Marc A. Rieffel*** (rieffel@math.berkeley.edu). *Vector bundles for "Matrix algebras converge to the sphere".* Preliminary report.

On looking through the literature of high-energy quantum physics one finds statements such as "matrix algebras converge to the sphere". Earlier I provided a general setting for understanding such statements, in which the matrix algebras are viewed as compact quantum metric spaces, and convergence is with respect to a quantum Gromov-Hausdorff-type distance. I will indicate briefly how this works.

But physicists want even more to treat structures on spheres (and other spaces), such as vector bundles, Yang-Mills functionals, Dirac operators, etc., and they want to approximate these by corresponding structures on matrix algebras. The main part of my talk will consist of indicating how to do this for vector bundles. One would like to be able to say that for two compact quantum metric spaces that are close together, to a given vector bundle on one of them there corresponds a unique vector bundle on the other. Even for ordinary compact metric spaces and ordinary Gromov-Hausdorff distance it is not so obvious how to do this. (Received August 08, 2016)

1122-46-175 **David R Pitts*** (dpitts2@unl.edu), Department of Mathematics, University of Nebraska–Lincoln, Lincoln, NE 68588. *Unique Pseudo-Expectations and Minimal Norms.*

Let $(\mathcal{D}, \Gamma, \alpha)$ be a C^*-dynamical system where Γ is a discrete group and $\mathcal{D}$ is a unital abelian C^*-algebra. Let $\mathcal{A}$ be the twisted convolution algebra of all finitely supported functions from Γ into $\mathcal{D}$. Generally, there are many

C^*-norms on $\mathcal{A}$: there is always a maximal one, but not a minimal one. But when Γ acts topologically freely, there is a minimal C^*-norm on $\mathcal{A}$, which follows from Theorem A below.

A regular MASA inclusion is a pair $(\mathcal{C}, \mathcal{D})$ of unital C^*-algebras where $\mathcal{D} \subseteq \mathcal{C}$ is a MASA and the set

$$\mathcal{N} := \{v \in \mathcal{C} : v\mathcal{D}v^* \cup v^*\mathcal{D}v \subseteq \mathcal{D}\}$$

has dense span in $\mathcal{C}$.

Let $I(\mathcal{D})$ be the injective envelope for $\mathcal{D}$. When $(\mathcal{C}, \mathcal{D})$ is a regular MASA inclusion, there is a unique pseudo-expectation $E : \mathcal{C} \to I(\mathcal{D})$. The left kernel of E is the unique ideal $\mathcal{L}$ of $\mathcal{D}$ maximal subject to $\mathcal{D} \cap \mathcal{L} = (0)$.

Theorem A. *If $(\mathcal{C}, \mathcal{D})$ is a regular MASA inclusion such that $\mathcal{L} = (0)$ and $\mathcal{A} = \operatorname{span}\mathcal{N}$, there are unique minimal and maximal C^*-norms on $\mathcal{A}$.* (Received August 12, 2016)

1122-46-235 **Konrad Aguilar*** (konrad.aguilar@du.edu) and **Frederic Latremoliere**. *Quantum ultrametrics on AF algebras and the Gromov-Hausdorff propinquity.*

We construct quantum metric structures on unital AF algebras with a faithful tracial state, and prove that for such metrics, AF algebras are limits of their defining inductive sequences of finite-dimensional C*-algebras for the quantum propinquity metric. We then study the geometry, for the quantum propinquity, of three natural classes of AF algebras equipped with our quantum metrics: the UHF algebras and the Effros—Shen AF algebras, which both form continuous images of the Baire space, and the Cantor space, on which our construction recovers traditional ultrametrics. Lastly, we will discuss possible new generalizations and applications, which may provide more continuity results with respect to the quantum propinquity topology. (Received August 15, 2016)

1122-46-242 **Albert Jeu-Liang Sheu*** (asheu@ku.edu). *Projective Modules over Quantum Projective Line.*

Taking a groupoid C*-algebra approach to the study of the quantum complex projective spaces $\mathbb{P}^n(\mathcal{T})$ constructed from the multipullback quantum spheres introduced by Hajac and collaborators, we analyze the structure of the C*-algebra $C\left(\mathbb{P}^1(\mathcal{T})\right)$ realized as a concrete groupoid C*-algebra, and find its K-groups. Furthermore after a complete classification of the unitary equivalence classes of projections or equivalently the isomorphism classes of finitely generated projective modules over the C*-algebra $C\left(\mathbb{P}^1(\mathcal{T})\right)$, we identify those quantum principal $U(1)$-bundles introduced by Hajac and collaborators among the projections classified. (Received August 15, 2016)

1122-46-281 **Elizabeth Gillaspy*** (elizabeth.gillaspy@colorado.edu) and **Jianchao Wu**. *Cubical = Categorical.*

Higher-rank graphs (k-graphs) are category theoretic objects which can also be viewed as generalizations of directed graphs. In order to better understand the C^*-algebras associated to k-graphs, Kumjian, Pask, and Sims introduced two cohomology theories for k-graphs. Using ad hoc methods, Kumjian, Pask, and Sims showed that the ith categorical and cubical cohomology groups of a k-graph Λ are isomorphic for $i \leq 2$.

This talk presents recent joint work with Jianchao Wu, in which we show that for all $i \in \mathbb{N}$, the ith cubical and categorical cohomology groups of any k-graph Λ are isomorphic. This proves a conjecture posed by Kumjian, Pask, and Sims in 2015. Our proof relies on the topological realization of a k-graph (as defined by Kaliszewski, Kumjian, Quigg, and Sims) and the reformulation of categorical cohomology using Λ-modules, as introduced by Gillaspy and Kumjian.

Time permitting, we will also explain how this result leads to a more thorough understanding of the cohomology of the groupoid associated to Λ (under the additional hypothesis that Λ be row-finite and source-free). (Received August 15, 2016)

1122-46-299 **Adam H Fuller*** (fullera@ohio.edu), **Michael Hartz** and **Martino Lupini**. *Boundary Representations of Operator Spaces.* Preliminary report.

We introduce the notion of boundary representations for an operator space. We will show that an operator space has enough boundary representations to generate the triple envelope (or Shilov boundary) of an operator space. This gives an operator space analogue for the result of Arveson and Davidson and Kennedy that an operator system has enough boundary representations to generate the C*-envelope. (Received August 15, 2016)

1122-46-324 **Carla Farsi***, Department of Mathematics, University of Colorado, Boulder, CO 90309, and **Elizabeth Gillaspy**, **Antoine Julien**, **Sooran Kang** and **Judith Packer**. *Spectral triples and wavelets for k-graphs.* Preliminary report.

In this talk I will report on spectral triples associated to a finite, higher-rank graph C*-algebras and the relation between eigenfunctions and wavelets. This is joint work with E. Gillaspy, A. Julien, S. Kang, and J. Packer. (Received August 16, 2016)

1122-46-326 **Jonathan H. Brown*** (jbrown@udayton.edu), Department of Mathematics, University of Dayton, 300 College Park, Dayton, OH 45469-2316, and **Lisa Clark**, **Adam Sierakowski** and **Aidan Sims**. *Purely infinite simple C^*-algebras that are principal groupoid C^*-algebras.*

From a suitable groupoid G, we show how to construct an amenable principal groupoid whose C^*-algebra is a Kirchberg algebra which is KK-equivalent to $C^*(G)$. Using this construction, we show by example that many UCT Kirchberg algebras can be realized as the C^*-algebras of amenable principal groupoids. This work was joint with L. Clark, A. Sierakowski and A. Sims. (Received August 16, 2016)

1122-46-339 **Judith A. Packer*** (judith.jesudason@colorado.edu), Department of Mathematics, Campus Box 395, University of Colorado, Boulder, Boulder, CO 80309. *Wavelets for higher-rank graph C^*-algebras.* Preliminary report.

This talk will review the construction and interpretations of a system of functions termed "wavelets" on a Hilbert space associated to a finite, higher-rank graph C^*-algebra. Some results of M. Marcolli and A. Paolucci for Cuntz-Krieger algebras are generalized to the higher-rank graph case. This is joint work with C. Farsi, E. Gillaspy, A. Julien and S. Kang. (Received August 16, 2016)

1122-46-341 **Timothy Rainone** and **Christopher Schafhauser*** (cschafhauser@uwaterloo.ca). *Approximations of crossed products and K-theoretic dynamics.*

A C*-algebra is MF (matricial field) if it can be approximately embedded into matrix algebras. A question of Blackadar and Kirchberg asks if every C*-algebra with a faithful trace is MF. In the case of crossed product C*-algebras, it is also of interest to find dynamical characterizations of the MF property. I will survey some known results about this question and discuss some recent results on certain crossed products by free groups. In particular, for large classes of nuclear C*-algebras, the MF property of the crossed product can be detected through the K-theory. This is based on joint work with Tim Rainone. (Received August 16, 2016)

1122-46-368 **Piotr M. Hajac*** (pmh@impan.pl), Ul. Sniadeckich 8, 00-656 Warsaw, Poland, and **Ludwik Dabrowski** (dabrow@sissa.it), Via Bonomea, 265, 34136 Trieste, Italy. *Noncommutative Borsuk-Ulam-type conjecture revisited.* Preliminary report.

Let H be the C*-algebra of a non-trivial compact quantum group acting freely on a unital C*-algebra A. Baum, Dabrowski and Hajac conjectured that there does not exist an equivariant *-homomorphism from A to the equivariant noncommutative join C*-algebra $A*H$. When A is the C*-algebra of functions on a sphere, and H is the C*-algebra of functions on $\mathbb{Z}/2\mathbb{Z}$ acting antipodally on the sphere, then the conjecture becomes the celebrated Borsuk-Ulam Theorem. Recently, Chirvasitu and Passer proved the conjecture when H is commutative. In a simple way, we extend this result to a far more general setting assuming only that H admits a character different from the counit. In particular, our result implies the non-contractibility of q-deformed compact Lie groups. (Received August 16, 2016)

47 ► Operator theory

1122-47-9 **Robert Carlson*** (rcarlson@uccs.edu), Department of Mathematics, University of Colorado at Colorado Springs, 1420 Austin Bluffs Parkway, Colorado Springs, CO 80918. *Quantum Cayley Graphs for Free Groups.*

A spectral theory for Schrödinger operators on metric Cayley graphs of free groups $\mathcal{F}_M$ is developed. The potential and graph edge lengths may vary with the M edge types. Using novel methods to extend the themes of Floquet theory, the main idea is to define and study a set of M multipliers $\mu_m(\lambda)$ depending on the spectral parameter. These multipliers are used to construct the resolvent and characterize the spectrum. (Received May 04, 2016)

1122-47-89 **Matthias Keller**, **Daniel Lenz**, **Marcel Schmidt** and **Radoslaw Krzysztof Wojciechowski*** (rwojciechowski@gc.cuny.edu), 94 - 20 Guy R. Brewer Blvd., Jamaica, NY 11451. *Uniformly transient graphs.*

We introduce a notion of uniform transience for infinite, weighted graphs. We will discuss connections to a uniform version of the Feller property as well as to the Green's function. Finally, we will discuss consequences for the Royden boundary of such graphs. (Received August 09, 2016)

1122-47-109 **Benton L Duncan*** (benton.duncan@ndsu.edu). *Operator algebras for edge-colored directed graph algebras.*

We will survey the concept of an edge-colored directed graph and the associated C^*-algebras (also called separated graphs). We will look at examples, including a description in certain cases for finite graphs. We will consider the question of when the reduced and universal C^*-algebras are isomorphic and use this to consider exactness of the associated C^*-algebra. (Received August 10, 2016)

1122-47-221 **Frank Alexander Kloster*** (kloster@math.ucr.edu). *Spectral Triples for the Sierpinski Gasket.* Preliminary report.

Spectral triples are one of the major objects of study in noncommutative geometry, and are used to encode geometric information into the language of operator algebras. Here, I will be constructing a spectral triple for the Sierpinski gasket constructed by F. Capriani, D. Guido, T. Isola and J. Sauvageot. From this construction, I will derive the standard Dirichlet form for the gasket, discuss some of the constraints and generalizations. In particular, I will compare it to a spectral triple constructed before by E. Cristensen, C. Ivan and M.L. Lapidus. In addition, I will be presenting some of my own work using this triple. (Received August 14, 2016)

1122-47-250 **Raphael Clouatre*** (raphael.clouatre@umanitoba.ca) and **Laurent W. Marcoux**. *Kadison's property for representations of amenable operator algebras.*

An operator algebra is said to have *Kadison's property* if all its bounded representations are completely bounded. It is a long-standing open problem to determine whether this is satisfied by every C^*-algebra. On the other hand, due to work of Haagerup and Gifford, it is known that Kadison's property for C^*-algebras is equivalent to a weaker version of amenability, called the *total reduction property*.

In this talk, we investigate whether non self-adjoint operator algebras with the total reduction property necessarily satisfy Kadison's property. We obtain positive results in the case where either the domain or codomain of the representation is residually finite dimensional. We also explain why these facts are meaningful with regards to the general problem. Finally, we exhibit connections to the harder question of determining whether (separable) operator algebras with the total reduction property are necessarily similar to C^*-algebras.

This is joint work with Laurent Marcoux. (Received August 15, 2016)

1122-47-264 **Trubee Hodgman Davison*** (trubeedavison@gmail.com), PO Box 3166, Boulder, CO 80307. *A Positive Operator-Valued Measure for an Iterated Function System.* Preliminary report.

Given an iterated function system (IFS) on a complete and separable metric space Y, there exists a unique compact subset $X \subseteq Y$ satisfying a fixed point relation with respect to the IFS. This subset is called the attractor set, or fractal set, associated to the IFS. The attractor set supports a specific Borel probability measure, called the Hutchinson measure, which itself satisfies a fixed point relation. P. Jorgensen generalized the Hutchinson measure to a projection-valued measure, under the assumption that the IFS does not have essential overlap. In previous work, we developed an alternative approach to proving the existence of this projection-valued measure. The situation when the IFS exhibits essential overlap has been studied by Jorgensen and colleagues. We build off their work to generalize the Hutchinson measure to a positive-operator valued measure for an arbitrary IFS, that may exhibit essential overlap. We also discuss Naimark's dilation theorem with respect to this positive operator-valued measure. (Received August 15, 2016)

1122-47-276 **Travis B Russell*** (trussell8@huskers.unl.edu). *Ordered operator spaces and real-completely positive maps.*

We demonstrate new abstract characterizations for unital, non-unital, self-adjoint, and non-self-adjoint operator spaces with respect to both norm and order structure. These characterizations make use of the theory of accretive operators (operators whose real part is positive) and the theory of matrix-gauges introduced by Effros and Winkler. As an application, we will demonstrate an extension theorem for real-completely positive maps on operator spaces. (Received August 15, 2016)

1122-47-357 **Michael Hartz*** (mphartz@uwaterloo.ca). *von Neumann's inequality for commuting weighted shifts.*

von Neumann's inequality asserts that if T is a contraction on a Hilbert space and p is a polynomial, then

$$||p(T)|| \leq \sup\{|p(z)| : |z| \leq 1\}.$$

While Andô's dilation theorem implies an analogous inequality for pairs of commuting contractions, the corresponding statement for triples of commuting contractions is false. The first counterexamples were found by Kaijser-Varopoulos and Crabb-Davie in the early seventies, but this phenomenon is still not well understood.

I will talk about a result which shows that von Neumann's inequality holds for a particularly tractable class of commuting contractions, namely multivariable weighted shifts. This provides a positive answer to a question of Lubin and Shields from 1974. (Received August 16, 2016)

49 ► Calculus of variations and optimal control; optimization

1122-49-383 **Kourosh Modarresi*** (modarres@adobe.com), 345 Park Av, San Jose, CA , and **Khashayar Khosravi** (khosravi@adobe.com), 345 Park Av, San Jose, CA. *Optimal Computation of the Winning Offers Among Multiple Offers.*

The objective is to find the winner of a pairwise test as fast as possible. The minimum cost is defined by using the smallest number of user's visits. As soon as there is a statistical significance between the two offers, the winner is chosen and the losing offer is dropped. We use two new models and compare them with two most often used models. Hypothesis testing, which is one of the most important and practical tools for comparing different distributions, has been recently drawn a huge interest among the practitioners. In many real-life scenarios, among many different options, one wants to find the best option in the quickest time. (Received August 17, 2016)

51 ► Geometry

1122-51-53 **J Mealy*** (jmealy@austincollege.edu) and **Ben Lehrman**. *Equidistant curves in staircase metric geometries.*

Further results in the category, staircase metric geometry. After providing an introduction to this general category of geometric systems and its distinct methodology as well as some recent examples, we then discuss a new general 'angle change law' that applies to curves in such systems that are equidistant to a point, or to a geodesic, or to a more general curve. This result is subsequently utilized to analyze fully an asymptotic cycle (that is, a point-wise limit of circles (with moving centers)) in a specific SMG system, and which features unusual asymptotic properties. Finally, on a broader note, we discuss briefly other forms of the 'angle change law' in a variety of SMG systems. (Received August 03, 2016)

1122-51-161 **Tim Penttila***, Department of Mathematics, Colorado State University, Fort Collins, CO 80523. *Elementary constructions of the Tits and Ree-Tits ovoids.*

An ovoid of a polar space is a set of points that meets every maximal in one point. The usual contructions of the Tits ovoid of symplectic four dimensional space and of the Ree-Tits ovoid of orthogonal seven dimensional space proceed via the Suzuki groups and the Ree groups in characteristic three or via the polarity of the associated generalised polygon. An alternative elementary construction is given, which establishes results that can then be used to give elementary constructions of these groups and polarities. One motivation of seeking these proofs is wider applicability of results, with an eye to both further constructions and to characterizations.

The construction given for both ovoids is considerably simpler than that previously given by Ball and Zieve for the Tits ovoid and the slice of the Ree-Tits ovoid. (Received August 12, 2016)

1122-51-189 **Andrea Arauza*** (arauza@math.ucr.edu), 900 University Ave., Surge 281, Riverside, CA 92521. *Spectral Triples and Fractal Geometry.*

The spectral triples of noncommutative geometry are a useful tool in finding algebraic formulations for geometric concepts. Of great interest in fractal geometry are the concepts of dimension, geodesic distance, and measure. We will see how one can use spectral triples to recover these concepts for fractal sets like the Sierpinski Gasket and the Hanoi attractors. Also of interest is the use of spectral triples to recovery the energy forms from the study of analysis on fractals. (Received August 13, 2016)

1122-51-253 **Michael Elgersma** and **Stan Wagon*** (wagon@macalester.edu). *The Octatetrahelix: A Near-Perfect Tetrahedral Loop.* Preliminary report.

In 1958, S. Swierczkowski proved that there cannot be a closed loop of congruent interior-disjoint regular tetrahedra that meet face-to-face. Such loops are easy to find for the other four regular polyhedra. It has been conjectured that, for any positive ϵ, there is a tetrahedral loop such that the gap error at the end is less than ϵ. We prove this conjecture by showing how a simple pattern can generate loops of tetrahedra in an octagonal

shape having arbitrarily small gap error. Moreover, computations provide explicit examples where the error is under 10^{-100}. (Received August 15, 2016)

1122-51-372 **Bailin Song*** (bailinso@ustc.edu.cn). *The global sections of the chiral de Rham complex on a K3 surface.*

The chiral de Rham complex is a sheaf of vertex algebras on any nonsingular algebraic variety or complex manifold M, which contains the ordinary de Rham complex as the weight zero subspace. We show that when M is a K3 surface, the algebra of global sections is isomorphic to an $N = 4$ superconformal vertex algebra with central charge 6. (Received August 16, 2016)

52 ► Convex and discrete geometry

1122-52-225 **Michael A Burr*** (burr2@clemson.edu), O-19 Martin Hall, Clemson University, Clemson, SC 29634. *An Introduction and Recent Advances on Continuous Amortization.*

Continuous amortization was recently introduced as a technique to compute the complexity of subdivision-based algorithms. This technique has been successfully applied, as a uniform technique, for computing the complexity of common root isolation algorithms. Continuous amortization can be used to compute many complexity-based quantities of subdivision-based algorithms, such as the number of subdivisions, the bit complexity, or the expected time. Moreover, the complexity resulting from continuous amortization is based on the intrinsic geometric complexity of the input instance. In practice, continuous amortization can be applied uniformly to a variety of algorithms and provides state-of-the-art results which are adaptive to the input data. In the first part of this talk, I will provide an introduction to the continuous amortization technique, illustrating its application to various subdivision-based algorithms for isolating the solutions of polynomials. In the second part of this talk, I will discuss new work on the application of continuous amortization to problems in higher dimensions. (Received August 14, 2016)

1122-52-239 **Henry Cohn*** (cohn@microsoft.com), One Memorial Drive, Cambridge, MA 02142. *The sphere packing problem in dimensions 8 and 24.*

What is the densest packing of congruent spheres in Euclidean space? This problem arises naturally in geometry, number theory, and information theory, but it is notoriously difficult to solve, and until recently no sharp bounds were known above three dimensions. This spring Maryna Viazovska found a remarkable solution of the sphere packing problem in eight dimensions. In this talk I'll describe how her breakthrough works and where it comes from, as well as follow-up work extending it to twenty-four dimensions (joint work with Kumar, Miller, Radchenko, and Viazovska). (Received August 15, 2016)

53 ► Differential geometry

1122-53-119 **David Packard**, **Barbara A. Shipman*** (bshipman@uta.edu) and **Patrick D. Shipman**. *Weierstrass-Enneper Representations of Surfaces in Euclidean and Lorentz spaces – A Unified Lie-Algebraic Formulation.*

The complex-analytic approach to constructing minimal surfaces carried out by Weierstrass and Enneper has since been extended to create conformal parametrizations on general Euclidean, spacelike, and timelike surfaces. There is a Lie-algebraic formulation that unites these representations into one coherent framework and fills in the gaps to cover general surfaces of all three types. The surfaces are built up inside of three-dimensional Lie algebras by starting with the standard constant frame and applying a scaling, together with an isometric action of a (complex) Lie group, to create integrable moving frames. For timelike surfaces, the complex numbers are replaced by the hyperbolic numbers for compatibility with the Lorentzian metric. We express in this framework the first and second fundamental forms and the mean and Gaussian curvatures on Euclidean, spacelike, and timelike surfaces and provide examples and illustrations of surfaces arising from these Weierstrass-Enneper representations. (Received August 10, 2016)

1122-53-283 **Ian Michael Zemke*** (ianzemke@math.ucla.edu), Department of Mathematics, UCLA, 520 Portola Plaza, Los Angeles, CA 90025. *Link cobordisms and functoriality in link Floer homology.* Preliminary report.

We will discuss a functorial construction of link Floer homology. To link cobordisms with certain decorations, we can assign maps on a version of the full link Floer complex. Such maps are invariants up to chain homotopies

of the appropriate type. We will explain how the link cobordism maps naturally induce a "graph TQFT" for invariants associated to closed 3-manifolds with collections of basepoints and cobordisms between them with embedded graphs, which agree with another construction of such a graph TQFT, due to the author. (Received August 15, 2016)

1122-53-391 **Ron Hadani*** (hadani@math.utexas.edu), University of Texas at Austin, 1 University station, C1200, Austin, TX 78712-0257. *Representation theoretic patterns in three dimensional cryo-electron microscopy.*

Three dimensional cryo-electron microscopy (3D cryo-EM, for short) is the problem of determining the three dimensional structure of a large molecule from the set of images, taken by an electron microscope, of randomly oriented and positioned identical molecular particles which are frozen in a thin layer of ice. A solution to this problem is of particular interest, since it promises to be an entirely general technique which does not require crystallization or other special preparation stages. Present approaches to the problem fail with particles that are too small, cryo-EM images that are too noisy or at resolutions where the signal-to-noise ratio becomes too small. The focus of my talk is the intrinsic reconstitution algorithm, due to Singer and Shkolnisky, which constitutes a basic step for the solution of the 3D cryo-EM problem and whose main appealing property is its remarkable numerical stability to noise. My goal is to give an introductory explanation of the mathematical principles underlying this novel algorithmic approach, while hinting about how they apply to other fundamental problems in cryo-EM and beyond. (Received August 17, 2016)

54 ► General topology

1122-54-91 **Sherry Gong*** (sgongli@mit.edu), 70 Pacific St Apt 389B, Cambridge, MA 02139. *Marked link invariants.*

We study the instanton spectral sequence associated to a link with a singular bundle and, in particular, relate it to a version of Khovanov homology with such data, in the case of alternating links. We will also explore the binary dihedral representations of alternating links with such singular bundle data. (Received August 09, 2016)

55 ► Algebraic topology

1122-55-87 **Markus J Pflaum*** (markus.pflaum@colorado.edu), Department of Mathematics, University of Colorado UCB 395, Boulder, CO 80309, and **Hessel Posthuma** and **Xiang Tang**. *On the Hochschild homology of convolution algebras over proper Lie groupoids and a complex of Brylinski.*

We describe the complex of basic relative forms on the inertia space of a proper Lie groupoid and show how it relates to the Hochschild homology theory of the convolution algebra. For the case of a compact Lie group action this complex was originally constructed by Brylinski. (Received August 09, 2016)

57 ► Manifolds and cell complexes

1122-57-32 **Jennifer Hom**, **Adam Simon Levine** and **Tye Lidman*** (tlid@math.ncsu.edu). *Concordance in homology spheres.*

Although not every knot in the three-sphere can bound a smooth disk in the four-ball, it must bound a PL disk. This is not true for knots in the boundaries of arbitrary smooth contractible manifolds. We give new examples of knots in homology spheres that cannot bound PL disks in any bounding homology ball and thus not concordant to knots in the three-sphere. (Received July 27, 2016)

1122-57-41 **Peter Feller** and **David Krcatovich*** (dk27@rice.edu). *Upsilon, knot cobordisms and braid index.*

If two knots occur as intersections of a given algebraic curve in $\mathbb{C}^2$ with concentric three-spheres, they are connected by a cobordism whose genus is the difference of the slice genera of the two knots. A cobordism with this genus is called optimal. We use the Upsilon invariant of Ozsváth-Stipsicz-Szabó to obstruct the existence of optimal cobordisms. In doing so, we generalize a result of Morton-Franks-Williams on the minimal braid index of knots with a "full twist", and show that Upsilon can provide a lower bound on the braid index of any representative of a concordance class of knots. (Received August 01, 2016)

1122-57-48 **Stanislav Jabuka*** (jabuka@unr.edu) and **Cornelia Van Cott**. *The non-orientable 4-genus and Donaldson's Diagnalizaton Theorem.*

While the smooth orientable 4-genus of knots has been studied extensively over the past several decades, the analogous non-orientable 4-genus has mostly been overlooked. For instance, until recently it was unknown whether the non-orientable 4-genus could become arbitrarily large, a question that was answered in the positive by Joshua Batson in 2012.

This talk will give a brief survey of recent advances on this subject, and then present a new obstruction - using Donaldson's Diagonalization Theorem - for certain knots to bound smoothly embedded Mobius bands in the 4-ball. We contrast our results with those obtainable by other means, a comparison we provide by examining the family of torus knots T(2k+1,2k).

This is joint work with Cornelia Van Cott. (Received August 02, 2016)

1122-57-131 **Diana Hubbard*** (dianahub@umich.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. We define an annular refinement of this element, kappa, and we show that while kappa is not an invariant of transverse links, it is a conjugacy class invariant of braids. We will see applications of kappa relating to transverse links, braid destabilization, and the word problem in the braid group. (Received August 10, 2016)

1122-57-147 **Robert Lipshitz*** (lipshitz@uoregon.edu), **Peter Ozsvath** and **Dylan Thurston**. *Towards bordered HF- with torus boundary.* Preliminary report.

We will outline work in progress towards extending bordered Floer homology to the "minus" variant of Heegaard Floer homology. (Received August 11, 2016)

1122-57-222 **Jianfeng Lin*** (jianfeng@mit.edu), 2, 182 Memorial Dr, Cambridge, MA 02140, and **Daniel Ruberman** and **Nikolai Saveliev**. *Invariants of 4 manifolds with the homology circle cross the 3-sphere.*

While classical gauge theoretic invariants for 4-manifolds are usually defined in the setting that the intersection form has nontrivial positive part, there are several invariants for a 4-manifold X with the homology S1 cross S3. The first one is the Casson type invariant LSW(X) defined by Mrowka-Ruberman-Saveliev; the second one, defined by Froyshov, is h(Y) for any embedded rational homology sphere Y generating the third homology of X. (This is actually an invariant of X.) In this talk, I will give a formula relating LSW(X) with h(Y) by the Lefschetz number on HM-red (the reduced monopole Floer homology of Y). Time permitted, I will also discuss various applications of this formula. This is joint work Daniel Ruberman and Nikolai Saveliev. (Received August 14, 2016)

1122-57-238 **Christine Ruey Shan Lee*** (clee@math.utexas.edu). *The Alexander polynomial of braids with adequate closure.*

In this talk, I will discuss some results on how the Alexander polynomial of an adequate knot changes after adding full twists, when the link is the closure of a 3-or 4-braid. This is motivated by the question of when an adequate knot can be an L-space knot. (Received August 15, 2016)

1122-57-252 **Christopher Scaduto*** (scaduto@ucla.edu) and **Matthew Stoffregen**. *Two-fold quasi-alternating links, Khovanov homology and instanton homology.*

We introduce a class of links strictly containing quasi-alternating links for which mod 2 reduced Khovanov homology is always thin. We also discuss evidence for a spectral sequence from a twisted variant of Khovanov homology to the framed instanton homology of the double branched cover, which collapses for our generalized class of links. (Received August 15, 2016)

1122-57-259 **Adam R Saltz*** (saltz.adam@gmail.com). *Invariants of tangles and surfaces from Szabó's perturbation of Khovanov homology.* Preliminary report.

Khovanov homology is a powerful link invariant, and work of Ozsvath and Szabó (as well as Kronheimer and Mrowka, and Baldwin, Hedden, and Lobb...) suggests that Khovanov homology is closely related to Floer homology. Szabó has combinatorially constructed a spectral sequence from Khovanov homology which conjecturally recovers Ozsvath and Szabó's. We will discuss work in progress to extend Szabó's construction to an invariant of tangles and knotted surfaces in S4. (Received August 15, 2016)

1122-57-268 **Tynan B. Kelly*** (tbkelly@unr.edu), Department of Mathematics & Statistics, MS 0084, University of Nevada, Reno, Reno, NV 89557. *Linking numbers in cyclic branched covers of S^3 and Casson-Gordon invariants.*

We show how to calculate linking numbers in cyclic branched covers of S^3, extending work of Przytycki-Yasuhara to address framings. These linking numbers are then applied to the calculation of certain Casson-Gordon invariants, allowing us to obtain concordance obstructions between K and $J(K)$, a knot obtained from K by doing surgery along a disjoint component J. (Received August 15, 2016)

1122-57-290 **Corrin Clarkson*** (cjclarks@indiana.edu), Math Department, Indiana University, 831 E. Third St., Bloomington, IN 47405. *A comparison of Heegaard Floer homology and quantum invariants.* Preliminary report.

In 2011 Funar, constructed two interesting, infinite families of pairs of torus bundles over the circle. In the first family, the elements of each pair are distinguished by their fundamental groups, but have the same Turaev–Viro invariants. Similarly, the second family consists of pairs of manifolds which are not distinguished by their Reshetikhin–Turaev invariants.

By contrast, I will show that the elements of the pairs in the fist family are distinguished by Heegaard Floer homology. I will also discuss progress that I've made towards computing the Heegaard Floer homology of the manifolds in the second family. (Received August 15, 2016)

1122-57-295 **Cristopher Scaduto** (cscaduto@brandeis.edu) and **Matthew Stoffregen*** (mstoffregen@math.ucla.edu). *Klein-four connections and the Casson invariant for non-trivial admissible $U(2)$ bundles.*

Given a rank 2 hermitian bundle over a 3-manifold that is non-trivial admissible in the sense of Floer, one defines its Casson invariant as half the signed count of its projectively flat connections, suitably perturbed. We show that the 2-divisibility of this integer invariant is controlled in part by a formula involving the mod 2 cohomology ring of the 3-manifold. This formula counts flat connections on the induced adjoint bundle with Klein-four holonomy. We will also discuss a generalization of these results to higher-rank bundles. (Received August 15, 2016)

1122-57-298 **Andrew Manion***, manion@math.ucla.edu. *Ozsváth–Szabó's bordered theory and quantum representations.* Preliminary report.

We outline some properties of Ozsváth and Szabó's new theory for knot Floer homology. Their constructions include dg algebras as well as bimodules, like those appearing in bordered Floer homology, which have "partial" Kauffman states as generators. On the decategorified level, we relate their algebras and bimodules to representations of $\mathcal{U}_q(\mathfrak{gl}(1|1))$ and maps between them. We show how this relationship extends to the categorifications for one summand of Ozsváth and Szabó's algebras and bimodules, via a connection with Khovanov–Seidel quiver algebras. (Received August 15, 2016)

1122-57-319 **Ina Petkova** (ina@math.columbia.edu) and **C.-M. Michael Wong*** (cmmwong@math.columbia.edu). *An unoriented skein exact triangle for tangle Floer homology.*

Knot Floer homology, a link invariant with rich applications defined by Ozsváth–Szabó and Rasmussen, has been shown by Manolescu to satisfy an unoriented skein exact triangle. A combinatorial proof has later been provided by the second author. More recently, inspired by the work of Lipshitz–Ozsváth–Thurston on bordered Floer homology, the first author and Vera Vértesi have defined tangle Floer homology, a tangle invariant that satisfies a pairing theorem, recovering the knot Floer homology of a link obtained by gluing tangles. In this talk, we prove that an analogous skein exact triangle is satisfied by combinatorial tangle Floer homology, indicating concretely how this skein relation can be viewed as a local property of links. The proof is reminiscent of the combinatorial proof for knot Floer homology mentioned above. No prior knowledge is necessary for the talk, as a brief introduction to tangle Floer homology will be given. (Received August 16, 2016)

1122-57-330 **Akram Alishahi*** (alishahi@math.columbia.edu) and **Eaman Eftekhary**. *Heegaard Floer homology for tangles and tangle cobordisms.*

Tangles are a generalization of classical oriented tangles such that any sutured manifold without toroidal sutures determines a tangle. In this talk, we introduce a framework that extends different versions of Heegaard Floer invariants for tangles, generalizing sutured Floer homology. Furthermore, associated with cobordisms between tangles we define an invariant homomorphism between Heegaard Floer homologies of the corresponding tangles. These maps generalize cobordism maps associated to 4-dimensional cobordisms between closed 3-manifolds and

define cobordism maps for decorated cobordisms between pointed knots. This is a joint work with Eaman Eftekhary. (Received August 16, 2016)

1122-57-354 **Shida Wang*** (wang217@indiana.edu). *The gap between algebraic knots and iterated torus knots.*

We will review the Ozsvath-Stipsicz-Szabo Upsilon invariant and give an application.

First we will introduce the semigroup of L-space knots. Then we will use the semigroup in the computation of the Upsilon invariant and show that there are infinitely many iterated torus knots linearly independent from connected sums of algebraic knots. (Received August 16, 2016)

1122-57-377 **William Ballinger**, **Ching-Yun Hsu**, **Wyatt Mackey**, **Yi Ni**, **Tynan Ochse** and **Faramarz Vafaee*** (vafaee@caltech.edu), 1200 E California Blvd, Pasadena, CA 91125. *The prism manifold realization problem.*

The spherical manifold realization problem asks which spherical 3–manifolds can be obtained by performing surgery on knots in S^3. In recent years, the integer surgery realization problem for C,T,O,I-type spherical manifolds has been solved, leaving the D-type prism manifold, $P(p, q)$, as the only remaining case. We determine a complete list of prism manifolds P(p, q) that arise by surgery on knots when $q < 0$. The arguments mostly rely on Floer homology and lattice theory.

In an unpublished manuscript, Berge and Kang give a complete list of primitive/Seifert fibered knots on which surgery can be performed to yield a prism manifold. (Recall that a primitive/Seifert fibered knot is a knot that lies on a genus two Heegaard surface Σ of S^3 bounding handlebodies H and H' such that adding a 2–handle to H' along the knot yields a solid torus, and adding a 2–handle to H along the knot yields an orientable Seifert fibered space.) By comparing our list of prism manifolds to that obtained from the Berge-Kang's paper, we find that every $P(p, q)$ with $q < 0$ may be realized by surgery on a primitive/Seifert fibered knot. (Received August 16, 2016)

1122-57-389 **John A Baldwin** and **David Shea Vela-Vick*** (shea@math.lsu.edu). *Refinements of the contact invariant in Heegaard Floer theory.*

We discuss two methods for refining Ozsvath and Szabo's contact invariant in Heegaard Floer theory. These refinements, which we denote b_g and b_a, take values in the positive integers union infinity, and extend the usual contact invariant in the sense that if $c(Y, \xi)$ is nonzero, then both b_g and b_a are infinity. We further show that if (Y, ξ) is overtwisted, then b_g and b_a are minimal, reflecting the usual vanishing of the usual contact invariant for such contact structures. Everything discussed in this talk is joint work with John Baldwin. (Received August 17, 2016)

58 ► Global analysis, analysis on manifolds

1122-58-200 **Michel L. Lapidus*** (lapidus@math.ucr.edu), University of California, Department of Mathematics, 900 University Avenue, Riverside, CA 92521-0135. *Noncommutative Fractal Geometry and Analysis on Fractal Manifolds: A Tale of Metrics, Hausdorff Measures and Geodesics.*

We discuss aspects of geometric analysis on fractals and noncommutative fractal geometry (NCG). We construct spectral triples and Dirac operators on a class of fractals built on curves, including the Sierpinski gasket (SG), the harmonic gasket (HG, which is ideally suited for developing analysis on fractals and is a good model for the elusive notion of a 'fractal manifold'), as well as suitable quantum graphs. We recover from the spectral triple the geodesic metric intrinsic to the fractal. This work is joint with Jonathan Sarhad (Journal of Noncommutative Geometry, vol. 8, 2014). It significantly extends earlier work of the author, joint with Eric Christensen and Cristina Ivan (Advances in Math., vol. 217, 2008) in which we constructed geometric Dirac operators allowing us to recover the natural geodesic metric and the natural Hausdorff measure of the Euclidean SG (as well of other fractals built on curves, but not HG). It also builds on earlier work of the author (carried out in the 1990s) in which, in particular, a broad research program was proposed for developing NCG. The new results highlighted enable us to get one step closer to developing aspects of geometric analysis truly connected with the study of fractal manifolds and their intrinsic families of geodesic curves. (Received August 13, 2016)

1122-58-202 **Frank Bauer**, **Sebastian Haeseler**, **Matthias Keller** and **Radoslaw Wojciechowski*** (rwojciechowski@gc.cuny.edu), 94 - 20 Guy R. Brewer Blvd., Jamaica, NY 11451. *Some applications of intrinsic metrics to spectral graph theory.*

We discuss some uses of intrinsic metrics for infinite, weighted graphs. In particular, we will discuss an analogue for a theorem of Brooks connecting volume growth and the bottom of the spectrum and an extension of Cheeger's inequality to the case of unbounded geometry. (Received August 14, 2016)

1122-58-234 **Wentao Fan** and **Farzad Fathizadeh*** (farzadf@caltech.edu), Department of Mathematics, Mail Code 253-37, Caltech, 1200 E. California Blvd., Pasadena, CA 91125, and **Matilde Marcolli**. *Modular forms in the spectral action of Bianchi-IX gravitational instantons.*

In a succession of papers, physicists and mathematicians have achieved an explicit parameterization of Bianchi-IX gravitational instantons in terms of theta functions with characteristics. By exploiting the latter, in this talk, I will shed light on a rationality phenomena in the spectral action of SU(2)-invariant Bianchi-IX metrics. This will be done by showing that for the instantons, each term in the expansion of their spectral action gives rise to a modular form of weight 2 that can be written explicitly in terms of well-known modular forms, namely the Eisenstein series and the modular discriminant. An elegant proof of the rationality result will also be presented, which is based on expressing Seeley-de Witt coefficients as noncommutative residues of Laplacians. This talk is based on joint works with Wentao Fan and Matilde Marcolli. (Received August 15, 2016)

60 ► Probability theory and stochastic processes

1122-60-15 **Davar Khoshnevisan*** (davar@math.utah.edu), University of Utah, Department of Mathematics, Salt Lake City, UT 84112. *A macroscopic multifractal analysis of parabolic stochastic PDEs.* Preliminary report.

We describe the spatio-temporal multifractal nature of the tall peaks of the solution to a large family of stochastic PDEs. Aspects of this multifractal behavior were predicted earlier in the physics literature.

This is based on on-going joint work with Kunwoo Kim and Yimin Xiao. (Received June 17, 2016)

1122-60-36 **Russell Lyons*** (rdlyons@indiana.edu), 831 E 3rd St, Dept. of Math., Indiana University, Bloomington, IN 47405-7106. *Comparing Unimodular Measures.*

Consider a Cayley graph of a group, Γ. Suppose that W is a random assignment of nonnegative numbers to the edges and that the law of W is Γ-invariant. Let X_t be continuous-time random walk on Γ in the random environment W: incident edges e are crossed at rate $W(e)$. Write $p^W(t) := \mathbf{E}\big[\mathbf{P}_o[X_t = o]\big]$ for the expected return probability at time t (averaged over W). Fontes and Mathieu asked whether given two such environments, W_1 and W_2, with $W_1(e) \le W_2(e)$ for all edges e, one has $p^{W_1}(t) \ge p^{W_2}(t)$ for all $t \ge 0$. When the pair (W_1, W_2) has a Γ-invariant law, this was shown by Aldous and the speaker. It remains open in general. What is required is to compare two different unimodular measures, each with its own trace. We attempt to attack this problem via similar questions for finite graphs. (Received July 28, 2016)

1122-60-37 **Natalie Coston*** (natalie.coston@gmail.com), **Sean O'Rourke** and **Philip Matchett Wood**. *Outliers in the Spectrum for Products of Independent Random Matrices.*

Given an $n \times n$ random matrix with independent and identically distributed (iid) entries, the well known Circular Law describes the limiting distribution of the eigenvalues as n tends to infinity. More generally, given the product of m independent iid matrices, the limiting distribution of the eigenvalues is the mth power of the Circular Law. In this talk, I will discuss what happens when the product is perturbed by a low-rank deterministic matrix. While the limiting distribution remains the same, the deterministic perturbation can create a number of outlying eigenvalues, and I will describe the asymptotic location of these outliers. (Received July 29, 2016)

1122-60-43 **Indrajit Jana*** (ijana@math.ucdavis.edu), 3800 Solano Park Circle, Apt 2421, Davis, CA 95616, and **Alexander Soshnikov** (soshniko@math.ucdavis.edu), One Shields Avenue, Mathematical Sciences Building, Davis, CA 95616. *Limiting spectral distribution of random band matrices.*

We consider the limiting spectral distribution of matrices of the form $\frac{1}{2b_n+1}(R+X)(R+X)^*$, where X is an $n \times n$ band matrix of bandwidth b_n and R is a non random band matrix of bandwidth b_n. We show that the Stieltjes transform of spectrum of such matrices converges to the Stieltjes transform of a non-random measure. And the limiting Stieltjes transform satisfies an integral equation. For $R = 0$, the integral equation yields the Stieltjes transform of Marchenko-Pastur law. (Received August 01, 2016)

1122-60-93 **Phil Kopel*** (pkopel@math.ucdavis.edu). *Linear Statistics of Independent Entry Random Matrices.*

Linear statistics generalize the central limit theorem of classical probability theory to the random matrix setting. We will discuss recent results concerning the linear statistics of independent entry random matrices, which are the non-Hermitian analogues of the famous Wigner matrices (and important ensembles in their own right). In particular, we will establish central limit theorems for random matrices matching GinUE or GinOE to four moments. (Received August 09, 2016)

1122-60-108 **Tom Alberts*** (alberts@math.utah.edu), 155 S 1400 E RM 233, Salt Lake City, UT 84112, and **Raoul Normand** and **Balint Virag**. *Random Geometry in the Spectral Measure of the Circular Beta Ensemble.* Preliminary report.

The Circular Beta Ensemble is a family of random unitary matrices whose eigenvalue distribution plays an important role in statistical physics. The spectral measure is a canonical way of describing the unitary matrix that takes into account the full operator, not just its eigenvalues. When the matrix is infinitely large (i.e. an operator on some infinite-dimensional Hilbert space) the spectral measure is supported on a fractal set and has a rough geometry on all scales. This talk will describe the analysis of these fractal properties. Joint work with Raoul Normand and Balint Virag. (Received August 10, 2016)

1122-60-129 **Megan McCormick Stone*** (mmccormick@math.arizona.edu), 617 N. Santa Rita Ave, P.O. Box 210089, Tucson, AZ 85721-0089. *The two-matrix model and Hurwitz numbers.*

The Hermitian two-matrix model consists of the product space $H(n) \times H(n)$, where $H(n)$ is the space of $n \times n$ Hermitian matrices, equipped with a prescribed probability distribution. This model is an extension of the Hermitian one-matrix model, for which the large n asymptotics have been characterized in detail. The interaction term in the probability distribution for the two-matrix model gives rise to the Harish-Chandra-Itzykson-Zuber (HCIZ) integral. A recent formula due to Golden, Guay-Paquet, and Novak connects the HCIZ integral to monotone Hurwitz numbers, which count a specific class of ramified coverings of the sphere. Using the leading order behavior of this formula, we present a strategy for characterizing the limiting distribution of eigenvalue pairs in the two-matrix model. (Received August 10, 2016)

1122-60-139 **Martin Hairer**, **Gautam Iyer*** (gautam@math.cmu.edu), **Leonid Koralov**, **Alexei Novikov** and **Zsolt Pajor-Gyulai**. *Anomalous Diffusion and Intermediate time Homogenization for cellular flows.*

Cellular flows arise in various contexts, most notably as a as a two dimensional model for heat transport in Bernard convection cells. Our interest is to study the behaviour of a passive scalar diffusing in the presence of a cellular flow. Well known homogenization results show that the long time behaviour can be modelled by a Brownian motion, with an enhanced diffusion coefficient. In contrast, we show that on intermediate time the effective behaviour is instead governed by a Brownian motion time changed by the local time of an independent graph diffusion. The proof is probabilistic, using the framework of Freidlin-Wentzel. This is joint work with M. Hairer, L. Koralov, A. Novikov and Z. Pajor-Gyulai. (Received August 11, 2016)

1122-60-150 **Toru Ohira*** (ohira@math.nagoya-u.ac.jp), Graduate School of Mathematics, Nagoya University, Nagoya, Aichi 4648602, Japan. *Delayed Random Relays.* Preliminary report.

We present here a system with collection of random walks relaying a signal in one dimension with a presence of a delay. We are interested in the time for a signal to travel from one end (start) to the other end (finish) of the lined group of random walkers. It is found that there are optimal number of walkers for the signal to travel fastest if the delay is present.

We discuss implications of this model and associated behaviors to physical and biological systems. For example, the sun generates its thermal energy at its core, but it takes unusually long time for the energy to go through the radiative zone to reach the sun's surface. The estimation of this time ranges from 170,000 to 50,000,000 years. Though the detailed reason is not known, we may infer from our results that some mechanism of local delaying transferring of the energy exists.

This work was partially supported by the Grant-in-Aid for Scientific Research from Japan Society for the Promotion of Science No. 16H01175. (Received August 12, 2016)

1122-60-160 **Diane Holcomb*** (dianeholcomb@math.arizona.edu). *From the hard-edge to the bulk: a point process transition.*

In the study of classical Hermitian random matrix ensembles three distinct types of local behavior have been observed in the $n \to \infty$ limit (where n is the size of the matrix). The Gaussian Unitary Ensemble (GUE) exhibits one type of behavior in the interior, or bulk, of its spectrum and another at its edge. The Laguerre (also called

Wishart) and Jacobi (MANOVA) ensembles exhibit the same behavior in the bulk, but depending on the choice of parameters may exhibit two different types of behavior at the edge. The first limits to the same process as the GUE and is referred to as a soft edge. The second limits to a family of determinantal point processes where the determinant is defined in terms of Bessel functions J_α and will be referred to as the hard-edge process. These distinct limiting behaviors remain when we study the generalization to β-ensembles. I will show a transition from the point process obtained at the hard-edge to the Sine_β process that appears in the bulk for general $\beta > 0$. The convergence will be shown through convergence of counting functions. On the way to the transition we also show a large deviation result for the hard-edge process. (Received August 12, 2016)

1122-60-162 **Christopher D Sinclair*** (csinclai@uoregon.edu), University of Oregon, Eugene, OR 97401, and **Maxim Yattselev** (maxyatts@math.iupui.edu), Indiana University Purdue University, Indianapolis, IN. *A Pfaffian point process for real ensembles with logarithmic weights .* Preliminary report.

The exponentiated equilibrium potential of the interval $[-2, 2]$ in the complex plane introduces a natural weight function for an ensemble of random real, asymmetric matrices. This is a Pfaffian point process similar to Ginibre's real ensemble and the real Mahler ensemble of random polynomials and we give both finite N and scaling limits of the resulting matrix kernel. (Received August 12, 2016)

1122-60-168 **Elliot Paquette*** (elliot.paquette@gmail.com). *Random matrices and log-correlated fields.*

This talk will introduce how log-correlated (almost)-Gaussian fields appear in random matrices. It will give a partial overview of conjectures and known results about the extrema of the log-determinant and in fluctuations of the eigenvalue counting function. These theorems can be connected to a specific, strong CLT for mesoscopic linear statistics. In the beta=2 case, they can be further connected to a specific type of orthogonal polynomial asymptotic away from the spectral support. (Received August 12, 2016)

1122-60-169 **Elliot Paquette*** (elliot.paquette@gmail.com). *Poisson Voronoi tessellations in symmetric spaces.*

This talk will introduce the Poisson-Voronoi tessellations in negatively curved spaces. In symmetric spaces, such as d-dimensional hyperbolic space, these tessellations are unimodular. We show some simple properties and open questions, as well as how to establish anchored expansion of these spaces in d-dimensional real hyperbolic space. (Received August 12, 2016)

1122-60-185 **Yuval Peres***, Microsoft Research, 1 Microsoft Way, Redmond, WA 98052. *Random walks on unimodular random graphs: Collisions and diffusivity.*

I will discuss two results involving random walks on unimodular random graphs. In a 2015 ECP paper with Tom Hutchcroft, We proved that in any recurrent unimodular random graph, two independent simple random walks started at the same vertex collide infinitely often almost surely. In particular, this applies to the Uniform Infinite Planar Triangulation (UIPT) and to the Incipient Infinite Cluster in $\mathbf{Z}^2$.

More recently, in joint work with Shirshendu Ganguly and James Lee, we consider the rate of escape for simple random walk on a unimodular random graph G of annealed polynomial growth. We prove that there is an infinite sequence of times $\{t_n\}$ at which the walk is at most diffusive. This result is new even in the case when G is a stationary random subgraph of $\mathbf{Z}^d$. Combined with the work of Benjamini, Duminil-Copin, Kozma, and Yadin (2015), it implies that G almost surely does not admit a non-constant harmonic function of sublinear growth. To complement this, we show that passing to a subsequence of times $\{t_n\}$ is necessary. (Received August 12, 2016)

1122-60-285 **Yu Zhang*** (yzhang3@uccs.edu), Department of Mathmatics, University of Colorado, Colorado Springs, CO 80918. *Large deviations in the reinforced random walk model on trees.*

In this talk, we consider the linearly reinforced and the once-reinforced random walk models in the transient phase on trees. We show the large deviations for the upper tails for both models. We also show the exponential decay for the lower tail in the once-reinforced random walk model. However, the lower tail is in polynomial decay for the linearly reinforced random walk model. (Received August 15, 2016)

1122-60-308 **Igor Rumanov*** (igor.rumanov@colorado.edu), Dept. of Applied Mathematics, University of Colorado Boulder, 526 UCB, Boulder, CO 80309. *Quantum Painleve II (QPII) and Tracy-Widom distribution for beta = 6.*

Quantum Painleve equations (QPE) are Fokker-Planck (or non-stationary Schroedinger) equations in two independent variables ("time" and "space")with diffusion-drift operators being quantized Painleve Hamiltonians. QPE are satisfied by certain eigenvalue probabilities of random matrix beta ensembles and are instances of Belavin-Polyakov-Zamolodchikov (BPZ) equations of conformal field theory. We construct classical integrable structure associated with linear QPII PDE, more explicit for even integer beta. Our main result is a second order nonlinear ODE for the log-derivative of Tracy-Widom distribution for beta = 6, involving the (Hastings-McLeod) Painleve II function in the coefficients. The nonlinear PDEs derived from QPII possess Painleve PDE property for all values of beta. Its general solutions are related by a Cole-Hopf transform with two linearly independent solutions of QPII. (Received August 15, 2016)

1122-60-333 **Riddhipratim Basu** and **Shirshendu Ganguly*** (sganguly@berkeley.edu). *$SO(N)$ Lattice Gauge Theory, under strong coupling.*

Lattice Gauge theories have been studied in the physics literature as discrete approximations to quantum Yang-Mills theory for a long time. Primary statistics of interest in these models are expectations of the so called "Wilson loop variables". In his recent seminal work Chatterjee (2015) rigorously established a gauge-string duality, by solving, what is known as the "Makeenko-Migdal" equations in the physics literature. This allows one to write the Wilson loop expectations in Lattice Gauge theories in a certain limit, as a sum of certain weights over string trajectories.

In this talk we will discuss some recent results towards a better geometric understanding of the string trajectories using correspondence to combinatorial objects such as decorated trees and non-crossing partitions. Using connections with Free Probability theory, the planar case can be explicitly described. We will also mention some structural results in higher dimensional lattice gauge theory which falls outside the exactly solvable regime. All the necessary background will be reviewed. Several open questions will be presented as well.

The talk will be based on joint work with Riddhipratim Basu (Stanford). (Received August 16, 2016)

1122-60-359 **Behrouz Touri*** (behrouz.touri@colorado.edu), 1111 Engineering Drive, Electrical Engineering 1B55, Boulder, CO 80309. *Products of random stochastic matrices and applications.*

Products of random stochastic matrices have applications in many engineering settings including coordination in multiagent networks, distributed optimization, and the study of random phenomena in time-varying environments. In this talk we will discuss some recent results on products of random stochastic matrices that relate their convergence properties to the study of certain types of flows. Also, a family of Lyapunov functions will be introduced for the study of such products including a quadratic one. The quadratic Lyapunov functions enable us to characterize the ergodic properties of a general class of stochastic matrices and provide a unified approach to convergence analysis of distributed averaging dynamics. (Received August 16, 2016)

1122-60-361 **Nicholas A Cook*** (niqcook@gmail.com), **Walid Hachem**, **Jamal Najim** and **David Renfrew**. *Limiting spectral distribution for non-Hermitian random matrices with a variance profile.*

We consider large $n \times n$ random matrices Y_n with entries $Y_{ij} = \sigma_{ij} X_{ij}$, where X_{ij} are iid copies of a fixed, centered random variable with unit variance and $4 + \epsilon$ finite moments, and σ_{ij} are deterministic, non-negative (possibly zero) quantities which may depend on i, j and n. Under certain assumptions on the "standard deviation profile" matrix $A = (\sigma_{ij})$ we prove convergence of the rescaled empirical spectral distribution of Y_n in the large n limit. A key component of the proof is a lower tail estimate for the smallest singular values of diagonal perturbations of Y_n. (Received August 16, 2016)

1122-60-365 **Scott A McKinley***, 6823 St Charles Ave, New Orleans, LA 70118. *Diffusion of foreign particle in viscoelastic fluids.*

Tracking experiments for microparticle movement in viscoelastic fluids repeatedly reveal non-Brownian statistics. Increments of particle positions often are significantly anti-correlated and the particle mean-squared displacement is typically subdiffusive. While there has been substantial success in modeling and inference for individual particles, progress for multi-particle interactions has been slow. This is, in part, because understanding correlations between distinct particles and modeling interaction forces among them requires the development of a viscoelastic fluctuating hydrodynamics framework. In this talk, I will cover recent progress in this direction

(joint work with Christel Hohenegger, Utah), emphasizing both theoretical and experimental problems that lie ahead. (Received August 16, 2016)

1122-60-379 **Eric E Brattain*** (brattaie@newpaltz.edu). *Integrability of the Periodic Asymmetric Simple Exclusion Process.*

The asymmetric simple exclusion process (ASEP) for N particles on a ring with L sites may be analyzed using the Bethe ansatz. We provide a rigorous proof that the Bethe ansatz is complete for the periodic ASEP. More precisely, we show that for all but finitely many values of the hopping rate, the solutions of the Bethe ansatz equations do indeed yield all $\binom{L}{N}$ eigenstates. The proof follows ideas of Langlands and Saint-Aubin, which draw upon a range of techniques from algebraic geometry, topology and enumerative combinatorics. Joint work with Axel Saenz. (Received August 16, 2016)

1122-60-388 **Kenneth D McLaughlin*** (kenmcl@rams.colostate.edu), Department of Mathematics, 1874 Campus Delivery, Fort Collins, CO 80523-1874. *The Normal Matrix Model, the Davey Stewartson equation, and Approximation Theory.*

Asymptotic analysis of integrable systems will connect the topics in the title. (Received August 17, 2016)

62 ► Statistics

1122-62-144 **Aaron T. Porter*** (aporter@mines.edu), 1500 Illinois St, Golden, CO 80401, and **Scott H. Holan** and **Christopher K Wikle**. *Bayesian Semiparametric Hierarchical Empirical Likelihood Spatial Models.*

This talk introduces a general hierarchical Bayesian framework that incorporates a flexible nonparametric data model specification through the use of empirical likelihood methodology, which we term semiparametric hierarchical empirical likelihood (SHEL) models. Although general dependence structures can be readily accommodated, we focus on spatial modeling, a relatively underdeveloped area in the empirical likelihood literature. Importantly, the models we develop naturally accommodate spatial association on irregular lattices. We illustrate our proposed framework by means of a spatial Fay-Herriot model and apply it to the problem of small area estimation in the American Community Survey. (Received August 11, 2016)

1122-62-385 **Kourosh Modarresi** (modarres@adobe.com), 345, San Jose, CA, and **Aran Nayebi** and **khashayar Khosravi**, 345 Park Av, San Jose, CA 95110, and **Yi Liu*** (yliu@adobe.com), 345 Park AV, San Jose, CA 95110. *Estimating Statistical Significance of Segments.*

Estimation of the statistical significance of a segment could be an extremely important step in the testing and validation of any clustering model and algorithm. Clustering is an unsupervised learning method and is based on collecting the most similar data points into each cluster to minimize the total inner distances of all clusters' data sets. In general, it is not trivial to test the validation of an unsupervised model. In this work, we use different statistical approaches to estimate the statistical significance of each cluster. We also try to make the problem a semi-supervised one to be able to apply different testing methodologies. (Received August 17, 2016)

65 ► Numerical analysis

1122-65-6 **Sanghyun Lee** and **Young Ju Lee*** (yjlee@txstate.edu), 601 University Drive, San Marcos, TX 78666, and **Mary Wheeler**. *A Locally Conservative Enriched Galerkin Approximation and Efficient Solver for Elliptic and Parabolic Problems.*

We present and analyze an enriched Galerkin finite element method (EG) to solve elliptic and parabolic equations with jump coefficients. The EG is formulated by enriching the conforming continuous Galerkin fi nite element method (CG) with piecewise constant functions which can be considered as a penalty stabilization. The method is shown to be locally and globally conservative, while keeping fewer degrees of freedom in comparison with discontinuous Galerkin fi nite element methods (DG). Moreover, we present and analyze a fast effective EG solver whose cost is roughly that of CG and which can handle an arbitrary order of approximations. A number of numerical tests in two and three dimensions are presented to con firm our theoretical results as well as to demonstrate the advantages of the EG when coupled with transport. (Received April 10, 2016)

1122-65-10 **James Rossmanith*** (rossmani@iastate.edu), Iowa State University, Department of Mathematics, 411 Morrill Road, Ames, IA 50011. *High-order DG-FEM for Micro-Macro Partitioned Kinetic Models.*

The dynamics of gases can be simulated using kinetic or fluid models. Kinetic models are valid over most of the spatial and temporal scales that are of physical relevance in many application problems; however, they are computationally expensive due to the high dimensionality of phase space. Fluid models have a more limited range of validity, but are generally computationally more tractable than kinetic models. One critical aspect of fluid models is the question of what assumptions to make in order to close the fluid model. In this work we develop a high-order discontinuous Galerkin finite element method (DG-FEM) for a so-called micro-macro decomposition approximation of the kinetic equations. The micro-macro decomposition approach allows us to obtain accurate solutions of the fluid model, but instead of forcing a particular moment-closure approximation, which would typically only have a limited range of validity, this approach directly solves a version of the kinetic equations and uses this solution to provide a closure for the fluid equations. The proposed approach in this work makes use of an efficient semi-Lagrangian DG method for solving the kinetic portion of the update. The resulting numerical method is validated on several standard test cases. (Received May 13, 2016)

1122-65-13 **Eka Oche Ogbaji*** (ogbajieka@yahoo.com), Department of Mathematics and Statistics, Federal university Wukari, Wukari, **E.S Onah**, Department of Maths/Stat/Comp.Sc, University of Agriculture Makurdi, Makurdi, and **A.R Kimbir**, Makurdi. *Simplified Stochastic Runge-Kutta (SSR-K) scheme for a Stock Market Model.* Preliminary report.

A system of stochastic differential equations in the form of a geometric Brownian motion was formulated. This was to model a compartmental stock market situation. We simplified stochastic Runge-Kutta scheme to solve four - dimensional stochastic differential equation and show N- dimension simplified stochastic Rung-Kutta (SSR-K) scheme . In this research work, the simplification follows the principle of Runge-Kutta scheme for ordinary differential equation. We showed the theoretical analysis of convergence, stability, consistence and order of the scheme by using the existence and uniqueness theorem. We conclude that the formulated model can be use to show the real application of stock market in four compartment.We conclude that n-dimensional stochastic differential equation can be solve by using n-dimensional simplified stochastic Runge-Kutta scheme. (Received June 16, 2016)

1122-65-24 **Volker John*** (john@wias-berlin.de), Weierstrass Institute for Applied Analysis, and Stochastics, Mohrenstr. 39, 10117 Berlin, Germany. *A review of variational multiscale methods for the simulation of turbulent incompressible flows.*

Various realizations of variational multiscale (VMS) methods for simulating turbulent incompressible flows have been proposed in the past fifteen years. All of these realizations obey the basic principles of VMS methods: They are based on the variational formulation of the incompressible Navier-Stokes equations and the scale separation is defined by projections. However, apart from these common basic features, the various VMS methods look quite different. In this review, the derivation of the different VMS methods is presented in some detail and their relation among each other and also to other discretizations is discussed. Another emphasis consists in giving an overview about known results from the numerical analysis of the VMS methods.

This is joint work with Naveed Ahmed (WIAS Berlin), Tomás Chacón Rebollo (Seville), and Samuele Rubino (Seville). (Received July 20, 2016)

1122-65-25 **Yulong Xing*** (xingy@ucr.edu). *Well-balanced discontinuous Galerkin methods for the Euler equations under gravitational fields.*

Hydrodynamical evolution in a gravitational field arises in many astrophysical and atmospheric problems. Improper treatment of the gravitational force can lead to a solution which oscillates around the equilibrium. In this presentation, we propose a recently developed well-balanced discontinuous Galerkin method for the Euler equations under gravitational fields, which can maintain the isothermal and polytropic hydrostatic equilibrium states exactly. Some numerical tests are performed to verify the well-balanced property, high-order accuracy, and good resolution for smooth and discontinuous solutions. (Received July 22, 2016)

1122-65-27 **Mihai Anitescu*** (anitescu@mcs.anl.gov), Mathematics and Computer Science Division, 9700 S Cass AVE, Chicago, IL 60439, and **Oana Marin**, **Michel Schanen** and **Hong Zhang**. *Asynchronous Two-Level Checkpointing Scheme for Large-Scale Adjoints in the Spectral-Element Solver Nek5000.*

Adjoints are an important computational tool for large-scale sensitivity evaluation, uncertainty quantification, and derivative-based optimization. An essential component of their performance is the storage/recomputation balance in which efficient adjoint checkpointing strategies play a key role. We introduce a novel asynchronous

two-level adjoint checkpointing scheme for numerical time discretizations targeted at large-scale numerical simulations. The checkpointing scheme combines bandwidth-limited disk checkpointing and space-limited binomial memory checkpointing. Based on assumptions about the target petascale systems, which we later demonstrate to be realistic on the IBM Blue Gene/Q system Mira, we create a model of the predicted performance of the adjoint computation and validate it using the highly scalable Navier-Stokes spectral-element solver Nek5000 on small to moderate subsystems of the Mira supercomputer. (Received July 25, 2016)

1122-65-39 **Martina Bukac*** (mbukac@nd.edu). *A partitioned numerical scheme for the interaction between fluid, elastic structure and poroelastic material.*

The interaction between a fluid, elastic structure, and poroelastic material plays a fundamental role in many biomedical applications. An example of such application is the interaction between blood, arterial wall and blood clot. This multi-physics problem features three different types of coupling: fluid-elastic structure coupling, fluid-poroelastic material coupling, and elastic structure-poroelastic material coupling, resulting in a fully coupled, non-linear, moving boundary problem. As a consequence, numerical algorithms that split the fluid dynamics, structure mechanics, and poroelastic material dynamics are a natural choice. We propose a stable, partitioned method to solve the coupled problem. We present numerical tests where we investigate the effects of the material properties of the poroelastic medium on the fluid flow. Our findings indicate that the flow patterns highly depend on the storativity of the poroelastic material. (Received August 01, 2016)

1122-65-72 **Nabil Chaabane***, nabil.chaabane@rice.edu, and **Beatrice Riviere**. *A splitting discontinuous Galerkin method for the coupling of flow and geomechanics.* Preliminary report.

A numerical method for solving the Biot problem is proposed and its convergence analysis is discussed. This method is a splitting scheme where the interior penalty discontinuous Galerkin method is employed for the spatial discretization and the backward Euler method is employed for the time discretization. This method only requires solving an elliptic equation and a parabolic equation which allows the use of the well studied linear solvers. The main result of this work is the the convergence analysis of the method accompanied with numerical simulation to validate the results. (Received August 07, 2016)

1122-65-77 **Michael Schneier*** (mschneier89@gmail.com), **Nan Jiang** and **Max Gunzburger**. *An Ensemble-Proper Orthogonal Decomposition Method for the Nonstationary Navier-Stokes Equations.*

We consider the case of the time-dependent Navier-Stokes equations for which a recently developed ensemble-based method allows for the efficient determination of the multiple solutions corresponding to many parameter sets. The method uses the average of the multiple solutions at any time step to define a linear set of equations that determines the solutions at the next time step. To significantly further reduce the costs of determining multiple solutions of the Navier-Stokes equations, we incorporate a proper orthogonal decomposition (POD) reduced-order model into the ensemble-based method. (Received August 08, 2016)

1122-65-78 **Jonathan D. Hauenstein*** (hauenstein@nd.edu), 152C Hurley Hall, Notre Dame, IN 46556, and **Daniel A. Brake** and **Alan C. Liddell**. *Decomposition of solution sets via derivatives.*

A core computation in numerical algebraic geometry is the decomposition of the solution set of a system of polynomial equations into irreducible components, called the numerical irreducible decomposition. One approach to validate a decomposition is what has come to be known as the "trace test." This test, described by Sommese, Verschelde, and Wampler in 2002, relies upon path tracking and hence could be called the "tracking trace test." We present a new approach which replaces path tracking with local computations involving derivatives, called a "local trace test." We conclude by demonstrating this local approach with examples from kinematics and tensor decomposition. (Received August 08, 2016)

1122-65-92 **Hyesuk Lee*** (hklee@clemson.edu). *Partitioned algorithms for a fluid-poroelastic interaction problem.*

Computational algorithms for the Stokes-Biot coupled system are proposed to study the interaction of a free fluid with a poroelastic material. The decoupling strategy we employ is to cast the coupled fluid-poroelastic system as a constrained optimization problem with a Neumann type control that enforces continuity of the normal components of the stress on the interface. The optimization objective is to minimize any violation of the other interface conditions. Two numerical algorithms based on a residual updating technique are presented. One solves a least squares problem and the other solves a linear problem when the fluid velocity in the poroelastic structure is smooth enough. Both algorithms yield the minimizer of the constrained optimization problem. Some

numerical results are provided to validate the accuracy and efficiency of the proposed algorithms. (Received August 09, 2016)

1122-65-132 **Songul Kaya Merdan*** (smerdan@metu.edu.tr), Department of Mathematics, 06800 Ankara, Turkey. *Numerical Analysis of a Fully Discrete Decoupled Penalty -Projection Algorithm for MHD in Elsässer Variables.*

This talk considers numerical analysis of MHD flow that is based on Elsässer variable formulation. I will present a fully discrete, efficient time stepping scheme that decouples the MHD system. The algorithm still provides unconditionally stability with respect to the time step and is extended a more efficient class of timestepping algorithm (penalty-projection type). Numerical simulations will be given on some benchmark problems. (Received August 11, 2016)

1122-65-135 **Zhu Wang*** (wangzhu@math.sc.edu), 1523 Greene Street, Department of Mathematics, USC, Columbia, SC 29208. *Exponential Time Differencing Gauge Method for Incompressible Viscous Flows.* Preliminary report.

In this talk, we present an exponential time differencing multistep method for solving the gauge system of incompressible viscous flows with high-order temporal accuracy. In particular, the momentum equation is completely decoupled from the kinematic equation in the discrete level at each time step and is solved by explicit exponential time stepping schemes. We analyze the stability of the proposed method and rigorously prove that the first order exponential time differencing scheme is unconditionally stable for the Stokes flows. We also present a compact representation of the method for problems on rectangular domains, which makes FFT-based fast solvers available for the resulting fully discrete problem. Various numerical experiments are carried out to demonstrate the accuracy and stability of the proposed method. (Received August 11, 2016)

1122-65-154 **Michael J Neilan*** (neilan@pitt.edu), 301 Thackeray Hall, 139 University Place, Pittsburgh, PA 15260. *de Rham complexes for the axisymmetric Stokes problem.*

Discrete de Rham complexes are now a standard tool in the construction of mixed finite element methods with several desirable properties. This is true for the Stokes problem since, e.g., such constructions lead to exactly divergence-free approximations. In this talk, we discuss de Rham complexes for the axisymmetric Stokes problem. Using averaged pullback operators, we make connections between the relevant three dimensional and two dimensional complexes. We then discuss how these results can extended to the finite element setting. (Received August 12, 2016)

1122-65-166 **Zhongjie Lu**, **Aycil Cesmelioglu*** (cesmelio@oakland.edu), **Jaap J. W. Van der Vegt** and **Yan Xu**. *Discontinuous Galerkin approximations of the Maxwell equations with periodic coefficients.*

Band structure of a photonic crystal can be understood by solving a Maxwell eigenvalue problem with periodic boundary conditions. In this talk, mixed and primal discontinuous Galerkin approximations with modified Nedelec basis functions will be discussed. These approximations provide a non-polluted numerical spectrum due to a discrete compactness property of the discrete space and the convergence rate of the numerical eigenvalues is twice the minimum of the order of the polynomial basis functions and the regularity of the solution of the Maxwell equations. Numerical examples will be presented to verify the convergence rate. (Received August 12, 2016)

1122-65-177 **Jeffrey M Connors*** (jeffrey.connors@uconn.edu), 1084 Shennocossett Road, Academic Building 114C, Groton, CT 06340. *Ensemble variance calculation for fluid-fluid interaction.*

A method is presented, analyzed and tested for ensemble variance calculations of coupled fluid-fluid interaction. Two different fluids are coupled across a flat interface. The underlying motivation is the problem of atmosphere-ocean interaction as used in climate or regional weather forecasting models. In these simulations, it is important to understand the responses to variations in data such as parameters, forcings and initial conditions. Here, the approach of Jiang, Kaya and Layton is adopted to reduce the computational cost for these ensemble calculations, in a way that addresses the problem of exchanging fluxes across the interface between the fluids. Various approaches are compared to handle the flux exchange. (Received August 12, 2016)

1122-65-184 **Hong Wang*** (hwang@math.sc.edu), Columbia, SC. *A fast numerical method for space-time fractional PDEs with optimal storage and almost linear computational complexity.*

Fractional partial differential equations (FPDEs) have been shown to provide a powerful tool for modeling challenging phenomena including anomalous diffusive transport and long range time memory or spatial interactions,

which often cannot be modeled accurately by integer-order PDEs. However, FPDEs raise new computational and numerical difficulties that have not been encountered in the context of integer-order PDEs. We present a fast numerical method for space-time FPDEs. (Received August 12, 2016)

1122-65-187 **Jue Yan*** (jyan@iastate.edu), 396 Carver Hall, Department of Mathematics, Iowa State University, Ames, IA 50010. *Direct discontinuous Galerkin methods for Keller-Segel Chemotaxis equations.*

We develop direct discontinuous Galerkin (DDG) methods to solve Keller-Segel Chemotaxis equations. Different to available DG methods or other numerical methods in literature, we introduce no extra variable to approximate the chemical density gradients and solve the system directly. With P^k polynomial approximations, we observe no order loss and optimal (k+1)th order convergence is obtained. The reason behind is the super convergence property of DDG solutions. With Fourier technique, we prove the DDG solution's spatial derivative is super convergent with at least (k+1)th order in the weak sense. We prove the density solutions approximations are strictly positive with at least third order of accuracy. Blow up solutions are captured well. (Received August 13, 2016)

1122-65-207 **Mahboub Baccouch*** (mbaccouch@unomaha.edu), 6001 Dodge St., DSC 233, Omaha, NE 68182. *Stochastic discontinuous Galerkin methods for stochastic differential equations.*

Stochastic initial-value problems and stochastic boundary-value problems are of increasing interest as their theoretical foundation is developed and new applications are discovered. In this talk, we apply a stochastic analogue of the deterministic discontinuous Galerkin (DG) finite element method to stochastic differential equations (SDEs). The method is shown to be numerically stable in the mean sense and also A-stable. As a result, it is suitable for solving stiff SDEs. Moreover, the method is proved to be convergent in the mean-square sense. Numerical evidence demonstrates that our proposed DG scheme for SDEs with additive noise has a strong convergence order of 2p+1, when p-degree piecewise polynomials are used. When applied to SDEs with multiplicative noise, the SDG method is strongly convergent with order p. We also apply a stochastic analogue of the deterministic local discontinuous Galerkin (LDG) method to linear diffusion problems driven by white noise. Numerical experiments are performed to show the robustness of our proposed schemes. (Received August 14, 2016)

1122-65-209 **Nan Jiang*** (njiang830@gmail.com), 301 Rolla Building, 400 W 12th Street, Rolla, MO 65409. *Corrected Eddy Viscosity Models for Turbulence Not At Statistical Equilibrium.*

Standard eddy viscosity models, while robust, cannot represent backscatter and have severe difficulties with complex turbulence not at statistical equilibrium. In this talk, we give a new derivation of eddy viscosity models from an equation for the evolution of variance in a turbulent flow. The new derivation also shows how to correct eddy viscosity models. We prove that the corrected models preserve important features of the true Reynolds stresses and give algorithms for their discretization including a minimally invasive modular step to adapt an eddy viscosity code to the extended models. (Received August 14, 2016)

1122-65-220 **He Yang***, 231 West 18th Avenue, Columbus, OH 43210, and **Fengyan Li**, Amos Eaton 301, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180. *Discontinuous Galerkin Methods for Relativistic Vlasov-Maxwell System.*

The relativistic Vlasov-Maxwell (RVM) system is a kinetic model that describes the dynamics of plasma when the charged particles move in the relativistic regime and their collisions are not important. In this paper, we formulate and investigate discontinuous Galerkin (DG) methods to solve the RVM system. When standard piecewise polynomial functions are used to define trial and test spaces, the methods conserve mass as expected. However the energy conservation does not hold due to the specific form of the total energy of the system. In order to obtain provable mass and energy conservation, we take advantage of the flexibility of DG discretizations and enrich the discrete spaces with some non-polynomial function. For the semi-discrete DG methods with standard and enriched spaces, stability and error estimates are established together with their properties in conservation. In actual implementation with the enriched space, special care is needed to reduce the loss of significance for better numerical stability. Numerical experiments, including streaming Weibel instability and wakefield acceleration, are presented to demonstrate the performance of the methods. Positivity-preserving limiter is also used in simulating wakefield acceleration to obtain physically more relevant solutions. (Received August 14, 2016)

1122-65-228 **Jiangguo Liu*** (liu@math.colostate.edu). *DarcyLite and DarcyLite+: Computational Tools for Flow and Transport in Porous Media.* Preliminary report.

DarcyLite and DarcyLite+ are two computational toolboxes recently developed by the presenter and collaborators. DarcyLite is developed in Matlab and targets mainly 2-dimensional problems, whereas DarcyLite+ is

developed in C++ and focuses on 3-dim problems. In this talk, we will discuss the overall design of these two toolboxes and the finite element solvers within, especially the novel weak Galerkin finite element methods. As applications, we will demonstrate how the toolboxes are used to solve a 2-phase flow model problem and a poroelasticity problem. (Received August 14, 2016)

1122-65-245 **Aziz Takhirov***, Dept. of Mathematics, Mailstop 3368, TAMU, College Station, TX 77845. *Voigt regularization for the explicit time stepping of the Hall effect term.*

The Hall effect term plays essential role in numerous plasma physics applictions. Since it contains two spatial derivatives, classical explicit time-stepping schemes result in very restrictive CFL condition. In this talk, we consider weakening the restrictive time step condition via Voigt regularization. (Received August 15, 2016)

1122-65-248 **David Wells*** (wellsd2@rpi.edu), Amos Eaton 301, Troy, NY 12180, and **Fengyan Li** and **Jeff Banks**. *A New Partitioned Fluid Structure Interaction Algorithm.* Preliminary report.

Fluid-structure interactions represent a wide range of physical phenomena where an equation governing fluid motion is coupled to an equation governing the motion of some structure. One common class of algorithms for simulating these phenomena are partitioned algorithms, where separate solvers are used to advance the structure and the fluid and they communicate only through some defined interface. Partitioned methods are known to experience instabilities when used with very light (relative to the fluid) structures: in this talk we discuss some recent work made towards improving partitioned algorithms in this case when the fluid and structure are both discretized with the finite element method. (Received August 15, 2016)

1122-65-249 **Yang Yang*** (yyang7@mtu.edu), Houghton, MI 49931, **W. Cao**, Beijing, Beijing 100193, Peoples Rep of China, and **Z Zhang** (zzhang@math.wayne.edu), Detroit, MI 48202. *Superconvergence of Discontinuous Galerkin methods based on upwind-biased fluxes for 1D linear hyperbolic equations.*

In this paper, we study superconvergence properties of the discontinuous Galerkin method using upwind-biased numerical fluxes for one-dimensional linear hyperbolic equations. A (2k+1)-th order superconvergence rate of the DG approximation at the numerical fluxes and for the cell average is obtained under quasi-uniform meshes and some suitable initial discretization, when piecewise polynomials of degree k are used. Furthermore, surprisingly, we find that the derivative and function value approximation of the DG solution are superconvergent at a class of special points, with an order k 1 and k+2, respectively. These superconvergent points can be regarded as the generalized Radau points. All theoretical findings are con firmed by numerical experiments. (Received August 15, 2016)

1122-65-272 **Thomas Trogdon*** (ttrogdon@math.uci.edu), Department of Mathematics, University of California, Irvine, Irvine, CA 92697-3875, and **Percy Deift** (deift@cims.nyu.edu), Courant Institute, New York University, New York, NY 10012. *Universality for the Toda algorithm to compute the eigenvalues of a random matrix.*

The Toda lattice, beyond being completely integrable, has many important properties. Classically, the Toda flow is seen as acting on a specific class of bi-infinite Jacobi matrices. Depending on the boundary conditions imposed for finite matrices, it is well known that the flow can be used as an eigenvalue algorithm. It was noticed by P. Deift, G. Menon and C. Pfrang that the fluctuations in the time it takes to compute eigenvalues of a random symmetric matrix with the Toda, QR and matrix sign algorithms are universal. In this talk, I will present a proof of such universality for the Toda algorithm. I will also discuss empirical and rigorous results for other algorithms from numerical analysis. This is joint work with P. Deift. (Received August 15, 2016)

1122-65-274 **Victor Ginting*** (vginting@uwyo.edu), 1000 E. University Avenue, Dept. 3036, Laramie, WY 82070, and **Prosper Torsu** (ptorsu@csub.edu), 14 SCI California State University, 9001 Stockdale Highway, Bakersfield, CA 93311. *A Multiscale Finite Element Method for Semilinear Singularly Perturbed Boundary Value Problems.* Preliminary report.

Mathematical modelings that utilize advection dominant boundary value problems appear in many applications of flow and transport in porous media. The fact that the diffusion component is much less pronounced in relative comparison to the advection component results in the creation of sharp gradient of the solution that can occur in the near boundary region of the domain or/and even internally. Unless the small diffusion is sufficiently resolved in classical numerical approximations, such problems typically exhibit instability especially in the neighborhood of the high gradient. In addition to advective forces, the aforementioned physical systems are mostly modeled by nonlinear differential equations. Nonlinearities usually arise in one or more forms of transport mechanisms such as diffusion, advection or reaction. The presence of such nonlinearities present a challenge to numerical

methods. We present a multiscale finite element method that has the capability to capture the boundary layer. The proposed method maintains efficiency of the approximation and retains its stability at relatively small extra cost. (Received August 15, 2016)

1122-65-316 **Tianran Chen*** (ti@nranchen.org). *A polyhedral approach for computing positive dimensional solution sets of polynomial systems.*

The computation and description of positive dimensional solution sets of polynomial systems is an important problem that has a wide range of applications. In the field of Numerical Algebraic Geometry the technique of linear slicing has became the standard method for sampling certain points on such positive dimensional solution sets. Following the philosophy of this approach, in this talk we propose a toric-linear slicing scheme that preserves the Newton polytope of the polynomial system. (Received August 16, 2016)

1122-65-328 **Owe Axelsson*** (owe.axelsson@it.uu.se), Institute of Geonics,ASCR, Studentska 1768, 70800 Ostrava-Poruba, Czech Rep. *An efficient preconditioning technique for porous media flow problems.*

The free flow in porous media problems is normally modeled by the Stokes or Navier-Stokes equation while the porous media is modeled by the Darcy equation.To avoid the need to use special transition zone boundary conditions and to enable the use of the same finite element approximation in the whole domain,one add a small diffusion term to the Darcy equation.The divergence free condition leads to a saddle point structure for which we use a block triangular factorization with an accurate preconditioner for the major,diffusion type block matrix.This leads to a preconditioned matrix with a close to identity diagonal block matrix,for which the degree of the minimal polynomial does not depend on the off-diagonal non-zero block. To solve the arising major block systems a recursively repeated coarse-fine mesh separation of node-points and a multiplicative,inverse type preconditioner is used.The action of the arising Schur complement matrix is then approximated by additive correction terms to the action of the inverse of the fine mesh matrix.To approximate the Schur complement for the saddle point matrix we use an augmented Lagrangian approach,which results in a Schur complement which is close to a scalar times the identity. (Received August 16, 2016)

1122-65-360 **Constantin Cordeanu*** (cordun@uta.edu). *On the third stage of Fourier Analysis.*

We discuss the third stage of Fourier Analysis (Received August 16, 2016)

68 ► Computer science

1122-68-384 **Kourosh Modarresi**, 345 Park Av, San Jose, CA, **Aran Nayebi** (nayebi@adobe.com), 345 Park Av, San Jose, CA, **Jamie Diner*** (jamdin@gmail.com), 345 Park, San Jose, CA , and **Elizabeth Chin** (chin@adobe.com), 345 Park AV, San Jose, CA. *Audience Discovery, Valuation of Segments and Attributes.*

This paper provides innovative, effective and accurate methods for evaluation of segments' significance and their attributes. The models could apply to any segment and attribute sets. The approach in this innovation is first to identify the most valuable features (attributes) for the data and then in final step, using the valuation of the data features, we compute the value of each segment. In other words, to be able to carry out segment valuation, we need to have the attributes of the data already evaluated and assessed. Thus, we start this work by attribute valuation (feature selection) and then using the results we establish the model for the evaluation of segments. For both these parts, we use our models and show that they accurately estimate the value of the features and the segments. (Received August 17, 2016)

74 ► Mechanics of deformable solids

1122-74-210 **Jay R Walton***, Department of Mathematics, Texas A&M University, College Station, TX 778433368. *Fracture Regularization through Higher-Gradient Surface Mechanics.*

Fracturing processes greatly influence the free-volume available for fluid storage and transport in solid-like porous media. Predictions of the pore volume increase due to fracturing processes are highly dependent upon how fracture is modeled. Classical fracture theories in elastic bodies give rise to stress and strain singularities at crack edges that tend to over predict crack opening volume. This talk discusses the crack-tip regularizing effect of modeling fracture surfaces as dividing surfaces endowed with surface stresses that depend upon higher surface displacement gradients. (Received August 14, 2016)

76 ► Fluid mechanics

1122-76-26 **Peter F Hoffman*** (peter.hoffman@ucdenver.edu). *Hyperbolic PDEs across Gasdynamics, Plasticity, and Granular Plasticity.*

This expository paper is presented in celebration of Bill Layton's 60th birthday. In mathematics genealogy, Bill is the gg-grandson of Göttingen's Ludwig Prandtl (1875-1953), who contributed enormously to both fluid and solid mechanics.

The Prandtl-Meyer fan is a simple tool to visualize solutions of hyperbolic PDEs in the context of gasdynamics. In later years, Prandtl adapted the fan to visualize solutions of hyperbolic PDEs in the context of plasticity in metals. By 1960, the fan had been used by Sokolovskii in the context of granular plasticity. Because the last introduces logarithms into plasticity's equivalent of the Riemann invariant, granular materials exhibit unexpected behaviors that are being ignored by the construction community with costly consequences. Interestingly, one of the consequences for soil is analogous to the Rankine-Hugoniot relation in gasdynamics. (Received July 24, 2016)

1122-76-42 **Xiaoming Wang*** (wxm@math.fsu.edu), Department of Mathematics, Florida State University, Tallahassee, FL 32306. *A mathematical model for hyporheic flows.* Preliminary report.

We present a model for hyporheic flow. The model couples surface flow, groundwater flow, and heat flow. We investigate the well-posedness of the model, the zero Darcy number limit, and the impact of various interface and boundary conditions. (Received August 01, 2016)

1122-76-45 **Roger Lewandowski*** (roger.lewandowski@univ-rennes1.fr), IRMAR, UFR de mathématiques, Bat. 22, Campus Beaulieu, 263 avenue du Général Leclerc, CS 74205, 35042 Rennes, Britanny, France. *Regular solutions for the NS-TKE turbulent model in the whole space.* Preliminary report.

We consider the NS-TKE turbulent model (NS referring to Navier-Stokes, TKE to turbulent kinetic energy) in the whole space. Using a Oseen potentials representation, we show the existence of a unique local time regular solution. (Received August 02, 2016)

1122-76-46 **Ivan C Christov*** (christov@purdue.edu), West Lafayette, IN 47907. *Self-similar regimes of gravity-driven spreading of viscous liquids in model heterogeneous porous media.*

We discuss a combined experimental–theoretical–computational study of the effects of horizontal heterogeneities on the propagation of viscous gravity currents with applications to porous media flows. Our model geometry is a horizontal channel (specifically, a Hele-Shaw cell) with variable gap thickness in the streamwise direction in the form of a power law. We demonstrate that two types of self-similar behaviors emerge as a result of such horizontal heterogeneity: (a) a"first-kind" solution is found using dimensional analysis for currents that propagate away from the origin (a point of zero permeability); (b) a "second-kind" solution is found using a phase-plane analysis for viscous gravity currents that propagate toward the origin. Using the phase-plane formalism, we construct the universal second-kind self-similar current shape. Additionally, we identify self-similar behaviors in the post-closure regime, i.e., once the current reaches the geometric origin and begins to fill the model porous medium. The theoretical predictions show good agreement with lab-scale experiments and also numerical solutions of the governing PDE developed under the lubrication approximation. Joint work with H.A. Stone and Z. Zheng (Princeton University). (Received August 02, 2016)

1122-76-81 **Ali Pakzad*** (alp145@pitt.edu), The Dietrich School of Arts and Sciences, 301 Thackeray Hall, Pittsburgh, PA 15260, and **Joseph A Fiordilino** (jaf150@pitt.edu), The Dietrich School of Arts and Sciences, 301 Thackeray Hall, Pittsburgh, PA 15260. *Numerical Analysis and Analysis from Laminar to Turbulent Fluid Flow.*

In this presentation, we discuss numerical analysis and analysis pertaining to laminar and turbulent fluid flow, respectively. In the first part of the presentation, we discuss methods for the solutions of laminar problems and quantifying uncertainty through the use of ensembles. In the second part, we present how damping functions correct over-dissipation of the Smagorinsky model. Follow up work may be achieved in extending the methods used in the laminar regime to the turbulent regime. (Received August 08, 2016)

1122-76-95 **Karen Zaya*** (zaya@umich.edu). *Regularity Criterion for the Three-dimensional Boussinesq Equations.*

We discuss a newly developed regularity criterion for the three-dimensional Boussinesq equations, which only imposes a condition on the low modes of the velocity u. The key tool in the development of this weaker regularity criterion is linked to the dissipation wave number. (Received August 09, 2016)

1122-76-104 **Timo Heister**, **Maxim Olshanskii*** (molshan@math.uh.edu) and **Leo Rebholz**. *On conservation laws of Navier-Stokes Galerkin discretizations.*

In the talk we discuss conservation properties of Galerkin methods for the incompressible Navier-Stokes equations, without the divergence constraint strongly enforced. In typical discretizations such as the mixed finite element method, the conservation of mass is enforced only weakly, and this leads to discrete solutions which may not conserve energy, momentum, angular momentum, helicity, or vorticity, even though the physics of the Navier-Stokes equations dictate that they should. We aim to construct discrete formulations that conserve as many physical laws as possible without utilizing a strong enforcement of the divergence constraint. Doing so leads to a new formulation that conserves each of energy, momentum, angular momentum, enstrophy in 2D, helicity and vorticity. (Received August 10, 2016)

1122-76-254 **Katie L Oliveras***, 901 12th Ave, Seattle, WA 98122, and **Christopher W. Curtis**. *Stability in Stratified Shear Flow.*

Euler's equations describe the dynamics of gravity waves on the surface of an ideal fluid with arbitrary depth. In this talk, we discuss the stability of periodic traveling wave solutions describing the interface between two fluids of varying density and vorticity. Using a generalization of a non-local formulation of the water wave problem due to Ablowitz, *et al.*, and Ashton & Fokas, we develop a numerical scheme to determine traveling wave solutions by exploiting the bifurcation structure of the non-trivial periodic solutions. Next, we determine numerically the spectral stability for the periodic traveling wave solution by extending Fourier-Floquet analysis to apply to the non-local problem. We generate the full spectra for all traveling wave solutions and explore the suppression or amplification of well-known instabilities such as Benjamin-Feir and "high-frequency" instabilities as a function of shear strength, density stratification, and the ratio of depths between the fluids. (Received August 15, 2016)

1122-76-263 **Aleksey S. Telyakovskiy*** (alekseyt@unr.edu), Department of Mathematics and Statistics, University of Nevada, Reno, NV 89557, and **Jeffrey S. Olsen** and **Jeff Mortensen**. *Polynomial Approximate Solutions of a Forchheimer Groundwater Flow Equation.* Preliminary report.

The nonlinear Forchheimer equation is often used to model flows in groundwater aquifers. We consider an aquifer of semi-infinite extend that is initially dry. The boundary conditions are specified at the inlet. For certain types of the boundary conditions the problem can be reduced using the dimensional analysis to a boundary-value problem for a nonlinear ordinary differential equation. We derive polynomial approximate solutions to that nonlinear ordinary differential equation. Newly constructed approximate solution compares well with a highly accurate numerical solution obtained through a rescaling algorithm. (Received August 15, 2016)

1122-76-273 **Myron B Allen*** (allen@uwyo.edu), Dept. 3036, University of Wyoming, 1000 E. University Ave., Laramie, WY 82071, and **Mookwon Seo**, **Craig C Douglas**, **Fred L Ogden** and **Jiantang Zhu**. *A Computationally Efficient Alternative to the Classical Model for Water Flow in Variably Saturated Soils.*

The Talbot-Ogden equation furnishes an alternative to the Richards equation for one-dimensional water flow through variably saturated soils. The idea is to facilitate approximations that discretize the moisture content and time, instead of space and time. We derive the alternative equation from basic principles, then show how it differs from the classical equation. The Talbot-Ogden approximation omits a term that causes numerical difficulties when solutions exhibit sharp infiltration fronts, which are characteristic of nonlinear parabolic equations like the Richards equation. The alternative model has the additional benefit that it can be solved numerically via an algorithm that is one or two orders of magnitude faster than the common Richards-equation solver Hydrus-1D on sample problems. (Received August 15, 2016)

1122-76-297 **Christopher Curtis*** (ccurtis@mail.sdsu.edu), San Diego, CA 92182, and **Katie Oliveras**. *Propagation of Nonlinear Waves in Two-Stratified Fluids Under Stratified Linear Shear.*

In this talk, we study the propagation of surface and internal waves in fluid environments featuring both density stratification and stratified linear shear currents. Using a non-local formulation of the Euler equations, we discuss

how to derive closed form equations describing the dynamics of each interface. We then describe when Kelvin-Helmholtz instabilities can arise. Finally, using a shallow water approximation, a coupled system of Korteweg-de Vries equations is presented. In certain parameter regimes, dispersive shock waves are seen, showing that varying shear and stratification can allow for complicated nonlinear phenomena to appear. (Received August 15, 2016)

1122-76-327 **Aseel Farhat*** (af7py@virginia.edu), Aseel Farhat, 141 Cabell Drive, Kerchof Hall, P.O. Box 400137, Charlottesville, VA 22904-4137, and **Zoran Grujić** and **Keith Leitmeyer**. *The space $B^{-1}_{\infty,\infty}$, volumetric sparseness, and 3D NSE.*

In the context of the L^∞-theory of the 3D NSE, it is shown that suitable smallness of a solution in Besov space $B^{-1}_{\infty,\infty}$ suffices to prevent a possible blow-up. (Received August 16, 2016)

81 ► Quantum theory

1122-81-20 **Jonathan Harrison**, **Tracy Weyand*** (tracy_weyand@baylor.edu) and **Klaus Kirsten**. *Zeta Functions of the Dirac Operator on Quantum Graphs.*

The spectral zeta function generalizes the Riemann zeta function by replacing the sum over integers with a sum over a spectrum. Here we take that spectrum to be the spectrum of the Dirac operator acting on a metric graph. Since all eigenvalues are roots of a secular equation, we can calculate the spectral zeta function explicitly by applying the argument principle to a particular contour integral. This will be done first for a rose graph, and then for general graphs with self-adjoint vertex matching conditions. (Received July 06, 2016)

1122-81-66 **Chelsea Walton*** (notlaw@temple.edu), 1805 N. Broad Street, Philadelphia, PA 02152. *Quantum Symmetry.*

The study of symmetries of a given object is a classical problem; mathematically, this is the study of group actions (or automorphisms) that the object admits. This is vital especially in analyzing either objects we can visualize (e.g. spaces, manifolds, varieties) or the algebras of functions on such objects. Moreover, quantum objects and their noncommutative algebras of functions have been ubiquitous in mathematics and physics since the birth of quantum mechanics in the 1920s – thus, an appropriate notion of symmetry is needed. Replacing group actions with actions of Hopf algebras is an effective approach.

The aim of this talk is to provide a gentle introduction to Quantum Symmetry in the context of (co)actions of Hopf algebras on algebras. Classification results and lots of examples will be presented. (Received August 06, 2016)

82 ► Statistical mechanics, structure of matter

1122-82-223 **Ben Dyhr*** (bdyhr@msudenver.edu), Associate Professor of Mathematics, Dept. of Mathematical and Computer Sciences, Metropolitan State University of Denver, Denver, CO 80217-3362. *Self-avoiding random walk and Schramm-Loewner evolution.*

The infinite length self-avoiding random walk (SAW) in the half-plane is decomposed into bridges. These bridges are related to SAW conditioned to cross an infinite strip. This bridge decomposition is exploited to produce numerical evidence supporting a conjecture that fine-mesh scaling limits of SAW converge to a Schramm-Loewner evolution (SLE) process. This is joint work with M. Gilbert, T. Kennedy, G. Lawler and S. Passon. In the talk, I will also describe properties of SAW that can be gathered from contemporary SLE results if the conjectured relationship between SAW and SLE is established. (Received August 14, 2016)

1122-82-301 **Rajinder Singh Mavi*** (rsmavi.hb@gmail.com) and **Jeffery Schenker**. *Decay of Fractional Moments of Greens' Functions for Random Lattices Decorated by Harmonic Oscillators.*

Polarons are physical quasiparticles modeling the interaction of a particle, in this case a Fermion on a graph, with fixed atoms, at the nodes of the graph, which are modeled by harmonic oscillators. We will discuss the graphical presentation of the such a model. We will show in the random case, which is modeled by random potentials, that all eigenfunctions at low energies are localized. This follows from a random walk expansion, in the graphical representation, of the fractional moment of the Greens' function. (Received August 15, 2016)

93 ► Systems theory; control

1122-93-126 **Matthias Kawski*** (kawski@asu.edu), School of Mathematical and, Statistical Sciences, Tempe, AZ 85287. *Algebraic foundations of nonlinear control and feedback transformations.* Preliminary report.

Noncommuting flows are the foundation of nonlinear control. They, and the corresponding iterated integral functionals are governed by Zinbiel algebras, and other closely related nonassociative algebras. Utilizing these algebraic structure is key for efficient calculations such as the factorization of exponential Lie series which has applications to path planning and characterizing optimal controls. A special focus is on the action of the group of feedback transformations, in particular, open problems on exact nilpotentization via feedback. (Received August 10, 2016)

94 ► Information and communication, circuits

1122-94-8 **James Mckeough*** (james_c_mckeough@nnmc.edu), **Ajit Hira** (hira@nnmc.edu), **Chloe Robinson** (chloe_c_robinson@nnmc.edu), **Aldo Arevalo** (aldo_g_arevalo@nnmc.edu) and **Ruben Rivera** (ruben_m_rivera@nnmc.edu). *Novel Algorithm for the Hashed-MQV Approach to Diffie Hellman Protocol.*

This report is on work in cryptography that formulates a novel approach to the Diffie-Hellman (DH) problem. The MQV is specifically designed to achieve a remarkable list of security properties, including resistance to active man-in the-middle attacks. Recently, Hugo Krawczyk invented a Hashed MQV (HMQV) protocol, which involves the hashing of the party's own DH value and the peer's identity. HMQV overcomes the security shortcomings of MQV, and moreover, preserves the efficient performance of MQV. Our protocol uses double hashing of the DH value and of the peer's identity. We use the idealized random oracle methodology and discard unnecessary safety margins. Simulations on resistance to KCI attacks have been performed. Such studies have important applications in communication systems. (Received May 03, 2016)

97 ► Mathematics education

1122-97-128 **Virgil U Pierce*** (virgil.pierce@utrgv.edu), 1201 W University Drive, Edinburg, TX 78542. *High School College Preparatory Mathematics Courses in Response to Texas State Legislation.*

We are engaged in a collaboration of the community colleges, technical college, and our university serving four counties of South Texas. In response to 2014 legislation in the State of Texas we joined with a local non-profit agency and the public school districts to develop and deliver College Prep Courses in English language arts and mathematics. The goal is for students to place into, and ultimately be successful in, college level writing intensive and mathematics intensive courses (for us this is mostly College Algebra and Statistics courses). While this is a state level mandate without funding our implementation has been unique in a very important way: our course can be implemented by a school district for no additional cost beyond that for the teacher and the classroom.

We are hosting the mathematics courses on the online homework server WebWork being managed at UTRGV, and now are offering the use of our server for all high school level mathematics courses in our local region. This presentation will focus on our development process, the research behind it, and the product we have put together. We will try to address how this effort could be replicated in other regions, and ways in which the goal of high efficiency use of existing resources can be maintained. (Received August 10, 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

0192-5857(2016)37:3;1-L