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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.

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1126	March 10–12, 2017	Charleston, SC	January 17	Vol 38, No. 2
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	NONE
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	Vol 39, No. 1

MINNEAPOLIS, MN, October 28–30, 2016

Abstracts of the 1123rd Meeting.

00 ► General

1123-00-49 **Cheri Shakiban*** (cshakiban@stthomas.edu). *Applications of Signature curves in Computer Vision.*

In this talk, we focus on the application of an Euclidean invariant curve, called the *signature curve*, formed by taking curvature and derivative of curvature with respect to arc length of a closed curve, $\Sigma = \{(\kappa(t), \kappa_s(t))\}$ to characterize the contour of melanomas and moles. We will then introduce another invariant curve called the *space signature curve* by bringing torsion $\tau(t)$ into the equation, $\Sigma = \{(\kappa(t), \kappa_s(t), \tau(t))\}$ for $3D$ closed curves and apply it to analyze circular DNA models. Finally, we will introduce the *skeletal signature curve* which is a new method we are investigating for charactering and identifying surfaces in $3D$. (Received August 10, 2016)

1123-00-217 **Huaqing Cai*** (huaqing.cai.civ@mail.mil), Buliding 1622, Headquarters Road, White Sands, NM 88002. *Is there Scale Invariance in Atmospheric Vortices?* Preliminary report.

From hurricanes to tornadoes, atmospheric vortices range in scales from hundreds of kilometers to tens of meters. It is a well-known fact that a power law relationship exists relating the radial velocity, as well as its derived vertical vorticity, as a function of radius in atmospheric vortices. This relationship has been confirmed to exist both from observational data and numerical simulations. The question becomes, what is the relationship between power laws describing, for example, a tornado and its parent mesocyclone, if both types of vortices co-exist simultaneously, as would be the case for a supercell storm containing a tornado? Cai (2005) hypothesized that scale invariance exists between tornado and mesocyclone scale. In other words, given a flow field with multiple vortices in different scales, the same power law in terms of maximum vertical vorticity derived from different scales would hold across all the scales. The scale invariance hypothesis has yet to be fully confirmed or refuted since it was introduced by Cai (2005), which motivated the current study; that is to further test this hypothesis using either available observational or numerically simulated data. In addition, the implications of this scale invariance hypothesis to tornadogenesis will also be discussed. (Received August 26, 2016)

1123-00-291 **Elaine Spiller*** (elaine.spiller@marquette.edu), Cudahy Hall, 307, 1313 West Wisconsin Ave, MIlwaukee, WI 53233. *Assimilating nonlinear Lagrangian data into a high-dimensional ocean model.*

We will discuss the hybrid particle-ensemble Kalman filter for assimilating Lagrangian data, and apply it to a high-dimensional quasi-geostrophic ocean model. Effectively the hybrid filter applies a particle filter to the highly nonlinear, low-dimensional Lagrangian instrument variables while applying an ensemble Kalman type update to the high-dimensional Eulerian flow field. We will focus on challenges in applying this filter to a high dimensional problem and compare the hybrid filter and Ensemble Kalman filter on some test cases. (Received August 29, 2016)

1123-00-355 **Amit Sharma*** (sharm121@umn.edu), 1247 Ray Place, Falcon Heights, MN 55108. *A model for higher Picard groupoids.*

In principle, a higher Picard groupoid is a coherently commutative group object in a suitably chosen category of (higher) groupoids. I will present a model of higher Picard groupoids based on Γ-spaces. I will further discuss a (weak) additive structure on the category of higher Picard groupoids. (Received August 30, 2016)

03 ► Mathematical logic and foundations

1123-03-41 **Mariya I Soskova*** (msoskova@fmi.uni-sofia.bg), Sofia University, Faculty of Mathematics and Informatics, 5 James Bourchier Blvd, 1164 Sofia, Bulgaria. *Cototality and the skip operator.*

I will describe recent work, joint with Andrews, Ganchev, Kuyper, Lempp, Miller and A. Soskova. This work was inspired by a question of Emmanuel Jeandel, who had noticed that, when relativizing certain theorems from symbolic dynamics, the sets that are enumeration reducible to their complements play an important role. We call these sets cototal and study their properties in the enumeration degrees. In search for a nice characterization of the class of cototal degrees, we discover a new operator in the structure of the enumeration degrees, the skip operator. The skip operator agrees with the enumeration jump on total degrees, but is not even necessarily monotone on enumeration degrees that contain no total set. We study the general behavior of the skip operator and its relationship to the jump operator. (Received August 08, 2016)

1123-03-52 **Takayuki Kihara*** (kihara@math.berkeley.edu), Evans Hall 735, Berkeley, CA 94720. *Computability-theoretic methods in descriptive set theory.*

Two given spaces are n-th level Borel isomorphic if there exists a bijection between these spaces which preserves the Borel hierarchy above $\mathbf{\Sigma}^0_{n+1}$. The finite level Borel isomorphism problem asks whether any uncountable Polish space is n-th level Borel isomorphic either to the real line or to the Hilbert cube for some integer n. Jayne's theorem (the Baire class version of the Gel'fand-Kolmogorov theorem) connects this problem with the ring-theoretic (and linear-isometric) classification of Banach algebras of finite class Baire functions on compacta (endowed with the supremum norm and the pointwise ring operation). We solve the finite level Borel isomorphism problem by using notions from computability theory such as degree spectra, Scott ideals (ω-models of weak König's lemma), the Shore-Slaman join theorem for the continuous degrees, etc. We also mention the relationship between our solution to the finite level Borel isomorphism problem and Pol's solution to Alexandrov's old problem in infinite dimensional topology. (Received August 11, 2016)

1123-03-65 **Matthew Harrison-Trainor**, **Gregory Igusa** and **Julia Knight*** (knight.1@nd.edu), 255 Hurley Hall, Mathematics Dept,, University of Notre Dame, Notre Dame, IN 46556. *Computable structures of Scott rank ω_1^{CK}.*

There are computable structures of Scott rank ω_1^{CK}. Most of these examples were derived from a particular tree, and they all had the feature that the computable infinitary theory is $\aleph_0$-categorical. We give a new example of a computable structure $\mathcal{A}$ of Scott rank ω_1^{CK} whose computable infinitary theory is not $\aleph_0$-categorical. This answers a question of Sacks and J. Millar, also asked by Calvert, Goncharov, and the third author. (Received August 15, 2016)

1123-03-107 **Rose Weisshaar*** (rweissha@nd.edu). *Comparing Notions of Effective Genericity.* Preliminary report.

In recent work, Cholak, Dzhafarov, Hirst and Slaman showed that for $n \geq 3$, every Mathias n-generic computes a Cohen n-generic. It is natural to wonder how other types of generic objects compare to one another. We consider generics for an effective version of Hechler forcing. Adapting a method developed by Cholak, Dzhafarov, and Soskova, we show that for $n \geq 3$, every Mathias n-generic computes a Hechler n-generic, and every Hechler

n-generic computes a Mathias n-generic. Finally, we explore the (open) question of whether, for $n \geq 3$, the Mathias n-generics and the Hechler n-generics occupy exactly the same Turing degrees. (Received August 20, 2016)

1123-03-109 **Johanna N.Y. Franklin*** (johanna.n.franklin@hofstra.edu), Department of Mathematics, Hofstra University, Room 306, Roosevelt Hall, Hempstead, NY 11549-0114, and **Timothy H. McNicholl** (mcnichol@iastate.edu) and **Jason Rute** (jmr71@math.psu.edu). *Fourier series and Schnorr randomness.*

Carleson's Theorem states that the Fourier series of a function in $L^p[-\pi, \pi]$ converges almost everywhere for $1 < p < \infty$. We prove that the Schnorr random points in $[-\pi, \pi]$ are essentially characterized as those points for which such a Fourier series converges for a certain effectivization of this theorem. (Received August 20, 2016)

1123-03-157 **Douglas Cenzer*** (cenzer@ufl.edu), Department of Mathematics, University of Florida, Gainesville, FL 3211-8105, and **Christopher Porter**, Department of Mathematics & Computer Science, Drake University, Des Moines, IA 50311. *The random members of a Π^0_1 class.* Preliminary report.

We examine the notion of algorithmic randomness for elements of a given effectively closed set P. Now P may be viewed as the set of infinite paths through a tree T_P, so one approach is to randomly produce a path through T_P. This notion of randomness for elements of P may be induced by a map from 2^N onto P, which is computable relative to T_P and also has a characterization in term of Kolmogorov complexity. Another approach is to define a relative measure on P, which becomes interesting if P has Lebesgue measure 0. We explore some notions of homogeneity for effectively closed sets, inspired by work of van Lambalgen. A key finding is that in sufficiently homogeneous sets P, each of these approaches coincides. (Received August 24, 2016)

1123-03-230 **Timothy H. Rute** and **Jason M. Rute*** (jmr71@math.psu.edu). *A uniform reducibility in computably presented Polish spaces.* Preliminary report.

Given computably presented Polish spaces $\mathbb{X}$ and $\mathbb{Y}$, we say $x \in \mathbb{X}$ is *reducible to* $y \in \mathbb{Y}$ if there is a Π^0_1 set $P \subseteq \mathbb{Y}$ and a computable map $f\colon P \to \mathbb{X}$ such that $f(y) = x$. For each space $\mathbb{X}$ one may consider the corresponding degree structure $\mathbf{deg}(\mathbb{X})$. For example, $\mathbf{deg}(2^{\mathbb{N}})$ is (isomorphic to) the truth-table degrees, whereas both $\mathbf{deg}(\mathbb{N}^{\mathbb{N}})$ and $\mathbf{deg}(\mathbb{R})$ are proper extensions of $\mathbf{deg}(2^{\mathbb{N}})$.

This new reducibility has many motivations. First, truth-table reducibility on $2^{\mathbb{N}}$ is too restrictive of a setting for computable analysis. For example, there are functions $f \in \mathbb{N}^{\mathbb{N}}$ not truth-table reducible to any $X \in 2^{\mathbb{N}}$ and sequences $X \in 2^{\mathbb{N}}$ such that $X/3 \not\leq_{tt} X$. Second, this project mirrors Miller's non-trivial work extending Turing reducibility to computably presented Polish spaces. Last, our reducibility grew naturally out of work of the first author on computable arcs and the second author on Schnorr randomness. For example, we show that, for $\mathbb{R}^d$, every Schnorr random is found in some computable arc. (Received August 27, 2016)

1123-03-239 **Christopher P Porter*** (cp@cpporter.com), Drake University, Department of Math/CS, 2505 University Ave, Des Moines, IA 50310, and **Cameron Fraize** (cameron.fraize@ufl.edu), Department of Mathematics, University of Florida, 1400 Stadium Rd, Gainesville, FL 32611. *Kolmogorov complexity and generalized length functions.*

Kolmogorov complexity measures the algorithmic complexity of a finite binary string σ in terms of the length of the shortest description σ^* of σ. Traditionally, the length of σ^* is taken to measure the amount of information contained in σ. However, we may also view the length of σ^* as a measure of the cost of producing σ, which permits one to generalize the notion of length, wherein the cost of producing a 0 or a 1 can vary in some prescribed manner.

In this talk, I will discuss this generalization of length based on the above information cost interpretation and a modification of the definition of Kolmogorov complexity in terms of generalized length functions. I will focus on a specific class of generalized length functions (called k-length functions) that are intimately related to a subcollection of the Bernoulli p-measures, namely those corresponding to the unique computable real $p \in (0, 1)$ such that $p^k = 1 - p$ for $k \geq 1$. Lastly, I will present a generalization of the classic Levin-Schnorr theorem that involves k-length functions and subsequent results that involve effective dimension and entropy. (Received August 27, 2016)

1123-03-250 **Damir Dzhafarov**, **Stephen Flood** and **Reed Solomon*** (david.solomon@uconn.edu), 196 Auditorium Road, U-3009, Department of Mathematics, University of Connecticut, Storrs, CT 06269, and **Linda Brown Westrick**. *Effectiveness for the Dual Ramsey theorem.* Preliminary report.

The Dual Ramsey theorem states that for any sufficiently nice ℓ-coloring of the k-block partitions of ω, there is a partition of ω into infinitely many pieces such that every coarsening of it to exactly k blocks has the same color. We will consider this theorem from the point of view of effective combinatorics and reverse mathematics. (Received August 28, 2016)

1123-03-253 **Valentina Harizanov*** (harizanv@gwu.edu), Department of Mathematics, George Washington University, Washington, DC 20052. *Khisamiev functions and algebraic structures.* Preliminary report.

N. Khisamiev introduced the notion of a limitwise monotonic function in his study of computability-theoretic properties of abelian p-groups of small Ulm length. This notion captures the dynamic enumeration of the elements in the sets being formed. More precisely, a unary function F on natural numbers is *limitwise monotonic* if there is a computable approximating binary function f such that for all i, s, we have $f(i, s) \leq f(i, s + 1)$, there is $\lim_{t\to\infty} f(i, t)$, and $F(i) = \lim_{t\to\infty} f(i, t)$. A set of natural numbers is limitwise monotonic if it is the range of a limitwise monotonic function. Limitwise monotonic functions and sets as well as their generalizations have been playing an increasingly important role in computable algebra and computable model theory. While every limitwise monotonic set is Σ^0_2, Khisamiev showed that there is a Δ^0_2 set that is not limitwise monotonic. We will present recent results involving applications of limitwise functions to further investigate computability-theoretic properties of certain countable algebraic structures. (Received August 28, 2016)

1123-03-303 **Oscar Levin*** (oscar.levin@unco.edu). *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 29, 2016)

1123-03-320 **Barbara Csima**, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada, and **Jonathan Stephenson***, University of Waterloo, 200 University Avenue West, Waterloo, Ontario N2L 3G1, Canada. *A computable structure of finite computable dimension without a strong degree of categoricity.*

We describe a procedure for building a structure of computable dimension 3 which does not have a strong degree of categoricity. This answers the question of Fokina, Kalimullin, and Miller of whether there is a computable structure with a degree of categoricity but not a strong degree of categoricity. In recent work, Bazhenov, Kalimullin, and Yamaleev also built a structure answering the question, although their structure has infinite computable dimension. (Received August 29, 2016)

1123-03-324 **Donald M. Stull*** (dstull@iastate.edu). *Polynomial space randomness and analysis.*

Recent work has used measure theoretic analysis to study algorithmic randomness. In the computable setting, this line of research has shown a deep connection between the two fields. However relatively few results have explored this connection for resource bounded randomness.

In this talk we discuss how to use measure theoretic analysis to study polynomial space randomness. We first define weak pspace randomness, a new notion of polynomial space randomness. We then show that the Lebesgue differentiation theorem characterizes weakly pspace random points. (Received August 29, 2016)

1123-03-335 **Jack H. Lutz*** (lutz@cs.iastate.edu), Department of Computer Science, 226 Atanasoff, Ames, IA 50011. *Efficient Computation of Absolutely Normal Numbers.*

This talk will discuss recent progress on efficient algorithms for computing real numbers that are Borel normal in every base. (This is joint work with Elvira Mayordomo.) (Received August 29, 2016)

1123-03-343 **Noam Greenberg**, **Joseph S. Miller**, **Alexander Shen** and **Linda Brown Westrick*** (westrick@uconn.edu). *Dimension 1 sequences are close to randoms.* Preliminary report.

We give another answer to the informal question: are sequences of effective Hausdorff dimension 1 just random sequences that have been "messed up"? We show that a sequence has effective Hausdorff dimension 1 if and only if it differs from a Martin-Loef random sequence on a set of density zero. The proof makes essential use of Harper's Theorem concerning finite combinatorics of Hamming spheres. We also ask and answer similar questions for sequences of effective dimension $s < 1$. (Received August 29, 2016)

1123-03-364 **Uri Andrews***, 480 Lincoln Dr., Madison, WI 53706. *The structure of computably enumerable equivalence relations.*

We say that a relation R on ω is reducible to a relation S on ω if there is a total computable function f so that $R(x_1, \ldots, x_n)$ holds if and only if $S(f(x_1), \ldots, f(x_n))$. This is a computability-theoretic analog of Borel reducibility, and, as in the Borel theory, we pay special attention to this reduction on equivalence relations. Note that this is akin to looking for computable maps (preserving equivalence and non-equivalence) from one equivalence structure to the other, thus also being similar to the trend of looking at computable isomorphisms between discrete structures.

We consider the degree structure of computably enumerable equivalence relations under this reduction and I will try to introduce and share as much as possible of what we know about this degree structure.

The work presented here will be from joint work with Andrea Sorbi. (Received August 30, 2016)

1123-03-389 **Tamvana Makuluni*** (makuluni@math.wisc.edu). *Bounded Quantifier Strong Minimality.*

A structure $\mathcal{M}$ is said to be *strongly minimal* if for every definable family of subsets of M^1 there is some n so that a set in the family is infinite iff it has more than n elements. The complex numbers and $\mathbb{Q}$-vector spaces are classic examples. Strongly minimal structures have a notion of indepence and a dimension which can be used to classify the structure and understand its definable structure. However, this notion of independance requires information of arbitrary quantifier-complexity, and so is not a priori computable on a computable structure.

This talk will investigate the notion of "bounded quantifier independance" which results from considering only a bounded quantifer fragment of the language. The resulting notion des not satisfy exchange or closure, however we demonstrate that it satisfies an analagous set of axioms and show how they can be used to similar effect. (Received August 30, 2016)

1123-03-405 **Mojtaba Moniri*** (m-moniri@wiu.edu). *A two-step computation paradigm.*

Motivated by coarse computability, we present new examples of computationally simplifying certain sequences presented as integer parts of a nondecreasing unbounded sequence of reals. The reduction might be at the cost of leaving out a set, of zero or rather small density, of exceptional inputs. A typical simplified output would most likely be the exact intended value, and when it is not it would just be the predecessor of the actual value. We would have a supplementary stand-by program of higher complexity to determine whether 1 must be added. Some of our of examples are of the generalized inverse type and initiate from the least modulus of convergence [given a nondecreasing function f, its generalized inverse is defined by $g(k) = (\mu m)(f(m) \geq k)$]. They include how nested square roots with addition, obtained by iterating $\sqrt{2+x}$ with certain initial values in $[-2, 2]$, converge to 2. Our examples also include the base-2 length of approximate multiplication by $\frac{3}{2}$ obtained by iterating $\lfloor \frac{3}{2}x \rfloor$, initially at 2, and the generalized inverse of that length function. (Received August 30, 2016)

05 ► Combinatorics

1123-05-7 **Robert Davis*** (davisr@math.msu.edu), Department of Mathematics, Michigan State University, 619 Red Cedar Rd., East Lansing, MI 48824, and **Bruce E. Sagan** (sagan@math.msu.edu). *Pattern-Avoiding Polytopes.*

The permutohedron and the Birkhoff polytope are two well-studied polytopes related to many areas of mathematics. This talk will discuss generalizations of these polytopes by considering subpolytopes whose vertices correspond to certain avoidance classes of permutations. We explore their combinatorial structure as well as their Ehrhart polynomials and Ehrhart series. In two specific cases we will identify when the polytopes have symmetric and unimodal h^*-vectors, whose proofs show an elegant interplay among pattern avoidance, poset topology, discrete geometry, and physics. (Received May 07, 2016)

1123-05-13 **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 possible connections to cluster algebras. (Received July 17, 2016)

1123-05-20 **Ryan R Martin*** (rymartin@iastate.edu), 396 Carver Hall, Department of Mathematics, Iowa State University, Ames, IA 50011, 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 22, 2016)

1123-05-21 **Benjamin J. Braun** and **Wesley K. Hough*** (wesley.hough@uky.edu), Department of Mathematics, 715 Patterson Office Tower, Lexington, KY 40506. *Matching and Independence Complexes Related to Small Grids.*

In this talk, we briefly survey tools from discrete Morse theory useful for analyzing the independence complexes of graphs. More specifically, we develop particular matching tree algorithms applied to certain grid graphs that obey cell-counting recursions connecting back to interesting combinatorial sequences. (Received July 25, 2016)

1123-05-26 **Bruce E. Sagan*** (sagan@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Descent and peak polynomials.* Preliminary report.

A permutation $\pi = \pi_1 \dots \pi_n$ in the summetric group $\mathfrak{S}_n$ has *descent set* $\operatorname{Des} \pi = \{i \mid \pi_i > \pi_{i+1}\}$. Given a set S of positive integers and $n > \max S$, the *descent polynomial* of S is the cardinality $d(S;n) = \#\{\pi \in \mathfrak{S}_n \mid \operatorname{Des} \pi = S\}$. It is easy to prove, using the Principle of Inclusion and Exclusion, that this is a polynomial in n. However, properties of this polynomail do not seem to have been studied much in the literature. The *peak set* of π is $\operatorname{Pea} \pi = \{i \mid \pi_{i-1} < \pi_i > \pi_{i+1}\}$. Recently Billey, Burdzy, and Sagan proved that $\#\{\pi \in \mathfrak{S}_n \mid \operatorname{Pea} \pi = S\} = p(S;n) \cdot 2^{n-\#S-1}$ where $p(S;n)$ is a polynomial in n which they dubbed the *peak polynomial* of S. These polynomials have since received the attention of a number of researchers. In this talk we will compare and contrast these two polynomials talking about their degrees, coefficients when expanded in the basis of binomial coefficients, roots, and analogues in other Coxeter groups. (Received August 03, 2016)

1123-05-33 **Sergi Elizalde*** (sergi.elizalde@dartmouth.edu), Department of Mathematics, Dartmouth College, 6188 Kemeny Hall, Hanover, NH 03755, and **Peter R.W. McNamara**. *The structure of the consecutive pattern poset.*

The consecutive pattern poset is the infinite partially ordered set of all permutations where $\sigma \leq \tau$ if τ has a subsequence of adjacent entries in the same relative order as the entries of σ. A recursive expression for the Möbius function of this poset was given by Bernini–Ferrari–Steingrímsson and Sagan–Willenbring. Following up on their work, we study the structure of the intervals in this poset from topological, poset-theoretic, and enumerative perspectives. In particular, we prove that all intervals are rank-unimodal and strongly Sperner, and we characterize disconnected and shellable intervals. We also show that most intervals are not shellable and have Möbius function equal to zero. (Received August 03, 2016)

1123-05-36 **Leslie Hogben*** (hogben@iastate.edu), **Jephian C.-H. Lin** and **Michael Young**. *Multi-part Nordhaus-Gaddum type problems for tree-width, Colin de Verdière type parameters, and Hadwiger number.*

A traditional Nordhaus-Gaddum problem for a graph parameter β is to find a (tight) upper or lower bound on the sum or product of $\beta(G)$ and $\beta(\overline{G})$ (where $\overline{G}$ denotes the complement of G). An r-decomposition $G_1, \ldots, G_r$ of the complete graph K_n is a partition of the edges of K_n among r spanning subgraphs $G_1, \ldots, G_r$. A traditional Nordhaus-Gaddum problem can be viewed as the special case for $r = 2$ of a more general r-part sum or product Nordhaus-Gaddum type problem. We establish results for the r-part sum and product Nordhaus-Gaddum type problems for the parameters tree-width and its variants largeur d'arborescence, path-width, and proper path-width; the Colin de Verdière number μ that is used to characterize planarity, and its variants ν and ξ; and the Hadwiger number. (Received August 05, 2016)

1123-05-43 **Chassidy Bozeman*** (cbozeman@iastate.edu), Carver Hall, 411 MORRILL RD, AMES, IA 50011-2104, Ames, IA 50010. *Zero forcing, power domination, and power propagation time.*

Zero forcing is an iterative coloring procedure that starts by initially coloring vertices white and blue and then repeatedly applies the following color change rule: if any vertex colored blue has exactly one white neighbor, then that neighbor is changed from white to blue. Any initial set of blue vertices that can color the entire graph blue is called a zero forcing set. The zero forcing number is the cardinality of a minimum zero forcing set. The zero forcing number of a simple graph is an upper bound for the maximum nullity of the graph (the largest possible nullity over all symmetric real matrices whose ijth entry (for $i \neq j$) is nonzero whenever $\{i, j\}$ is an edge in G and is zero otherwise). Power domination (motivated by the monitoring of the electric power grid system), uses the power color change rule that starts by initially coloring vertices white and blue and then applies the following rules: 1) In step 1, for any white vertex w that has a blue neighbor, change the color of w from white to blue. 2) For the remaining steps, apply the color change rule. We present results on the power domination problem of a given graph by considering the power dominating sets of minimum cardinality and the amount of steps necessary to color the entire graph blue. (Received August 09, 2016)

1123-05-46 **David Galvin*** (dgalvin1@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *Restricted Stirling and Lah numbers, and their inverses.*

The matrix of Stirling numbers of the second kind (counting partitions of a set into non-empty blocks) is lower triangular with integer entries and 1's down the diagonal, so its inverse shares the same properties. It's well-known that the entries in the inverse matrix have a nice combinatorial meaning — they are Stirling numbers of the first kind (counting permutations by number of cycles).

We explore restricted Stirling numbers of the second kind, in which the block sizes are required to lie in some specified set. As long as this set contains 1, the matrix of these restricted Stirling numbers has an inverse with integer entries, so it is natural to ask, do these integers count things?

In many cases, we find that they do. In particular, we give a combinatorial interpretation of the inverse r-restricted Stirling numbers of the second kind (all blocks must have size at most r) for all even r, settling a question posed by Choi, Long, Ng and Smith in 2006. Our interpretations involve counts of trees and forests.

We carry out an analogous project for restricted Lah numbers (counting partitions of a set into non-empty lists). There are plenty of open questions. All this is joint work with John Engbers (Marquette) and Cliff Smyth (UNC Greensboro). (Received August 09, 2016)

1123-05-48 **Stephen G. Hartke*** (stephen.hartke@ucdenver.edu), Dept. of Math. and Stat. Sciences, University of Colorado Denver. *Coloring the square of subcubic planar graphs.*

Given a graph G, the square of G is the graph formed from G by adding edges between vertices that are distance at most two apart. A graph is subcubic if the maximum degree is at most 3. In 1977, Wegner showed that the square of a subcubic planar graph can be properly colored with at most 8 colors and conjectured that 7 colors suffice. We prove this conjecture using discharging and computation for the reducible configurations.

This is joint work with Sogol Jahanbekam (Rochester Institute of Technology) and Brent Thomas (Utah State University). (Received August 10, 2016)

1123-05-50 **Zdenek Dvorak** and **Bernard Lidicky*** (lidicky@iastate.edu). *Independent sets near the lower bound in bounded degree graphs.*

By Brook's Theorem, every n-vertex graph of maximum degree at most $\Delta \geq 3$ and clique number at most Δ is Δ-colorable, and thus it has an independent set of size n/Δ. We give an approximate characterization of graphs

with independent set near this bound, and use it to show that the problem of deciding whether such a graph has an indepdendent set of size at least $n/\Delta + k$ has a kernel of size $O(k)$. (Received August 11, 2016)

1123-05-56 **Hao Huang*** (hao.huang@emory.edu), Atlanta, GA 30322, and **Yi Zhao** (yzhao6@gsu.edu), Atlanta, GA 30302. *Degree versions of the Erdos-Ko-Rado Theorem and Erdos hypergraph matching conjecture.*

In this talk, I will use an algebraic method to prove the following degree version of the celebrated Erdős-Ko-Rado theorem. Given integers $n > 2k$, every intersecting k-uniform hypergraph H on n vertices contains a vertex that lies on at most $\binom{n-2}{k-2}$ edges.

This result could be viewed as a special case of the degree version of a well-known conjecture of Erdős on hypergraph matchings. I will also mention some progress on it. Joint work with Yi Zhao. (Received August 12, 2016)

1123-05-58 **Michael Tait*** (mtait@cmu.edu), Pittsburgh, PA 15224, and **Josh Tobin**. *4 conjectures in spectral extremal 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)

1123-05-59 **Alan Frieze** and **Xavier Pérez-Giménez***, xperez@ryerson.ca, and **Pawel Pralat** and **Benjamin Reiniger**. *Perfect matchings and Hamilton cycles in the preferential attachment model.*

In this talk we will discuss recent results concerning the existence of perfect matchings and Hamilton cycles in the preferential attachment model. This model was proposed by Barabási and Albert in 1999 to describe the growth of the World Wide Web, and it is one of the best-known models for complex networks. In the preferential attachment model, vertices are added to the graph one by one, and each time a new vertex is created it establishes a connection with m random vertices selected with probabilities proportional to their current degrees. We prove that if $m \geq 317$, then asymptotically almost surely there exists a perfect matching. Moreover, we show that there exists a Hamilton cycle asymptotically almost surely, provided that $m \geq 6{,}429$. (This is joint work with Alan Frieze, Paweł Prałat and Benjamin Reiniger.) (Received August 12, 2016)

1123-05-62 **Richard A Brualdi** and **Michael W Schroeder*** (schroederm@marshall.edu), 1 John Marshall Drive, Huntington, WV 25705. *Alternating Sign Matrices and their Bruhat Order.*

The set $\mathcal{S}_n$ of $n \times n$ permutation matrices forms a ranked partially ordered set under the Bruhat order. The Bruhat order on $\mathcal{S}_n$ can be equivalently defined by means of an entrywise partial order on an associated matrix. Lascoux and Schützenberger proved that the MacNeille completion (the unique smallest lattice containing a partially ordered set) of the Bruhat order on $\mathcal{S}_n$ is the set $\mathcal{A}_n$ of $n \times n$ alternating sign matrices (ASMs) with a partial order defined by this same entrywise order giving a ranked lattice. In this talk, we will further investigate the structure of this lattice, including embedded sub-lattices, saturated chains, rank sizes, maximum degree, and its join-irreducible elements. (Received August 13, 2016)

1123-05-64 **Darij Grinberg*** (darijgrinberg@gmail.com), 515 Huron Blvd SE, Apt 207T, Minneapolis, MN 55414. *Sign functions for reduced expressions in Coxeter groups: proof of a conjecture of Bergeron, Ceballos and Labbé.*

The reduced expressions for a given element w of a Coxeter group (W, S) can be regarded as the vertices of a directed graph $\mathcal{R}(w)$; its arcs correspond to the braid moves. Specifically, an arc goes from a reduced expression $\vec{a}$ to a reduced expression $\vec{b}$ when $\vec{b}$ is obtained from $\vec{a}$ by replacing a contiguous subword of the form $ststst\cdots$ (for some distinct $s, t \in S$) by $tstst\cdots$ (where both subwords have length $m_{s,t}$, the order of $st \in W$). We prove a strong bipartiteness-type result for this graph $\mathcal{R}(w)$: Not only does every cycle of $\mathcal{R}(w)$ have even length; actually, the arcs of $\mathcal{R}(w)$ can be colored (with colors corresponding to the type of braid moves used), and to every color c corresponds an "opposite" color c^{op} (corresponding to the reverses of the braid moves with color c), and for any color c, the number of arcs in any given cycle of $\mathcal{R}(w)$ having color in $\{c, c^{\mathrm{op}}\}$ is even. This generalizes and improves a 2014 result by Bergeron, Ceballos and Labbé.

After stating the results and briefly discussing the idea of the proof, I shall present a few conjectural generalizations. (Received August 14, 2016)

1123-05-83 **James D Currie*** (j.currie@uwinnipeg.ca), 515 Portage Ave., Winnipeg, Manitoba R3B 2E9, Canada. *Formal languages, topology, and some challenging computations.*

Combinatorics on words is a part of theoretical computer science which has historically drawn much of its motivation from dynamical systems. One thus is led to consider topological concepts, such as **entropy** or **perfect sets**, in connection with trees of words. It turns out that effectively deciding certain language questions can be boiled down to completing challenging searches on infinite trees. In this talk we will explore the links betwen words, topology, decision procedures and these searches. (Received August 18, 2016)

1123-05-84 **Eva Czabarka**, **Laszlo A. Szekely*** (szekely@math.sc.edu) and **Stephan Wagner**. *The number of non-isomorphic subtrees of trees.*

There is continuing interest in the distribution of small subgraphs of graphs by isomorphism type. For trees, the corresponding question is the distribution of small subtrees by isomorphism type, as a small random subset of vertices in a tree likely has no edges at all. We prove the following conjecture of Bubeck and Linial: if in a sequence of trees, where the tree size goes to infinity, the proportion of k-vertex paths among k-vertex subtrees becomes negligible, then almost all k-vertex subtrees are stars. We also show that the maximum number of nonisomorphic subtrees (of all sizes) of trees on n vertices is $\Theta(5^{n/4})$. (Received August 18, 2016)

1123-05-85 **Jozsef Balogh**, **Andrew McDowell**, **Theodore Molla*** (molla@illinois.edu) and **Richard Mycroft**. *Triangle-tilings in graphs without large independent sets.*

We study the minimum degree necessary to guarantee the existence of perfect and almost-perfect triangle-tilings in an n-vertex graph G with sublinear independence number. In this setting, we show that if $\delta(G) \geq n/3 + o(n)$ then G has a triangle-tiling covering all but at most four vertices. Also, for every $r \geq 5$, we asymptotically determine the minimum degree threshold for a perfect triangle-tiling under the additional assumptions that G is K_r-free and n is divisible by 3. (Received August 18, 2016)

1123-05-86 **Marika Diepenbroek**, **Monica Maus** and **Lara Pudwell*** (lara.pudwell@valpo.edu), Department of Mathematics and Statistics, 1900 Chapel Drive, Valparaiso, IN 46383, and **Alex Stoll**. *Pattern avoidance in reverse double lists.*

In this talk, we consider classical pattern avoidance in the subset of words that use each letter from $[n]$ exactly twice with the symmetry $w = w^r$. In particular, we define the set of reverse double lists on n letters to be $\mathcal{R}_n := \{\pi\pi^r \mid \pi \in \mathcal{S}_n\}$. We enumerate reverse double lists avoiding a single permutation pattern of length at most 4 and completely determine the corresponding Wilf classes. We also consider special results for patterns of length 5 and monotone patterns.

This is joint work with Marika Diepenbroek (University of North Dakota), Monica Maus (Minnesota State Moorhead), and Alex Stoll (Clemson University). (Received August 18, 2016)

1123-05-91 **Gretchen L Matthews*** (gmatthe@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29631. *Semigroups from divisors on graphs.*

We consider semigroups associated with divisors of functions on graphs. Specifically, we study the collection $H_f(P)$ of nonnegative integers α that arise as coefficients of pole divisors of functions supported by a single vertex P of a finite, simple graph G. Our work is motivated by the classical Weierstrass semigroup of a rational point on a curve whose properties are tied to the Riemann-Roch Theorem as well as its analogue for finite graphs demonstrated by Baker and Norine. Here, we show that $H_f(P)$ is a numerical semigroup with at most g gaps, where g denotes the cyclomatic number of the graph G. In addition, we determine $H_f(P)$ for vertices P of certain families of graphs. This is joint work with Justin Peachey. (Received August 19, 2016)

1123-05-96 **Andrzej Dudek*** (andrzej.dudek@wmich.edu), Department of Mathematics, Western Michigan University, Kalamazoo, MI 49008. *Ramsey-Turán numbers with small s-independence number.*

Let s be an integer, $f = f(n)$ a function, and H a graph. Define the *Ramsey-Turán number* $\mathbf{RT}_s(n, H, f)$ as the maximum number of edges in an H-free graph G of order n with $\alpha_s(G) < f$, where $\alpha_s(G)$ is the maximum number of vertices in a K_s-free induced subgraph of G. The Ramsey-Turán number attracted a considerable amount of attention and has been mainly studied for f not too much smaller than n. In this talk, we consider $\mathbf{RT}_s(n, K_t, n^\delta)$ for fixed $\delta < 1$. In particular, we show that for an arbitrarily small $\varepsilon > 0$ and $1/2 < \delta < 1$, $\mathbf{RT}_s(n, K_{s+1}, n^\delta) = \Omega(n^{1+\delta-\varepsilon})$ for all sufficiently large s. This is nearly optimal, since a trivial upper bound yields $\mathbf{RT}_s(n, K_{s+1}, n^\delta) = O(n^{1+\delta})$. Furthermore, the range of δ is as large as possible. We also discuss a phase transition of $\mathbf{RT}_s(n, K_{2s+1}, f)$ extending some recent result of Balogh, Hu and Simonovits.

This is a joint work with Patrick Bennett. (Received August 19, 2016)

1123-05-103 **Vasu Vineet Tewari*** (vasut@math.washington.edu). *Ascents and descents in binary trees, hyperplane arrangements and rook placements.*

Gessel introduced a family of multivariate polynomials to study the distribution of ascent-descent statistics on labeled binary trees. He further observed that evaluations of these polynomials at special values coincided with the number of regions in certain well-known deformations of Coxeter arrangements, and asked for a satisfying explanation for this phenomenon. We study these polynomials from a rook-theoretic perspective, with a special emphasis on connections between non-attacking rook placements on skew Ferrers boards and regions of extended Linial arrangements. (Received August 20, 2016)

1123-05-104 **Madhusudan Manjunath*** (m.manjunath@qmul.ac.uk), Mile End Road, E14NS, London, United Kingdom, and **Fink Alex**. *Brill-Noether theory for Graphs and Commutative Algebra.* Preliminary report.

This talk takes a commutative algebraic point of view on Brill-Noether theory for graphs. In particular, connections between Brill-Noether theory for graphs and Boij-Sóderberg style problems over the quotient ring of the toppling ideal of the graph. Infinite resolutions, the Serre-Kaplansky problem, Golod rings make an appearance. (Received August 20, 2016)

1123-05-106 **Eva Czabarka*** (czabarka@math.sc.edu), **Laszlo A. Szekely** and **Stephan Wagner**. *Inducibility in binary trees and tanglegram crossing numbers.*

For a rooted binary tree on n leaves, any subset of k leaves induces a rooted binary tree by taking all paths connecting these leaves, placing the new root on the vertex closest to the original root of the tree, and suppressing all non-root degree two vertices in the resulting tree. The inducibility of a k-leaf rooted binary tree in another rooted binary tree is the proportion of k-subsets of leaves that induce a tree isomorphic to that tree; the inducibility of any rooted binary tree is the limit superior of it inducibility in any sequence of binary trees increasing in size. A tanglegram is a pair of rooted binary trees on the same number of leaves with a fixed matching on the leaves; its crossing number is the minimum number of crossings we can have when we draw this in the plane such that only edges in the matching are allowed to cross. The tanglegram crossing number is used to estimate relevant biological quantities (e.g. in parasite-host trees). We prove some results on the inducibility of certain classes of binary trees, and use some of the to show that the expected value of tangregram crossing number in a random tanglegram on n-leaf trees is $\Theta(n^2)$, i.e. as large as possible. (Received August 20, 2016)

1123-05-108 **Andrew Beveridge*** (abeverid@macalester.edu), Department of Mathematics, Macalester College, 1600 Grand Avenue, St Paul, MN 55105. *A hitting time formula for the discrete Green's function.*

The discrete Green's function $\mathbb{G}$ is a pseudo-inverse of the combinatorial Laplace operator of a graph. We describe a fundamental connection between Green's function and the theory of exact stopping rules for random walks on graphs. A stopping rule is characterized by its exit frequencies, which are the expected number of exits at a given vertex before the rule halts the walk. We show that Green's function is, in fact, a matrix of exit frequencies plus a rank one matrix. This leads to an elementary formula for Green's function in terms of state-to-state hitting times. (Received August 23, 2016)

1123-05-111 **Wayne W Barrett*** (wb@mathematics.byu.edu). *Effective resistance and link-prediction in network science.* Preliminary report.

Let L be the Laplacian matrix of a connected graph G on n vertices. The *effective resistance* between two nodes i and j is $r(i,j) = (e_i - e_j)^T L^\dagger (e_i - e_j)$ where e_i is the ith unit vector in R^n and $L^\dagger$ is the Moore-Penrose inverse of L. The effective resistance $r(i,j)$ is the resistance between nodes i and j in a circuit represented by G when one unit of current flows in at node i, one unit flows out at node j and there is one unit of resistance on each edge. Effective resistance is a metric on the vertex set of G and satisfies $r(i,j) \leq d(i,j)$ where d is the usual distance function of a graph.

Link prediction for an information or social network is concerned with either foretelling the most likely new edges to form in the near future or conjecturing edges already present but unobserved. We have written code to calculate effective resistances of all non-edges in a given graph and then rank them in ascending order. In comparison with a few other predictors on small networks we believe that link prediction based on effective resistance is a fruitful method. (Received August 20, 2016)

1123-05-114 **Tri Lai*** (tlai3@unl.edu), 1400 R Street, 203 Avery Hall, Department of Mathematics, University of Nebraska - Lincoln, Lincoln, NE 68588-0130. *Enumeration of domino tilings of a double Aztec rectangle.*

We investigate the connection between enumeration of lozenge tilings and enumeration of domino tilings by introducing the "double Aztec rectangles", a new family of regions obtained by attaching two different Aztec rectangles. We prove a simple product formula for the generating function of domino tilings of a double Aztec rectangle, which involves the statistics as in the Aztec diamond theorem by Elkies, Kuperberg, Larsen, and Propp. Moreover, we consider the connection between the generating function and MacMahon's q-enumeration of plane partitions fitting in a given box. (Received August 21, 2016)

1123-05-116 **Patricia Hersh** (plhersh@ncsu.edu), Box 8205, Department of Mathematics, North Carolina State University, Raleigh, NC 27695, and **Cristian Lenart*** (clenart@albany.edu), Department of Mathematics and Statistics, State University of New York at Albany, 1400 Washington Avenue, Albany, NY 12222. *From the weak Bruhat order to crystal posets.*

We investigate the ways in which fundamental properties of the weak Bruhat order on a Weyl group can be lifted (or not) to a corresponding highest weight crystal graph, viewed as a partially ordered set. The latter projects to the weak order via the so-called key (poset) map, defined based on the Demazure crystal structure. We work mostly in symmetrizable Kac-Moody generality, and first give positive results for lower intervals in a crystal poset. The main ones are: the analogue of the word property, the fact that the Möbius function is always 0 or ± 1, and that the corresponding order complexes are homotopy equivalent to balls or spheres. Then we show that these results fail for arbitrary intervals, even in type A. (Received August 21, 2016)

1123-05-122 **Sam Payne*** (sam.payne@yale.edu) and **David Jensen** (dave.jensen@uky.edu). *Chip-firing and algebraic curves.* Preliminary report.

I will discuss recent results at the interface between chip-firing and the theory of algebraic curves, including joint work with Dave Jensen on a combinatorial conjecture on chip-firing and piecewise-linear functions that would imply the maximal rank conjecture. As time permits, I will also discuss recent work of Koplewitz, and joint work with Len, related to chip-firing and sandpile groups for bipartite graphs, and curves on smooth quadric surfaces. (Received August 22, 2016)

1123-05-124 **Gregg Musiker*** (musiker@math.umn.edu), School of Mathematics, Minneapolis, MN 55113, and **Tom Roby** (tom.roby@uconn.edu), Department of Mathematics, Storrs, CT 06269. *Combinatorial Interpretation of Birational Rowmotion on Rectangular Posets.* Preliminary report.

In this talk, we will elaborate on a theme discussed in the IMA Volume Recent Trends in Combinatorics article "Dynamical algebraic combinatorics and the homomesy phenomenon" by the second author. The combinatorial action of toggling order ideals of a poset may be lifted to the tropical semiring, becoming piece-wise linear (PL) toggling on the associated order polytope of a poset. This can be further lifted to the birational setting by de-tropicalizing the PL toggles hence obtaining rational function formulas in formal variables associated to the elements of a poset. Birational rowmotion is the lift of a combinatorial action known as rowmotion, defined as a sequence of toggles at each element of the poset in a specified order, to this setting.

On special posets, the order of birational rowmotion turns out to be unexpectedly small, in fact the same as for combinatorial rowmotion. In this work, we focus on rectangular posets, i.e., [n] x [m] where n and m are chosen to be arbitrarily large. We show that iterated applications of birational rowmotion to such a poset yields formulas that can be interpreted in terms of weighted enumeration of non-intersecting lattice paths. We thank AIM for its hospitality during a 2015 workshop where the two authors began this research. (Received August 22, 2016)

1123-05-126 **Fatemeh Mohammadi*** (mohammad@math.tu-berlin.de), Technical University Berlin (TU Berlin), Berlin, 10623. *Combinatorial and Geometric View of the System Reliability Theory.* Preliminary report.

Associated to every coherent system there is a canonical ideal whose Hilbert series encodes the reliability of the system. We study various ideals arising in the theory of system reliability. Using ideas from the theory of divisors on graphs, orientations, and matroids on graphs we associate a polyhedral complex to our system so that the non-cancelling terms in the reliability formula can be read from the labeled faces of this complex. Algebraically, this polyhedron resolves the minimal free resolution of these ideals. In each case, we give an explicit combinatorial description of non-cancelling terms in terms of acyclic orientations of graph and the number of regions in the graphic hyperplane arrangement. This resolves open questions posed by Giglio-Wynn and develops

new connections between the theory of oriented matroid, the theory of divisors on graphs, and the theory of system reliability. (Received August 22, 2016)

1123-05-130 **Jeremy L. Martin*** (jlmartin@ku.edu). *Arithmetical structures on graphs and Catalan combinatorics.* Preliminary report.

Let G be a finite simple graph with vertex set $\{1, \ldots, n\}$ and adjacency matrix A. An *arithmetical structure* on G is a pair $(\mathbf{d}, \mathbf{r})$ of positive integer vectors of length n such that the pseudo-Laplacian $\mathrm{diag}(\mathbf{d}) - A$ is singular, with nullvector $\mathbf{r}$. In the cases that G is a path or a cycle, the set of arithmetical structures turns out to be rich with Catalan patterns. This is joint work with C. Alfaro, B. Braun, H. Corrales, S. Corry, L. García-Puente, D. Glass, N. Kaplan, L. Levine, H. Lopez, G. Musiker, and C. Valencia. (Received August 22, 2016)

1123-05-132 **Nathan Warnberg*** (nwarnberg@uwlax.edu), Nathan Warnberg, 1725 State Street, La Crosse, WI 54601. *Propagation Time on Graphs.*

The propagation time of a graph is computed by starting out with a subset of vertices colored blue, then applying a vertex color-change rule and counting how many iterations are needed to turn the entire graph blue. There are several such color change rules, which will be briefly discussed, but the main focus of the talk will be on the positive-semidefinite color change rule and the corresponding positive semidefinite propagation time of a graph. (Received August 22, 2016)

1123-05-138 **William H Kuszmaul***, william.kuszmaul@gmail.com. *Fast Algorithms for Finding Pattern Avoiders and Counting Pattern Occurrences in Permutations.*

Given a set Π of permutation patterns of length at most k, we present an algorithm for building $S_{\leq n}(\Pi)$, the set of permutations of length at most n avoiding the patterns in Π, in time $O(|S_{\leq n-1}(\Pi)| \cdot k + |S_n(\Pi)|)$. Whereas the previous best algorithms, based on generate-and-check, require exponential time per permutation analyzed, our algorithm is the first to run in time polynomial per outputted permutation. Moreover, our algorithm can be adapted to compute the cardinality of $S_{\leq n}(\Pi)$ using space $O(n^k)$.

Additionally, we present an $O(n!k)$-time and $O(n^{k+1}k)$-space algorithm for counting the number of copies of patterns from Π in each permutation in S_n. Surprisingly, when $|\Pi| = 1$, this runtime can be improved to $O(n!)$, spending only constant time per permutation.

Using our algorithms, we generate $|S_5(\Pi)|, \ldots, |S_{16}(\Pi)|$ for each $\Pi \subseteq S_4$. For thousands of Π, we are able identify OEIS sequences which we conjecture to enumerate $S_n(\Pi)$. (Received August 23, 2016)

1123-05-144 **Sam Hopkins*** (shopkins@mit.edu) and **James Propp**. *Sorting via chip-firing.*

Taking chip-firing back to its roots, we investigate the chip-firing process on a one-dimensional infinite path. However, rather than treating the chips as indistinguishable, we label them. To fire an unstable vertex, we choose any two chips at that vertex and move the lesser labeled chip to the left and the greater labeled chip to the right. Under certain conditions, this labeled version of the chip-firing process still exhibits remarkable (and much subtler) confluence properties: when the number of chips is even, the chip always end up in sorted order. (Received August 23, 2016)

1123-05-151 **Steve Butler*** (butler@iastate.edu). *Constructions of cospectral graphs for the normalized Laplacian.*

The spectrum of the normalized Laplacian matrix gives important information about graphs and is tied to random processes. Because of its unusual definition (involving square roots) it can be an unwieldy matrix to work with and it has some unusual properties. We will look at several constructions of cospectral graphs for the normalized Laplacian with special focus on graphs which have differing number of edges and still have the same set of eigenvalues. This includes examples where one graph is a subgraph of the other!

Part of this is joint work with Kristin Heysse. (Received August 24, 2016)

1123-05-156 **James McKeown*** (mckeown@math.miami.edu). *Waldspurger and Meinrenken Symmetric Group Tilings.* Preliminary report.

Consider the reflection representation of the symmetric group

$$\phi : \mathfrak{S}_n \longrightarrow GL_{n-1}(\mathbb{R})$$

and define the Waldspurger matrix, $\mathbf{W}(g)$, of a permutation g to be the matrix of $\phi(1) - \phi(g)$ expressed in root coordinates. We have a slick trick for computing $\mathbf{W}(g)$, which exposes beautiful combinatorial structure.

Column vectors of Waldspurger matrices are in bijection with unimodal-Motzkin paths and relate to abelian ideals of the Lie Algebra $\mathfrak{sl}$. $\mathbf{W}(g)$ has distinct non-zero columns iff g is a SIF permutation as defined by Callan.

The cones over columns of Waldspurger matrices give a surprising decomposition of the closed root cone. What's more, Waldspurger matrices give a tiling of $\mathbb{R}^n$. Define the Meinrenken simplex, $\mathbf{M}(g)$, of a permutation g to be the convex hull of the zero vector and the columns of $\mathbf{W}(g)$. Meinrenken showed $\mathbf{MT}(g) := \bigsqcup_{g \in \mathfrak{S}_n} \mathbf{M}(g)$ forms a (non-convex!) tile for Euclidean space under the action of the root lattice. The intersection of $\mathbf{M}(g)$ and the boundary of $\mathbf{MT}$ is the convex hull of the columns of $\mathbf{W}(g)$. This restriction to the boundary has curious enumerative properties. (Received August 24, 2016)

1123-05-159 **Luis David Garcia Puente*** (lgarcia@shsu.edu), **Elizabeth Herman**, **Amadeus Martin** and **Bryan Oakley**. *Accessibility numbers in abelian sandpile model on a directed graph.* Preliminary report.

Let G be a digraph with a global sink s. A sandpile is a vector of non-negative integers indexed by the non-sink vertices of G. Given a sandpile c, if c(v) < outdeg(v) for each vertex v, then c is stable; otherwise, c is unstable. In the latter case, the sandpile c may be stabilized by a sequence of vertex topplings where an unstable vertex topples sending one grain of sand through each of its outgoing edges. The set of stable sandpiles is known as the sandpile monoid of G.

A sandpile c is accessible from a sandpile b if one can reach c from b by a series of sand additions and topplings. The accessibility number of a stable sandpile c is the number of stable sandpiles that access c. The largest accessibility number equals the order of the sandpile monoid. Sandpiles with this accessibility number are called recurrent and play a fundamental role in understanding the dynamics of the sandpile model. If a sandpile is not recurrent, it is called transient. In this talk we discuss some properties of the accessibility numbers in the sandpile monoid of a digraph. We will focus on the second largest accessibility number. It can be checked that this number is at most the number of transient sandpiles. We present a characterization of the graphs for which this bound is achieved. (Received August 24, 2016)

1123-05-167 **Rosa C Orellana*** (rosa.c.orellana@dartmouth.edu), Mathematics Department, 6188 Kemeny Hall, Hanover, NH 03755, and **Mike Zabrocki** (zabrocki@mathstat.yorku.ca). *The Partition algebra and Kronecker coefficients.*

The Schur-Weyl duality between the symmetric group and the general linear group allows us to connect the representation theory of these two groups. A consequence of this duality is the Frobenius formula which connects the irreducible characters of the general linear group and the symmetric group via symmetric functions. In this talk we use the Schur-Weyl duality between the partition algebra and the symmetric group to give the analogous Frobenius formula. We then show how we can use symmetric functions to study the representation theory of the partition algebra and how this relates to the Kronecker coefficients. This is join work with Mike Zabrocki. (Received August 25, 2016)

1123-05-171 **Jacques Verstraete*** (jacques@ucsd.edu), 9500 Gilman Drive, La Jolla, CA 92093-0112, and **Michael Molloy** and **Benjamin Sudakov**. *On Relative Turán Numbers.*

The *relative Turán number* for graphs G and F, denoted $\mathrm{ex}(G, F)$, is the maximum number of edges in an F-free subgraph of G. In the special case $G = K_n$, we recover the well-researched Turán numbers $\mathrm{ex}(n, F)$. In this talk we outline a proof for many graphs F, including all graphs of diameter at most three, of the conjecture of Foucaud, Krivelevich and Perarnau that every graph G of minimum degree d and maximum degree Δ has a spanning F-free subgraph of minimum degree $\Omega(d \cdot \frac{\mathrm{ex}(\Delta,F)}{\Delta^2})$. One of the ingredients is our proof that if G is a Δ-regular graph, then G has a spanning subgraph of minimum degree at least $\Delta/24$ which has a Δ-coloring such that no two vertices at distance at most two have the same color. Our methods also show for many graphs F that $\mathrm{ex}(G, F) \geq d \cdot \frac{\mathrm{ex}(\Delta,F)}{e\Delta^2}$, which is tight up to a factor $1/e$. (Received August 30, 2016)

1123-05-176 **Mark Bly*** (bly@math.utk.edu). *Two q-countings related to q-multinomial coefficients.*

Let V be an n-dimensional vector space over a finite field, and let Δ be the set of sequential arrangements of n-element multisets of the form $\{1^{n_1}, 2^{n_2} \ldots, k^{n_k}\}$. In the spirit of D.Knuth's (1971) providing a q-counting of integer partitions relating to q-binomial coefficients, we provide two q-countings of Δ relating to q-multinomial coefficients: (1) via a map from the set of chains of subspaces of V; (2) via a map from the set of ordered direct sum decompositions of V. (Received August 25, 2016)

1123-05-178 **Manda R Riehl*** (riehlar@uwec.edu), Hibbard Hall 512, 105 Garfield Ave, Eau Claire, WI 54702, and **Megan Martinez**. *A bijection between the set of nesting-similarity classes and L & P matchings.*

In her PhD thesis, Jefferson enumerated L & P matchings arising from a particular type of RNA secondary structures. In 2005, Klazar encountered the same sequence enumerating nesting-similarity classes. We present

a bijection between the two collections of objects, and note some properties which are preserved under this bijection. (Received August 25, 2016)

1123-05-185 **Tobias Johnson** and **Anne Schilling*** (anne@math.ucdavis.edu), Department of Mathematics, University of California, One Shields Avenue, Davis, CA 956616, and **Erik Slivken**. *Local limit of the fixed point forest.*

Consider the following partial "sorting algorithm" on permutations: take the first entry of the permutation in one-line notation and insert it into the position of its own value. Continue until the first entry is 1. This process imposes a forest structure on the set of all permutations of size n, where the roots are the permutations starting with 1 and the leaves are derangements. Viewing the process in the opposite direction towards the leaves, one picks a fixed point and moves it to the beginning. Despite its simplicity, this "fixed point forest" exhibits a rich structure. In this talk, we consider the fixed point forest in the limit $n \to \infty$ and show using Stein's method that at a random permutation the local structure weakly converges to a tree defined in terms of independent Poisson point processes. We also show that the distribution of the length of the longest path to a leaf converges to the geometric distribution with mean $e - 1$, and the length of the shortest path converges to the Poisson distribution with mean 1. In addition, the higher moments are bounded and hence the expectations converge as well. (Received August 25, 2016)

1123-05-191 **Bo Lin***, Department of Mathematics, University of California, Berkeley, Berkeley, CA 94720. *Computing Linear Systems on Metric Graphs.*

The linear system $|D|$ of a divisor D on a metric graph has the structure of a cell complex. We introduce the anchor divisors and anchor cells in it - they serve as the landmarks for us to compute the f-vector of the complex and find all cells in the complex. A linear system can also be identified as a tropical convex hull of rational functions. We compute its extremal generators using the landmarks. We apply these methods to some examples - namely the canonical linear systems of some small trivalent graphs. (Received August 26, 2016)

1123-05-193 **Craig Timmons*** (craig.timmons@csus.edu), **Po-Shen Loh** and **Michael Tait**. *Induced Turán numbers.*

Let $s \geq t \geq 2$ be integers and H be a non-bipartite graph. It is easy to see that the maximum number of edges in an n-vertex graph with no induced copy of $K_{s,t}$ is $\binom{n}{2}$ because K_n has no induced $K_{s,t}$. However, if we ask for the maximum number of edges in an n-vertex graph with no copy of H and no induced copy of $K_{s,t}$, then we can no longer use the complete graph. A $(\chi(H)-1)$-partite Turán graph, which will be H-free, cannot be used for a lower bound either because a sufficiently large Turán graph will contain induced copies of $K_{s,t}$. We will present some bounds on the number of edges in an n-vertex graph with no copy of H and no induced copy of $K_{s,t}$, as well as some related results involving clique counts. This is joint work with Po-Shen Loh and Mike Tait. (Received August 26, 2016)

1123-05-197 **Bonnie C. Jacob*** (bcjntm@rit.edu). *Failed skew zero forcing and two-set orderability of graphs.*

Given a graph G and an initial assignment of each vertex as "filled" or "empty," the *skew color change rule* states that a vertex becomes filled if and only if it is the unique empty neighbor of some other vertex. If repeated application of the color change rule eventually results in all vertices becoming filled, then the set of vertices that were originally filled is called a *skew zero forcing set*. For a given graph G, the minimum cardinality of any such set, $\mathrm{Z}^-(G)$, is called the *skew zero forcing number* of G. We introduced the *failed skew zero forcing number* $\mathrm{F}^-(G)$, which is the maximum cardinality of a filled set that will not result in all vertices in the graph eventually being filled.

The parameter $\mathrm{F}^-(G)$ is undefined for some graphs. We introduced a concept called two-set orderability that is key in classifying graphs for which $\mathrm{F}^-(G)$ is undefined. In this talk, we define two-set orderability and describe how it relates to $\mathrm{F}^-(G)$ being undefined. We also classify graphs with high and low values of $\mathrm{F}^-(G)$, and establish connections between $\mathrm{F}^-(G)$ and other parameters related to zero forcing and minimum rank. (Received August 26, 2016)

1123-05-198 **Xiaoyu Liu*** (xiaoyu.liu@wright.edu), 3640 Colonel Glenn HWY, Dayton, OH 45435. *Equality Conditions for an Erdős-Ko-Rado Theorem for Direct Products.* Preliminary report.

Let X be an n-element set, and let $\binom{X}{k}$ be the family of all k-subsets of X. Suppose that $n = n_1 + n_2 + \cdots + n_d$, $k = k_1 + k_2 + \cdots + k_d$, and $X = X_1 \cup X_2 \cup \cdots \cup X_d$, where $|X_i| = n_i$. Let

$$\mathcal{H} = \left\{ F \in \binom{X}{k} : |F \cap X_i| = k_i, \forall i = 1, 2, \ldots, d \right\}.$$

Frankl proved an Erdős-Ko-Rado theorem for direct products: Suppose that $\mathcal{F} \subset \mathcal{H}$ is intersecting and $k_d/n_d \leq \cdots \leq k_1/n_1 \leq 1/2$. Then $|\mathcal{F}|/|\mathcal{H}| \leq k_1/n_1$ holds. In this talk, we will examine the conditions when equality holds in Frankl's theorem, i. e., when $\mathcal{F}/\mathcal{H} = k_1/n_1$. (Received August 26, 2016)

1123-05-200 **Farbod Shokrieh*** (farbod@math.cornell.edu), 436 Malott Hall, Department of Mathematics, Cornell University, Ithaca, NY 14853-4201. *Matroids and their Jacobians.*

After defining the notion of Jacobian groups for certain matroids, I will discuss a very general class of bijections between the Jacobian group and the collection of bases. Although these bijections are described purely combinatorially, it turns out that there is a beautiful geometry behind the scenes. (Received August 26, 2016)

1123-05-201 **Ben Salisbury*** (salis1bt@cmich.edu), Department of Mathematics, Central Michigan University, Pearce Hall 206H, Mount Pleasant, MI 48859, and **Travis Scrimshaw** (tscrimsh@umn.edu), School of Mathematics, University of Minnesota, 204 Vincent Hall, Minneapolis, MN 55455. *Rigged Configurations and $B(\infty)$.*

The crystal $B(\infty)$ is a combinatorial skeleton of the negative half of the quantum group, and its importance in the theory of crystal bases has been highlighted since Kashiwara's original papers on the subject. Since then, many combinatorial models for $B(\infty)$ have been developed (i.e., tableaux, MV polytopes, quiver varieties, modified Nakajima monomials, etc). In this talk, we introduce yet another model for $B(\infty)$; one that is uniform across all symmetrizable types. Our new model, denoted $\mathrm{RC}(\infty)$, is a collection of rigged configurations, which are multipartitions whose parts are "rigged" with, or labeled by, integers. The connection between our model and the marginally large tableaux model will be discussed, as well as the calculation of the $*$-involution on $\mathrm{RC}(\infty)$. (Received August 26, 2016)

1123-05-211 **Dylan Heuer**, **Chelsey Morrow**, **Benjamin Noteboom**, **Sara Solhjem**, **Jessica Striker*** (jessica.striker@ndsu.edu) and **Corey Vorland**. *Chained permutations and alternating sign matrices - inspired by three-person chess.*

We define and enumerate two new two–parameter permutation families, namely, placements of a maximum number of non-attacking rooks on k chained-together $n \times n$ chessboards, in either a circular or linear configuration. The linear case with $k = 1$ corresponds to usual permutations of n, and the circular case with $n = 4$ and $k = 6$ corresponds to a three-person chessboard. We give bijections of these rook placements to matrix form, one-line notation, and matchings on certain graphs. Finally, we define chained linear and circular alternating sign matrices, enumerate them for certain values of n and k, and give bijections to analogues of monotone triangles and fully-packed loops. (Received August 26, 2016)

1123-05-214 **Andrew Berget*** (andrew.berget@wwu.edu). *Critical groups and symmetry.*

I will present some results where symmetries of graphs help determine the structure of their critical groups. I will also report on progress of determining the critical groups of Kneser graphs using representation theory of the symmetric group. (Received August 26, 2016)

1123-05-221 **Howard Skogman** and **Rebecca Smith*** (rnsmith@brockport.edu). *Sorting permutations using $t+1$ passes through a stack.* Preliminary report.

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

We consider the number of passes a permutation needs to take through a stack if we only pop the appropriate output values and start over with the remaining entries in their original order. We define a permutation π to be $(t+1)$-pass sortable (and having tier at most t) if π is sortable using $t+1$ passes through the stack. Permutations that are 1-pass sortable are simply the stack sortable permutations as defined by Knuth.

We show that the $(t+1)$-pass sortable permutations are a permutation class for all values of t. We also provide an exact enumeration for the tier t permutations by giving a bijection between these permutations requiring exactly $t+1$ passes to be sorted and certain sequences considered by Parker of nonnegative integers with values restricted by position and with t descents. (Received August 26, 2016)

1123-05-227 **Alejandro Morales** (ahmorales@math.ucla.edu), **Igor Pak** (pak@math.ucla.edu) and **Greta Panova*** (panova@math.upenn.edu). *Hook formulas for skew shapes I.*

The celebrated hook-length formula of Frame, Robinson and Thrall from 1954 gives a product formula for the number of standard Young tableaux of straight shape. No such product formula exists for skew shapes. In

2014, Naruse announced a formula for skew shapes as a positive sum of products of hook-lengths using "excited diagrams" [Ikeda-Naruse, Kreiman, Knutson-Miller-Yong].

We prove Naruse's formula algebraically and combinatorially in several different ways. We exhibit a bijection between SSYTs or reverse plane partitions of skew shape and certain integer arrays that gives two q-analogues of the formula. We also give an elementary proof of the formula based on verifying it for the case of border strips. Also, we show how excited diagrams give asymptotic results for skew tableaux enumeration and uncover identities involving Euler numbers and Dyck paths.

This is part I of the talk, part II will be given by Alejandro Morales subsequently in the same session. (Received August 29, 2016)

1123-05-237 **Prasad Tetali***, School of Mathematics, 686 Cherry St., Georgia Institute of Technology, Atlanta, GA 30332-0160. *Counting independent sets in hypergraphs.* Preliminary report.

I will report on recent joint work (with Emma Cohen and Will Perkins) on counting the number of independent sets in 3-uniform, d-regular hypergraphs. Our main theorem implies an improved bound for a problem studied by Ordentlich and Roth (2004) concerning ternary Hamming codes. (Received August 27, 2016)

1123-05-249 **Maria Monks Gillespie*** (mgillespie@math.ucdavis.edu), 1528 Walnut St., Apt. 4, Berkeley, CA 94709. *On q,t-symmetry in Macdonald polynomials and its relation to the $n!$ conjecture.* Preliminary report.

We discuss some recent results on q,t-symmetry in Macdonald polynomials and how this may help us understand the Garsia-Haiman bigraded S_n-modules. In particular, the Carlitz bijection is an alternative to the Foata bijection that proves the equidistribution of the inv and maj statistics on permutations. This bijection can be extended in a way that describes the combinatorics of a certain basis of the Garsia-Procesi modules, which essentially correspond to the $q = 0$ specialization of Macdonald polynomials, and we will present some progress towards extending this correspondence to the general setting. (Received August 28, 2016)

1123-05-251 **Michael H Albert**, **Jay Pantone*** (jay.pantone@gmail.com) and **Vincent Vatter**. *On the Growth of Merges and Staircases of Permutation Classes.*

There is a well-known upper bound on the growth rate of the merge of two permutation classes. Curiously, there is no known merge for which this bound is not achieved. Using staircases of permutation classes, we provide sufficient conditions for this upper bound to be achieved. In particular, our results apply to all merges of principal permutation classes. We end by demonstrating how our techniques can be used to reprove a result of Bóna. (Received August 28, 2016)

1123-05-258 **Georgia Benkart*** (benkart@math.wisc.edu), Department of Mathematics, University of Wisconsin-Madison, Madison, WI 53706. *Tensor Invariants, Dimensions, and Multiplicities - A Walking Tour.*

In 1897, Molien gave a formula for the Poincaré series for the invariants of a finite group G acting on symmetric powers of a G-module (the polynomial invariants). This talk will focus on analogues of Molien's formula for tensor invariants and will discuss connections with dimensions of centralizer algebras and their irreducible modules. The approach is via walking on certain related graphs. (Received August 28, 2016)

1123-05-265 **Nathan Kaplan*** (nckaplan@math.uci.edu), Department of Mathematics, 340 Rowland Hall, Irvine, CA 92697. *Cokernels of Random Matrices and Sandpile Groups.*

The sandpile group of a graph can be defined as the cokernel of its reduced Laplacian. Families of graphs then give rise to families of matrices and we would like to understand the distribution of their cokernels. We will discuss results about cokernels of random matrices and sandpile groups of random graphs, and describe connections to the Cohen-Lenstra heuristics from number theory. (Received August 28, 2016)

1123-05-275 **Quang-Nhat Le*** (qnhatle@math.brown.edu), **Ricardo Diaz** and **Sinai Robins**. *Fourier analysis and counting lattice points inside polytopes.*

Counting lattice points inside polytopes has been used to study chip-firing games on finite graphs. For example, Jon Schneider has used this method to establish exact and asymptotic formulas for the numbers of reachable and debt-reachable chip-firing configurations on a finite graph. 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 August 29, 2016)

1123-05-277 **Alejandro H. Morales*** (ahmorales@math.ucla.edu), **Igor Pak** and **Greta Panova**. *Hook formulas for skew shapes II.*

The celebrated hook-length formula of Frame, Robinson and Thrall from 1954 gives a product formula for the number of standard Young tableaux of straight shape. No such product formula exists for skew shapes. In 2014, Naruse announced a formula for skew shapes as a positive sum of products of hook-lengths using "excited diagrams" [Ikeda-Naruse, Kreiman, Knutson-Miller-Yong].

We prove Naruse's formula algebraically and combinatorially in several different ways. We exhibit a bijection between SSYTs or reverse plane partitions of skew shape and certain integer arrays that gives two q-analogues of the formula. We also give an elementary proof of the formula based on verifying it for the case of border strips. Also, we show how excited diagrams give asymptotic results for skew tableaux enumeration and uncover identities involving Euler numbers and Dyck paths. (Received August 29, 2016)

1123-05-283 **Jonathan Cutler*** (jonathan.cutler@montclair.edu) and **A. J. Radcliffe**. *Minimizing the independence polynomial over regular graphs.*

Davies, Jenssen, Perkins, and Roberts recently proved that the independence polynomial of a d-regular graph is maximized by disjoint copies of $K_{d,d}$. This built on work of Kahn, Galvin and Tetali, and Zhao. The proof of Davies et al. used linear programming bounds on a cleverly chosen random variable. In this talk, we use this method to give lower bounds on the independence polynomial of regular graphs. These give new bounds on the number of independent sets in triangle-free graphs. (Received August 29, 2016)

1123-05-284 **Michael Young*** (myoung@iastate.edu), Ames, IA 50011. *Problems on Rainbow 3-term Arithmetic Progressions.*

A 3-term arithmetic progression is a sequence of the form $a, a+d, a+2d$, where a and d are nonnegative integers. Given a coloring of $[n]$, we say that an arithmetic progression is *rainbow* if no two elements of the arithmetic progression have the same color. An *anti-van der Waerden number* is the number of colors needed to guarantee that any coloring of $[n]$ using all the colors must contain a rainbow 3-term arithmetic progression. In this talk, we will discuss some known and new results about anti-van der Waerden numbers in $[n]$ and finite abelian groups. (Received August 29, 2016)

1123-05-285 **Franco V Saliola*** (saliola.franco@uqam.ca). *Combinatorial representation theory and random-to-random shuffles.*

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

The talk will outline how the representation theory of the symmetric group leads to a beautiful recursive structure of the eigenspaces of these transition matrices, which in turn leads to combinatorial statistics for the eigenvalues.

This talk is based on joint work with Ton Dieker. (Received August 29, 2016)

1123-05-287 **Jing Hao*** (jing.hao@wisc.edu), 480 Lincoln Dr., 618, Madison, WI 53704, and **Nigel Boston**. *Quasi-quadratic residue codes and their weight distributions.*

In coding theory, quasi-quadratic residue codes have nice properties including being self-dual when $p \equiv 3 \pmod 4$ and having surprising good minimum distances when $p \equiv 3 \pmod 8$. They initially drew attention because they give critical cases in testing Goppa's conjecture, which says Gilbert-Varshamov bound should be tight for binary linear codes.

In the study of these codes, we found their weight polynomials have interesting patterns, and the structure of the codes can be studied using quadratic residue codes when $p \equiv 7 \pmod 8$. The weight distribution of these codes are asymptotically normal, and the weight of their codewords count the number of points on corresponding hyperelliptic curves. This enables us to give similar results on the asymptotic behavior of point distributions on the corresponding hyperelliptic curves. (Received August 29, 2016)

1123-05-289 **Zoltan Furedi** and **Sogol Jahanbekam***, sowkam305@gmail.com. *Minimum number of edges in digraphs with specified diameter.*

Let $r(n,d)$ be the smallest number of edges an n-vertex digraph with diameter at most d can have. In 1987 Dawes and Meijer conjectured that when $d \geq 4$, we have $r(n,d) = n + \frac{n}{\lfloor \frac{d}{2} \rfloor} + O(1)$. Earlier, Goldberg determined $r(n,d)$ for the case d is even. We prove this conjecture for odd integers d, (Received August 29, 2016)

1123-05-293 **Jay Pantone** and **Vincent Vatter***, vatter@ufl.edu. *Growth rates of permutation classes.*

We establish that there is an algebraic number $\xi \approx 2.30522$ such that while there are uncountably many growth rates of permutation classes arbitrarily close to ξ, there are only countably many less than ξ. We further categorize all growth rates under ξ. Central to the proof are various structural notions regarding generalized grid classes, a new property of permutation classes called concentration, and a reconstruction result for sum indecomposable permutations. (Received August 29, 2016)

1123-05-296 **James Haglund**, **Brendon Rhoades** and **Mark Shimozono*** (mshimo@math.vt.edu), Department of Mathematics, MC 0123, 460 McBryde Hall, Virginia Tech, 225 Stanger St., Blacksburt, VA 24061. *Ordered set partitions, generalized coinvariant algebras, and the Delta Conjecture.*

The coinvariant algebra R_n is the quotient of the polynomial ring P in n variables by the ideal I_n generated by symmetric polynomials with vanishing constant term. This algebra arises as the cohomology ring of the flag variety and as the coordinate ring of the schematic intersection of the nullcone of nilpotent $n \times n$ matrices, with the diagonal matrices. We introduce a generalization $I_{n,k}$ of the ideal I_n indexed by two positive integers $k \leq n$. The quotient $R_{n,k} = P/I_{n,k}$ is a graded S_n-module and specializes to R_n when $k = n$. Many nice properties of R_n generalize to $R_{n,k}$. We describe the Hilbert series of $R_{n,k}$, give extensions of the Artin and Garsia-Stanton monomial bases of R_n to $R_{n,k}$, determine the Gröbner basis for $I_{n,k}$, and describe the graded Frobenius series of $R_{n,k}$. The bases of $R_{n,k}$ are indexed by ordered partitions of a set of n elements with k blocks. The Delta Conjecture of Haglund, Remmel, and Wilson is a generalization of the Shuffle Conjecture in the theory of diagonal coinvariants. We show that the graded Frobenius series of $R_{n,k}$ is (up to a minor twist) the $t = 0$ specialization of the combinatorial side of the Delta Conjecture. (Received August 29, 2016)

1123-05-300 **Michael Dairyko**, **Michael Ferrara**, **Bernard Lidický**, **Ryan Martin**, **Tyrrell McAllister**, **Florian Pfender** and **Andrew Uzzell*** (andrew.uzzell@unl.edu). *Degree conditions for small contagious sets in bootstrap percolation.*

Bootstrap percolation is a cellular automaton introduced in 1979 by Chalupa, Leath, and Reich. Fix $r \geq 2$. In *r-neighbor bootstrap percolation* on a graph G, all vertices are either "infected" or "uninfected". In this process, an initially infected set $A \subseteq V(G)$ grows by iteratively infecting all uninfected vertices with at least r infected neighbors. If all vertices eventually become infected, we say that the initial set A is *r-contagious*.

Let $m(G,r)$ denote the minimum size of an r-contagious set in G. Clearly, $m(G,r) \geq \min\{|V(G)|, r\}$. What conditions on G imply that $m(G,r) = r$? Let $\sigma_2(G) = \min\{d(x) + d(y) : xy \notin E(G)\}$. Freund, Poloczek, and Reichman recently showed that if $\sigma(G) \geq n$, then $m(G,2) = 2$. We show that in fact, $\sigma_2(G) \geq n - 2$ is almost enough to imply $m(G,2) = 2$: if $\sigma_2(G) \geq n - 2$ and $m(G,2) > 2$, then either G is in one of four infinite families or G is one of nine exceptional graphs. We also show that if G is a graph with degree sequence $d_1 \leq \cdots \leq d_n$ such that for all $1 \leq i < n/2$, either $d_i \geq i + 1$ or $d_{n-1} \geq n - i - 1$, then either $m(G,2) = 2$, $G \cong C_5$, or G is in one of two infinite families. (Received August 29, 2016)

1123-05-313 **Spencer Backman*** (spencerbackman@gmail.com), Hausdorff Center for Mathematics, Endenicher Allee 62, Villa Maria, 53115 Bonn, Germany, and **Matthew Baker** and **Chi Ho Yuen**. *Orientations, Ehrhart Theory, and Geometric Bijections.*

I will describe a new bijective derivation of a result of Stanley which states that the Ehrhart polynomial of a unimodular zonotope is a specialization of the Tutte polynomial, using circuit reversal classes of orientations of the associated regular matroid. In the limit under dilation (with appropriate scaling) we obtain a tiling of the zonotope by volume 1 parallelotopes. We use this new description of zonotopal tilings to produce efficiently computable orientation-based geometric bijections between the Jacobian of a regular matroid and its bases. These bijections are similar to ones discovered earlier by Shokrieh. We then prove that the circuit-cocircuit reversal classes are a natural torsor for the Jacobian and apply our results to produce a new algorithm for sampling bases of a regular matroid. (Received August 29, 2016)

1123-05-314 **Ryan R. Martin**, **Brendon Stanton** and **Shanise Walker***, 443 Carver Hall, 411 Morrill Road, Ames, IA 50011. *A new lower bound for a vertex identifying code in general graphs.*

Let $N[v]$ denote the closed neighborhood of a vertex v. For a finite graph G, a vertex-identifying code in G is a subset $C \subset V(G)$, with the property that $N[u] \cap C \neq N[v] \cap C$, for all distinct $u, v \in V(G) - C$ and $N[v] \cap C \neq \emptyset$, for all $v \in V(G)$. Karpovsky, Chakrabarty, and Levitin proved that for a graph G on n vertices such that $|N[v]| < \beta$ for all $v \in V(G)$ and C a vertex-identifying code, $|C| \geq \max\left\{\lceil \log_2(n+1) \rceil, \left\lceil \frac{2n}{\beta+1} \right\rceil\right\}$. We improve upon the lower bounds of Kaprovsky, et al. when $e\sqrt{n} < \beta < \frac{n}{2} - \sqrt{\frac{n \ln 2}{2}}$. (Received August 29, 2016)

1123-05-315 **Art M. Duval*** (aduval@utep.edu), **Caroline J. Klivans** (caroline_klivans@brown.edu) and **Jeremy L. Martin** (jlmartin@ku.edu). *Metric polyhedral complexes.* Preliminary report.

A metric polyhedral complex is, roughly, a polyhedral cell complex along with a volume function that respects subdivisions. We define the Jacobian and Picard groups on metric polyhedral complexes, as the first step towards generalizing the idea of chip-firing on metric graphs to higher dimensions. (Received August 29, 2016)

1123-05-321 **Emily J Olson*** (ognacevi@msu.edu) and **Bruce Sagan**. *Lattices and the* $1/3 - 2/3$ *Conjecture.* Preliminary report.

In a partial order P, let a pair of elements (x, y) be α-balanced if the proportion of linear extensions that has x before y is between α and $1-\alpha$. The $1/3-2/3$ Conjecture states that every finite partial order that is not a chain has some 1/3-balanced pair. While the conjecture remains unsolved, we present progress toward a confirmation. We extend the known partial orders that have a 1/3-balanced pair. (Received August 29, 2016)

1123-05-325 **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 and surjections (joint work with Michael Joseph), and bijections/permutations (joint work with Michael LaCroix) of finite sets. (Received August 29, 2016)

1123-05-333 **Hugo Corrales***, Av. Instituto Politecnico Nacional #2508, Col. San Pedro Zacatenco, Del. G. A. Madero, México, Mexico. *Arithmetical structures over the path.* Preliminary report.

In his paper *Arithmetical graphs* D. Lorenzini introduce arithmetical graphs as a generalization of the classical concept of intersection matrices of degenerating curves in algebraic geometry. He also prove that if we fix the associated graph and it is connected, then there is a finite number of arithmetical graphs. We will prove that if the fixed graph is the path on $n+1$ vertices, then exists exactly C_n arithmetical graphs (C_n stand for the n-Catalan number). (Received August 29, 2016)

1123-05-342 **Olya Mandelshtam*** (olya@math.ucla.edu), UCLA Mathematics Department, Los Angeles, CA 90095. *Combinatorics of the asymmetric simple exclusion process and Koornwinder polynomials.*

The asymmetric simple exclusion process (ASEP) is a process from statistical physics that describes the dynamics of interacting particles hopping right and left on a one-dimensional finite lattice with open boundaries, with parameters α, β, and q describing the hopping rates. One can compute the steady state probabilities of the ASEP as sums over combinatorial objects such as alternative tableaux.

The two-species ASEP is a generalization in which there are two species of particles, heavy and light. Only the heavy particles are able to enter and exit at the left and right of the lattice and with rates α and β, respectively. Two adjacent particles of different species can swap with rate 1 if the heavier particle is on the left, and rate q if it is on the right. We give a combinatorial formula for the steady state probabilities of the two-species ASEP by introducing the *rhombic alternative tableaux*.

Recently, a fascinating connection was discovered between a more general 5-parameter two-species ASEP and Koornwinder-Macdonald polynomials. We introduce *rhombic staircase tableaux* and provide combinatorial formulae for the 5-parameter two-species ASEP, and consequently for moments of Koornwinder-Macdonald polynomials. (Received August 29, 2016)

1123-05-345 **Tianyuan Xu*** (tianyuan@uoregon.edu), Department of Mathematics, University of Oregon, Eugene, OR 97401. *The subregular part of asymptotic Hecke algebras.* Preliminary report.

The asymptotic Hecke algebra J of an arbitrary Coxeter system (W, S), constructed by G. Lusztig, is an associative algebra closely related to the usual Iwahori-Hecke algebra of the system. In this talk, we will recall the construction of J via Kazhdan-Lusztig polynomials and present results on a subalgebra of J corresponding to a special 2-sided Kazhdan-Lusztig cell of W. In particular, we show how products in this subalgebra can be computed combinatorially without inputs from Kazhdan-Lusztig polynomials, and we describe the structure of the subalgebra for various families of Coxeter systems. (Received August 29, 2016)

1123-05-350 **Alexander Burstein*** (aburstein@howard.edu), Department of Mathematics, Howard University, Washington, DC 20059. *Restricted Dumont permutations.* Preliminary report.

We consider several new cases of pattern-restricted Dumont permutations, including some enumerative results and Wilf-equivalences. (Received August 29, 2016)

1123-05-351 **Woong Kook*** (woongkook@snu.ac.kr), Department of Mathematical Sciences, Seoul National University, Seoul, 08826, and **Kang-Ju Lee**. *High-dimensional effective resistance.* Preliminary report.

We define effective resistance for high-dimensional networks following Kirchhoff's laws, and provide two formulas. One of them provides a combinatorial interpretation via top-dimensional tree numbers, and the other is an elegant consequence of Kirchhoff's equation in codimension 1. These results are natural generalizations of those for ordinary networks, and can be used in formulating high-dimensional analogues of related network invariants. As an application, we will suggest a definition of information centrality for top-dimensional simplices. (Received August 30, 2016)

1123-05-357 **Rosa Orellana** (rosa.c.orellana@gmail.com), NH , and **Michael Zabrocki*** (zabrocki@mathstat.yorku.ca), Toronto, Ontario , Canada. *Pieri rules and combinatorics of symmetric group characters.*

The characters of the general linear group are the Schur functions and they form a basis of the symmetric functions. The permutation matrices are a subgroup of the general linear group and, seen in the right way, their characters can also be expressed as symmetric functions and they form a basis. We will present several equivalent definitions for the character symmetric functions coming from orthonormality arising from a scalar product and from Pieri rules. This is joint work with Rosa Orellana. (Received August 30, 2016)

1123-05-358 **Susanna Fishel*** (sfishel1@asu.edu), School of Mathemaical and Statistical Science, Arizona State University, PO Box 871804, Tempe, AZ 85287-1804. *Maximal Chains in the Tamari Lattices and its Generalizations.*

I will discuss recent work on the enumeration of maximal chains in the Tamari lattice and its generalizations. The generalizations include the Cambrian lattices of Reading and the m-Cambrian of Stump, Thomas, and Williams. This is joint work with Sultan Al-Suleiman (ASU), Mahir Can (Tulane), Luke Nelson (ASU), and Kevin Treat (ASU). (Received August 30, 2016)

1123-05-359 **Jonathan S Bloom*** (bloomjs@lafayette.edu), Lafayette College, Math Department, 1 Pardee Drive; Room 230 Pardee Hall, Easton, PA 18042, and **Dan Saracino** (dsaracino@colgate.edu), Colgate University, Department Math, Hamilton, NY 13346. *On a systematic study of avoidance within integer partitions.*

One of the most famous integer partition identities states that the number of partitions (of n) into odd parts is equal to the number of partitions (of n) into distinct parts. This identity is part of a huge class of integer partition identities that have been well studied over the years. In a series of seminal papers, authored by A. Garsia, S. Milne, and J. Remmel and published in the early 1980's, a general framework for constructing bijections for such identities emerged. One of the key ideas behind this work was in viewing restricted classes of partitions in terms of what they "avoid". For example, integer partitions with distinct parts "avoid" the parts $\{11, 22, 33, \ldots\}$.

This concept of avoidance (with respect to parts) naturally suggests the following related notion. Given two partitions σ and μ we say that σ *contains* μ if one can delete rows and columns from σ (viewed as a Young diagram) to obtain μ. In this talk we take up the systematic study of this definition. In doing so we reveal a significant amount of unexpected structure involving integer partitions. (Received August 30, 2016)

1123-05-360 **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 $Gr(k,n)$, corresponding to the union of Kirillov-Reshetikhin modules indexed by the k^{th} node of the type A Dynkin diagram. 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 August 30, 2016)

1123-05-375 **Karen Gunderson*** (karen.gunderson@umanitoba.ca), 186 Dysart Road, Department of Mathematics, Winnipeg, MB R3T2N2, Canada. *Infection processes on infinite trees.*

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 is the following update rule for the states of vertices: 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 infinite trees and present some new results on the possible values of critical probabilities for such processes on Galton–Watson trees. (Received August 30, 2016)

1123-05-377 **Iwan M Duursma*** (duursma@illinois.edu). *Rank weight as q-analogue of Hamming weight.* Preliminary report.

Delsarte (1976) points out the role of the rank weight as the q-analogue of Hamming weight. Certain properties for the Hamming weight hold for the rank weight after replacing binomial coefficients with Gaussian polynomials. We establish q-analogues for two such properties: The use of zeta functions as generating functions for weight distributions and the use of the Bombieri inner product to express MacWilliams identities. Joint work with Eimear Byrne, Iván Blanco-Chacón, and John Sheekey. (Received August 30, 2016)

1123-05-381 **Kirk Boyer**, **Paul Horn*** (paul.horn@du.edu) and **Mario Lopez**. *The combinatorics of ray sensor networks.*

In this talk we'll discuss some interesting problems in combinatorics and discrete geometry that arise when studying a very simple model of sensor networks. We will describe a way of forming a graph from ray sensor networks, and study the properties of such graphs – including proving a type of rigidity theorem that allows us to understand how rare these graphs are. We will also describe a very natural generalization of the initial problem that leads immediately to some very nice extremal problem in discrete geometry. Some algorithmic issues will also be discussed. (Received August 30, 2016)

1123-05-383 **Amanda Redlich*** (aredlich@bowdoin.edu). *The waiting game: Balanced allocation via random choices.*

We discuss a balanced allocation process, placing m balls into n bins. To place each ball, options are generated randomly, and then the best option is chosen. The algorithm dynamically waits "just long enough" before placing each ball into a bin. This variation on previous power-of-two-choices processes improves performance while decreasing computational complexity. It also has interesting implications for related processes (e.g. Achlioptas processes). Joint work with John Augustine and William K. Moses Jr. (IIT Madras) and Eli Upfal (Brown University). (Received August 30, 2016)

1123-05-385 **Anton Dochtermann*** (dochtermann@math.utexas.edu), San Marcos, TX. *Monomial ideals from restricted chip-firing.* Preliminary report.

Associated to a graph G on vertex set $[n+1]$ is a monomial ideal M_G called the 'G-parking function ideal'. A list of (possibly redundant) generators of M_G is indexed by the nonempty subsets of $[n]$. The ideal M_G is a certain initial ideal of the binomial toppling ideal, which encodes the linear equivalence of divisors on G. It has been shown that the Betti numbers of M_G are encoded by certain data coming from the flats of the underlying matroid of G.

Motivated by Backman's notion of 'restricted set chip-firing', we study the monomial subideals of M_G generated by only the subsets of $[n]$ of size two. If G is the complete graph K_{n+1}, we show that the Betti numbers of these ideals are given by certain 'non-crossing' subforests of the bipartite graph $K_{2,n}$, By interpreting this data as coming from as a pair of fans dual to the simplex, we generalize the construction to more general graphs by identifying cones in these fans. (Received August 30, 2016)

1123-05-387 **Hemanshu Kaul*** (kaul@iit.edu), Department of Applied Mathematics, Illinois Institute of Technology, Chicago, IL 60616, and **Jeffrey Mudrock**. *On the List Chromatic Number of the Cartesian Product of Graphs.*

The list chromatic number of the Cartesian product of graphs is not well understood. The best result is by Borowiecki, Jendrol, Kral, & Miskuf (2006) who proved that the list chromatic number of the Cartesian product of two graphs can be bounded in terms of the list chromatic number and the coloring number of the factors, implying a bound exponential in the list chromatic number of the factors. We show how to improve this bound for certain large classes of graphs and by finding classes of chromatic-choosable Cartesian product of graphs. We generalize the notion of strong critical graphs (Stiebitz, Tuza & Voigt, 2008) to strong k-chromatic choosable graphs, and, we show, it gives a strictly larger family of graphs that includes odd cycles, cliques, join of a clique with any other such graph, and many more families of graphs. Our main result gives a sharp bound on choosability of the Cartesian product of a strong k-chromatic choosable graph and a traceable graph. This result can be applied to find chromatic-choosable families of graphs improving the existing bounds. The proof uses the notion of unique-choosability as a sufficient condition for list colorability (Akbari, Mirrokni & Sadjad, 2006) to set up a loaded inductive statement that guarantees non-unique list colorings. (Received August 30, 2016)

1123-05-398 **Heather Russell** and **Julianna Tymoczko*** (jtymoczko@smith.edu), Department of Mathematics and Statistics, 44 College Lane, Northampton, MA 01060. *Comparing web and tableau bases for certain symmetric group representations.*

We consider the complex representations of the symmetric group corresponding to the partition (n, n) and compare two bases: the classical Specht module basis and the web basis. Specht basis vectors are indexed by Young tableaux and connect algebra and combinatorics through a rich network of ideas. Web basis vectors are indexed by noncrossing matchings and developed from topological considerations. We show that the change-of-basis matrix between these two matrices is upper-triangular with ones along the diagonal. Time permitting, we will also describe other results and conjectures. (Received August 30, 2016)

1123-05-401 **Boris Brimkov**, **Jennifer Edmond**, **Robert Lazar**, **Bernard Lidický**, **Kacy Messerschmidt*** (kacymess@iastate.edu), **Abhishek Methuku** and **Shanise Walker**. *Injective choosability of subcubic planar graphs with girth 6.*

An injective coloring of a graph G is an assignment of colors to the vertices of G so that any two vertices with a common neighbor have distinct colors. A graph G is injectively k-choosable if it has an injective coloring where the color of each vertex v of G can be chosen from any list $L(v)$ of size k. Injective colorings have applications in the theory of error-correcting codes and are closely related to other notions of colorability. In our paper, we were able to show that a subcubic graph with girth at least 6 is injectively 5-choosable. This result improves several known bounds on the injective chromatic number of planar graphs. (Received August 30, 2016)

1123-05-404 **David S. Gunderson*** (david.gunderson@umanitoba.ca), Department of Mathematics, 521 Machray Hall, 186 Dysart Road, Winnipeg, Manitoba R3T 2N2, Canada. *Extremal graphs forbidding an odd cycle.*

For a positive integer n and a simple graph F, the extremal number $\mathrm{ex}(n; F)$ is the maximum number of edges in any n-vertex F-free graph. An extremal graph for F is an F-free graph on n vertices with $\mathrm{ex}(n; F)$ edges.

Mantel's theorem for forbidding triangles says that $\mathrm{ex}(n; C_3) = \lfloor n^2/4 \rfloor$, and the complete bipartite $K_{\lfloor n/2 \rfloor, \lceil n/2 \rceil}$ is the unique extremal graph. One might guess that since $K_{\lfloor n/2 \rfloor, \lceil n/2 \rceil}$ is a maximal graph with no odd cycles, it is also the unique extremal graph for any other odd cycle as well. In 1968, Simonovits showed that indeed this is true, but only for sufficiently large n. In the 1970s, Bondy and Woodall showed that for $n \geq 4k - 1$, $\mathrm{ex}(n; C_{2k+1}) = \lfloor n^2/4 \rfloor$, but without finding the extremal graphs.

In recent work with Furedi, for each $k \geq 2$ and for all n, we find the extremal number $\mathrm{ex}(n; C_{2k+1})$ together with all extremal graphs. For some values of k and n, there are three extremal graphs. (Received August 30, 2016)

1123-05-411 **Isaiah Harney*** (isaiah.harney@uky.edu), 184 Simpson Ave. Apt. 211, Lexington, KY 40504. *Robust Colorings of the Hamming-Distance Graph.*

The Hamming-Distance Graph, $H_q(n, d)$, is defined as the graph with vertex set $\mathbb{Z}_q^n$ where two vertices are adjacent if their Hamming distance is at least d. Cliques of $H_q(n, d)$ correspond to q-ary block codes of length n and Hamming distance at least d. In a paper by Rouayheb et al., the authors use graph theoretical techniques applied to $H_q(n, d)$ to produce new proofs for many classical bounds on error-correcting codes. Moreover, they determine the chromatic number of this graph for many parameters.

A result by Greenwell/Lovász exists which states that $\chi(H_q(n,n)) = q$ for all n and that all minimal colorings of $H_q(n,n)$ are coordinate colorings, meaning the color of every vertex is assigned as its value in a fixed coordinate. For $d < n$, we can color $H_q(n,d)$ in a similar way using $n-d+1$ coordinates. Moreover, the results from Rouayeb et al. show that these coordinate colorings are minimal colorings for all parameters for which the authors were able to determine the chromatic number of the graph. However, it is easily demonstrated that these coordinate colorings are not the only minimal colorings when $d < n$.

In this talk, we will present an analog of the result of Greenwell/Lovász which holds for the case $q = 2$ and $d = n - 1$. (Received August 30, 2016)

1123-05-412 **Jesus A De Loera**, **Sonja Petrovic** and **Despina Stasi***, Applied Mathematics Department, Illinois Institute of Technology, 10 West 32nd Street, Chicago, IL 60616. *Random sampling in computational algebra: Helly numbers and violator spaces.*

We transfer a randomized algorithm, originally used in geometric optimization, to computational problems in commutative algebra. We show that Clarkson's sampling algorithm can be applied to two problems in computational algebra. The cornerstone of our work is showing that the theory of violator spaces of Gärtner et al applies to polynomial ideal problems. (Received August 30, 2016)

06 ► Order, lattices, ordered algebraic structures

1123-06-186 **Harry J Altman*** (haltman@umich.edu). *The Surreal Exponential and Order-Reversing Maps between Well-Ordered Sets: Preliminary Report.* Preliminary report.

In this talk we will discuss, for given well ordinals α and β, how one may compute the maximum extending ordinal of the poset of all order-reversing functions from α to β – a feat that has not actually been performed for that many other well partial orders. We focus on the case where we restrict to functions which are eventually zero, and observe that by choosing α to be ω, one may provide an order-theoretic interpretation for the surreal exponential as applied to limit ordinals. (Received August 25, 2016)

1123-06-403 **Marcelo Aguiar*** (maguiar@math.cornell.edu) and **Swapneel Mahajan**. *Möbius functions for noncommutative lattices.*

We initiate a theory of noncommutative Möbius functions. The departing point is a classical result of Solomon which states that the algebra of a lattice is split-semisimple and provides an expression for the primitive idempotents of the algebra in terms of the Möbius function of the lattice. We consider left regular bands, a certain class of idempotent semigroups which arise in connection to real hyperplane arrangements. Such semigroups may be regarded as "noncommutative lattices". Geometry motivates the introduction of objects such as faces, flats, and lunes. Flats and lunes constitute the objects and morphisms of a category. Its incidence algebra contains two distinguished affine subspaces of equal dimension, one of *noncommutative zeta functions* and the other of *noncommutative Möbius functions*. The two are in bijection under inversion. The primitive idempotents of the semigroup algebra admit an explicit expression in terms of these noncommutative Möbius functions. Solomon's result, and classical facts about Möbius functions, are recovered when the semigroup is commutative (and hence a lattice). (Received August 30, 2016)

11 ► Number theory

1123-11-9 **Chen Wan*** (wanxx123@umn.edu), 107 Vincent Hall, 206 Church St SE, Minneapolis, MN 55455. *Multiplicity one theorem for the Ginzburg-Rallis model.*

Following the method developed by Waldspurger and Beuzart-Plessis in their proof of the local Gan-Gross-Prasad conjecture, we were able to prove the multiplicity one theorem on Vogan L-packet for the Ginzburg-Rallis model. In some cases, we can also relate the multiplicity to the central value of epsilon factor. (Received June 03, 2016)

1123-11-14 **Liang Xiao*** (liang.xiao@uconn.edu), Storrs, CT 06269, **Rufei Ren**, Irvine, CA 92697, **Daqing Wan**, Irvine, CA 92697, and **Ruochuan Liu**, Beijing, 100088, Peoples Rep of China. *Eigencurves for Artin-Schreier-Witt tower and Igusa tower.*

The goal of this talk is to survey some recent development on the study of slopes of eigencurves, in the setup of both Artin-Schreier-Witt tower (or exponential sums) and Igusa tower (or modular forms). I will focus on explaining the strong analogy between the two cases, what we can prove in each case, and what the future

challenges are. This includes the joint works of Ruochuan Liu, Rufei Ren, Daqing Wan, and Liang Xiao. (Received July 18, 2016)

1123-11-15 **John Bergdall*** (bergdall@math.bu.edu), Department of Mathematics and Statistics, 111 Cummington Street, Boston, MA 02215, and **Robert Pollack**. *Some questions about slopes of modular forms.*

In this talk we will discuss the U_p-slopes of p-adic modular forms. Our main goal will be to describe a recent conjecture giving a precise description of such slopes in many cases. We will also discuss several consequences of our conjecture which may be answered separately. This is based on joint work with Robert Pollack. (Received July 18, 2016)

1123-11-17 **Rufei Ren*** (rufeir@uci.edu), 69306 Verano Pl, Irvine, CA 92617, and **Daqing Wan**, **Liang Xiao** and **Myungjun Yu**. *Slopes for higher rank Artin–Schreier–Witt Towers.*

We fix a monic polynomial $\bar{f}(x) \in \mathbb{F}_q[x]$ over a finite field of characteristic p, and consider the $\mathbb{Z}_{p^\ell}$-Artin–Schreier–Witt tower defined by $\bar{f}(x)$; this is a tower of curves $\cdots \to C_m \to C_{m-1} \to \cdots \to C_0 = \mathbb{A}^1$, whose Galois group is canonically isomorphic to $\mathbb{Z}_{p^\ell}$, the degree ℓ unramified extension of $\mathbb{Z}_p$, which is abstractly isomorphic to $(\mathbb{Z}_p)^\ell$ as a topological group. We study the Newton slopes of zeta functions of this tower of curves. This reduces to the study of the Newton slopes of L-functions associated to characters of the Galois group of this tower. We prove that, when the conductor of the character is large enough, the Newton slopes of the L-function asymptotically form a finite union of arithmetic progressions. As a corollary, we prove the spectral halo property of the spectral variety associated to the $\mathbb{Z}_{p^\ell}$-Artin–Schreier–Witt tower. This extends the main result in [**?**] from rank one case $\ell = 1$ to the higher rank case $\ell \geq 1$. (Received July 19, 2016)

1123-11-29 **Ian Whitehead*** (iwhitehe@umn.edu). *Whittaker functions for affine Kac-Moody groups.*

I will discuss recent progress on constructing local Whittaker functions for affine and metaplectic affine Kac-Moody groups. These constructions generalize the Casselman-Shalika formula and Weyl group multiple Dirichlet series for finite-dimensional groups. The new ingredient is a factor which takes the form of an infinite product over imaginary roots in the affine root system. My talk will attempt to explain this factor and its relation to the Macdonald constant term conjecture and related formulae. (Received August 03, 2016)

1123-11-71 **Manish M Patnaik** and **Anna Puskas*** (puskas@ualberta.ca). *Metaplectic Iwahori-Whittaker functions and Demazure-Lusztig operators.*

This talk will present joint work with Manish Patnaik on the construction of p-adic Iwahori-Whittaker functions in the metaplectic setting. The constructions are in terms of Demazure-Lusztig operators for covers of both finite dimensional and affine Kac-Moody groups. This work provides a metapletic analogue of earlier work by Brubaker-Bump-Licata and Patnaik. The metaplectic Demazure-Lusztig operators utilize the Chinta-Gunnells action, a metaplectic action of the Weyl group on the coweight lattice. The formulae in the affine case are related to Macdonald's constant term conjecture through combinatorics of Weyl group symmetrizers. (Received August 15, 2016)

1123-11-92 **Kimball Martin*** (kmartin@math.ou.edu), Norman, OK 73019, and **Nahid Walji**, Zurich, Switzerland. *On refined refinements of strong multiplicity one.*

Strong multiplicity one, say for general linear groups, essentially says that two cuspidal automorphic L-functions are equal if and only if almost all local factors are equal. The refined strong multiplicity one conjecture of Ramakrishnan (a theorem for degree 1 and 2) predicts how many (in the sense of density) local factors one should need to check. The bound in Ramakrishnan's conjecture should be sharp for certain imprimitive L-functions. We discuss some preliminary work on studying this problem for primitive L-functions. (Received August 19, 2016)

1123-11-100 **Aaron Pollack*** (aaronjp@stanford.edu). *Easy theorems on orthogonal groups.*

Recall the group GSpin(V), which is a central GL(1) extension of SO(V). I will explain how certain old calculations related to the standard L-functions of automorphic representations of SO(V) can be done easily by lifting to GSpin(V). The reason that GSpin(V) is easier to work with in this context has to do with Godement-Jacquet theory, in the sense of Braverman-Kazhdan and Bouthier-Ngo-Sakellaridis. More precisely, we explain how GSpin(V) has a nice "approximate" Godement-Jacquet theory, different from the "exact" formulation of Braverman-Kazhdan yet similar to the classical theory on GL(n). (Received August 19, 2016)

1123-11-113 **Hui June Zhu*** (hjzhu@math.buffalo.edu), Department of Mathematics, SUNY at Buffalo, BUFFALO, NY 14260. *Newton Slopes for Artin-Schreier-Witt Tower in two variables.*

We compute the generic p-adic Newton slopes of L-functions associate to characters χ of Galois group of Artin-Schreier-Witt tower of a family of polynomials f in two variables of degree d_1 in x_1 and d_2 in x_2. For a generic such f for p large enough we prove that $L^*(\chi, s)$ of f mod p with respect to χ is independent of the character χ or f. (Received August 21, 2016)

1123-11-139 **Heekyoung Hahn*** (hahn@math.duke.edu), Department of Mathematics, 120 Science Dr., Durham, NC 27708. *Langlands' beyond endoscopy proposal and the Littlewood-Richardson semigroup.*

Langlands' beyond endoscopy proposal for establishing functoriality motivates the study of irreducible subgroups of $\mathrm{GL}(n)$ that stabilize a line in a given representation of $\mathrm{GL}(n)$. Such subgroups are said to be detected by the representation. In this talk we study the important special case where the representation of $\mathrm{GL}(n)$ is the triple tensor product representation. We prove a family of results describing when subgroups isomorphic to classical groups of type A_n, B_n, C_n, D_{2n} are detected. (Received August 23, 2016)

1123-11-147 **Baiying Liu*** (liu2053@purdue.edu), Department of Mathematics, Purdue University, 150 N. University St, West Lafayette, IN 47907, and **Herve Jacquet** (hj@math.columbia.edu), Department of Mathematics, Columbia University, Room 509, MC 4406 2990 Broadway, New York, NY 10027. *On the Local Converse Theorem for p-adic GLn.*

In this talk, I will introduce a complete proof of a standard conjecture on the local converse theorem for generic representations of GLn(F), where F is a non-archimedean local field. This is a joint work with Prof. Herve Jacquet. (http://arxiv.org/abs/1601.03656) (Received August 23, 2016)

1123-11-194 **Vlad Matei*** (matei@wisc.edu). *A geometric perspective on Landau's problem over function fields.*

We improve on results presented in Lior Bary-Soroker, Yotam Smilansky, Adva Wolf, *On the Function Field Analogue of Landau's Theorem on Sums of Squares* which deals with a function field version of Landau's theorem on the asymptotic number of positive integers $\leq X$ which can be written as a sum of two squares. The above paper presents the results in the large degree limit and q limit. We obtain an expansion of $B_q(n)$ which counts the number of degree n monic polynomials that can be written as $f = |A^2 - TB^2|$ for $A, B \in \mathbb{F}_q[T]$ that works in the $q^n \to \infty$ regime. Our approach is by using a twisted Grothendieck Lefschetz trace formula analogous to the one in Thomas Church, Jordan S. Ellenberg, Benson Farb, *Representation stability in cohomology and asymptotics for families of varieties over finite fields*, Contemporary Mathematics 620 (2014), 1-54. (Received August 26, 2016)

1123-11-196 **C. Douglas Haessig*** (chaessig@math.rochester.edu), Department of Mathematics, 915 Hylan Hall, Box 270138, Rochester, NY 14627. *L-functions of symmetric powers of Kloosterman sums.*

The L-function of symmetric powers of classical Kloosterman sums is a polynomial whose degree is now known, as well as the complex absolute values of the roots. In this talk, we will present estimates for the p-adic absolute values of these roots. Our method is indirect. We first develop a Dwork-type p-adic cohomology theory for the two-variable infinite symmetric power L-function associated to the Kloosterman family, and then study p-adic estimates of the eigenvalues of Frobenius. A continuity argument then provides the desired p-adic estimates. (Received August 26, 2016)

1123-11-199 **Tianyi Mao*** (maotianyi1@gmail.com), 365 5th Ave, Department of Mathematics, New York, NY 10035. *The Distribution of Integers in a Totally Real Cubic Field.*

Hecke studies the distribution of fractional parts of quadratic irrationals with Fourier expansion of Dirichlet series. This method is generalized by Behnke and Ash-Friedberg, to study the distribution of the number of totally positive integers of given trace in a general totally real number field of any degree. When the field is cubic, we show that the asymptotic behavior of a weighted Diophantine sum is related to the structure of the unit group. The main term can be expressed in terms of Grössencharacter L-functions. (Received August 26, 2016)

1123-11-207 **James W Cogdell*** (cogdell@math.ohio-state.edu), Department of Mathematics, Ohio State University, 231 W. 18th Ave., Columbus, OH 43210. *On stability of γ.*

The local γ factor $\gamma(s, \pi, R, \psi)$ occurs as the factor of proportionality in local functional equations. This is true both for integral representations and the Langlands-Shahidi method of analyzing L-functions. The stability of γ is the statement that $\gamma(s, \pi \otimes \chi, R, \psi)$ becomes "essentially" independent of π for sufficiently highly ramified characters χ. This stability has important applications. It plays a role in the proof of Langlands functoriality via the L-function method and in the preservation of the exterior square and symmetric square ε-factor for GL_n under the local Langlands correspondence. In this talk I hope to discuss what we know about the stability of γ, how it plays a role in the above applications, and how one proves such results. (Received August 26, 2016)

1123-11-220 **Michiel Filip Kosters*** (kosters@gmail.com). *Wild symbols in local class field theory.*

Let $K = k((T))$ be a Laurent series ring where k is a finite field of characteristic p. One can construct a symbol, using class field theory and Artin-Schreier-Witt theory, which helps us to understand the cyclic extensions of K of degree p^m for any m. In this talk, we will discuss an easy formula for computing this symbol.

This research is joint work with Daqing Wan. (Received August 26, 2016)

1123-11-243 **Qinghua Pi*** (qhpi@sdu.edu.cn). *On some results proved by analytic properties of automorphic L-functions.*

It is well known that automorphic forms have deep relation with the associated automorphic L-functions. By the analytic properties of L-functions, we can prove some results on relevant automorphic forms. In this talk, we will review some results such as effective multiplicity one theorem, determination of automorphic forms by L-values, and then report some relevant problem we are working on. (Received August 28, 2016)

1123-11-247 **Yuanqing Cai*** (yuanqing.cai@bc.edu), 140 Commonwealth Ave, Maloney 524, Chestnut Hill, MA 02467. *Theta representations on metaplectic groups.*

We study Fourier coefficients for residues of Eisenstein series on metaplectic groups and discuss several new phenomena in the metaplectic setting. In certain cases we show that such representations support unique models. Time permitting, we will also discuss applications in Rankin-Selberg constructions. (Received August 30, 2016)

1123-11-262 **Rodney L Keaton***, keatonr@etsu.edu. *An application of the Waldspurger model to a conjecture of Tonghai Yang.* Preliminary report.

In a 2005 paper, Yang constructed families of Hilbert Eisenstein series, which when restricted to the diagonal are conjectured to span the underlying space of elliptic modular forms. One approach to these conjectures is to show the non-vanishing of an inner product of elliptic eigenforms with the restrictions of Eisenstein series. In this talk, I will present a new technique for computing such inner products. (Received August 28, 2016)

1123-11-272 **Jeremiah Bartz*** (jeremiah.bartz@und.edu). *Patterns in base b digital roots series.* Preliminary report.

Let $b, n \in \mathbb{Z}_{>0}$ with $b \geq 2$. The *base b digital root* of n, denoted $\rho_b(n)$ is defined as the single digit obtained by the addition of the corresponding digits of n expressed in base b (and process repeated if needed). The *base b digital root series* $\{n_i\}$ beginning at $n_1 \in \mathbb{Z}_{>0}$ is defined recursively for $i \geq 2$ by $n_i = n_{i-1} + \rho_b(n_{i-1})$. In this talk, we discuss several patterns observed by V.S. Kumar for $b = 10$ and their extensions to certain other values of b. (Received August 29, 2016)

1123-11-282 **Ruochuan Liu*** (liuruochuan@math.pku.edu.cn), Peking University, 78 Jing Chun Yuan, Beijing, 100871, Peoples Rep of China, and **Daqing Wan** (dwan@math.uci.edu), Rowland Hall 410C, Irvine, CA 92697-3875. *Artin Conjecture for p-adic Galois Representations of Function Fields.*

For a global function field K of positive characteristic p, we show that Artin conjecture for L-functions of geometric p-adic Galois representations of K is true in a non-trivial p-adic disk but is false in the full p-adic plane. In particular, we prove the non-rationality of the geometric unit root L-functions. (Received August 29, 2016)

1123-11-307 **Martin Luu*** (mluu@math.ucdavis.edu). *Local Fourier transforms and Langlands dualities.*

Laumon's l-adic local Fourier transform has been instrumental in understanding the structure of local Langlands parameters. An example is Henniart's proof of the numerical local Langlands correspondence. Bloch and Esnault have introduced a geometric version of Laumon's transform and I will explain how this allows to understand some

aspects of local geometric Langlands parameters and related questions concerning integrable systems. (Received August 29, 2016)

1123-11-309 **Philip Matchett Wood*** (pmwood@math.wisc.edu), Van Vleck Hall, 480 Lincoln Drive, Madison, WI 53706, and **Sean O'Rourke**. *Low-degree factors of random polynomials.*

We study the probability that a monic polynomial with integer coefficients has a low-degree factor over the integers. It is known that certain models are very likely to produce random polynomials that are irreducible, and our project can be viewed as part of a general program of testing whether this is a universal behavior exhibited by many random polynomial models. Interestingly, though the question comes from algebra and number theory, we primarily use tools from combinatorics, including additive combinatorics, and probability theory. We prove for a variety of models that it is very unlikely for a random polynomial with integer coefficients to have a low-degree factor—suggesting that this is, in fact, a universal behavior. For example, we show that the characteristic polynomial of random matrix with independent $+1$ or -1 entries is very likely to be irreducible. Joint work with Sean O'Rourke. (Received August 29, 2016)

1123-11-316 **Amy T. DeCelles*** (adecelles@stthomas.edu). *Applications of Modern Analysis to Automorphic Forms and Analytic Number Theory.*

We discuss some recent applications of the spectral theory of automorphic forms, in particular, the use of modern analysis to obtain spectral identities systematically, with corollaries in analytic number theory, namely subconvexity of L-functions (Diaconu, Garrett, Letang), lattice point counting in symmetric spaces (D.), and vanishing of zeta and L-functions on the critical line (Bombieri, Garrett). The first two of these applications rely on "pre-trace" formulas obtained via automorphic differential equations. This approach necessitates a more careful treatment of analytic issues than one would usually need when using trace formula methods. Global automorphic and global zonal spherical Sobolev spaces provide a robust framework for decisively treating many of these analytic issues. The viewpoint of global automorphic Sobolev theory is also what has enabled Bombieri and Garrett to clarify the circumstances under which the existence of eigenvalues of pseudo-Laplacians give information about the vanishing of zeta functions. (Received August 29, 2016)

1123-11-322 **Clifton Cunningham**, **Andrew Fiori**, **James Mracek**, **Ahmed Moussaoui** and **Bin Xu*** (bin.xu2@ucalgary.ca), Department of Mathematics and Statistics, University of Calgary, 2500 University Drive, Calgary, Alberta T2N4C5, Canada. *Arthur packets are microlocal packets?* Preliminary report.

The irreducible smooth representations of Arthur class are the local components of automorphic representations. They are conjectured to be parametrized by the Arthur parameters, which can be included as a subset of the usual Langlands parameters. The set of irreducible representations associated with a single Arthur parameter is called an Arthur packet. On the other hand, Adam-Barbasch-Vogan (1992) (in real case) and Vogan (1993) (in the p-adic case) defined a set of irreducible smooth representations for each Langlands parameter through the microlocal geometry on certain parametrizing space of Langlands parameters, which can be called microlocal packet. Moreover, they suggested for an Arthur parameter, the microlocal packet is the Arthur packet. In this talk, I would like to compare these two different point of views by examining an example of SO(7) over the p-adic field. In particular, this example confirms Vogan's speculation in the p-adic case. This is joint work with Clifton Cunningham, Andrew Fiori, James Mracek and Ahmed Moussaoui. (Received August 29, 2016)

1123-11-337 **Fan Gao*** (fan166@purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907. *On the Whittaker models for genuine representations of covering groups.*

For a linear algebraic group over local field, the uniqueness of Whittaker models for irreducible representations plays a pivotal role for the representation theory of the group. For instance, the Langlands-Shahidi method of studying L-functions relies crucially on such uniqueness property. However, on the other hand, uniqueness of Whittaker models (for genuine representations) rarely holds for covering groups. In the talk, we will investigate some of the problems related to this, and provide partial answers to several more accessible questions. (Received August 29, 2016)

1123-11-341 **Marco Aldi*** (maldi2@vcu.edu) and **Andrija Perunicic**. *Invertible Hypersurfaces over a Finite Field and Mirror Symmetry.*

Berglund-Huebsch duality is an explicit construction of mirror pairs of Calabi-Yau manifolds. In this talk we present some applications of Berglund-Huebsch duality to the study of the Frobenius operator acting on the Monsky-Washnitzer cohomology of invertible hypersurfaces. (Received August 29, 2016)

1123-11-348 **Sandi Xhumari*** (sandi_xhumari@yahoo.co.uk). *Generalized Stickelberger's congruence for generalized Gauss sums.*

I start by recalling classical Gauss sums over finite fields and their corresponding Stickelberger's congruence in the p-adic setting. Next, I introduce an infinite family of uniformizers that can be used in place of the standard uniformizer in the classical Stickelberger's congruence. These uniformizers lead to a better congruence. I will then define some generalized Gauss sums and state their corresponding generalized Stickelberger's congruence. Lastly, I outline a proof of this generalized Stickelberger's congruence through the Artin-Hasse exponential series. (Received August 29, 2016)

1123-11-353 **Shaofang Hong*** (sfhong@scu.edu.cn), Prof. Shaofang Hong, Mathematical College, Sichuan University, Chengdu, Sichuan 610064, Peoples Rep of China, and **Chunlin Wang** (wdychl@126.com), Dr. Chunlin Wang, Center for Combinatorics, Nankai University, Tianjin, Tianjin 300071, Peoples Rep of China. *On the integrality of hypergeometric series with parameters from quadratic fields.*

For the hypergeometric series with parameters from the rational fields, there is an effective criterion due to Christol to decide whether the hypergeometric series is N-integral or not. In this paper, we develop a systematic theory on the N-integrality of the hypergeometric series with parameters from quadratic fields. We first present a detailed p-adic analysis to set up a criterion of the p-adic integrality of the hypergeometric series with parameters from rational fields. Then we present two equivalent statements for the hypergeometric series with parameters from algebraic number fields to be N-integral. Finally, by using these results, introducing a new function that extends the Christol's function and developing a further p-adic analysis, we establish a criterion of the N-integrality of the hypergeometric series with parameters from the quadratic fields. In the process, there are two important ingredients. One is the uniform distribution result of roots of a quadratic congruence which is due to Duke, Friedlander and Iwaniec together with Toth. Another one is an upper bound on the number of solutions of polynomial congruences obtained by Stewart in 1991. (Received August 30, 2016)

1123-11-368 **Daniel Johnstone*** (dljohnst@math.uchicago.edu), 5734 S. University Avenue, Chicago, IL 60637. *A Gelfand-Graev Formula and Stable Transfer Factors for SL_n.*

A result of Gelfand and Graev shows that the supercuspidal representations of SL_2 are neatly parameterized by characters of elliptic tori, and that the stable character data for all such representations may be collected into a single function by means of a Fourier Transform. Using recent advances in the computation of characters of supercuspidal representations, we prove analogous results for the group SL_n. (Received August 30, 2016)

1123-11-397 **Alan C Adolphson***, adolphs@math.okstate.edu, and **Steven Sperber**. *Integrality properties of A-hypergeometric series.* Preliminary report.

We describe some sufficient conditions for the coefficients of a series solution of an A-hypergeometric system to have integral coefficients. (Received August 30, 2016)

1123-11-416 **Daniel R Moore*** (moore@math.osu.edu). *Revisiting the Tensor Product Theorem for Smooth Automorphic Representations.*

Let $G = \mathbb{G}(\mathbb{A}_k)$ for k a global field, $\mathbb{G}$ a reductive algebraic group defined over k, and $\mathbb{A}_k$ the adele ring of k. We will define the notion of smooth automorphic forms and automorphic representations on the former. In analogy with the lifting of $(\mathfrak{g}, K)$-modules to their Casselman-Wallach globalizations in the theory of real reductive groups, we introduce a certain convolution algebra $\mathcal{S}(G)$ of "Schwartz functions" on G and describe an equivalence of categories between smooth automorphic representations of G and "admissible" $\mathcal{S}(G)$-modules. The algebra $\mathcal{S}(G)$ decomposes into a tensor product of analogous algebras $\mathcal{S}(G_v)$ over the places v of k, and this permits us to discuss a tensor product theorem for admissible $\mathcal{S}(G)$-modules and, hence, for smooth automorphic representations, showing that every such representation π factors into a tensor product $\otimes_v \pi_v$ of representations of the groups $\mathbb{G}(k_v)$. Our talk will be introductory in nature with a goal of introducing smooth automorphic representations to the audience for the first time. (Received August 30, 2016)

13 ► Commutative rings and algebras

1123-13-169 **Michael Gekhtman*** (mgekhtma@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46530. *Generalized cluster structures in Poisson-Lie groups.* Preliminary report.

We will explain how generalized cluster structures naturally appear in the context of Poisson-Lie groups associated with the Belavin-Drinfeld classification. This is a joint project with M. Shapiro and A. Vainshtein. (Received August 25, 2016)

14 ► Algebraic geometry

1123-14-79 **Thomas Nevins*** (nevins@illinois.edu). *Algebraic Symplectic Varieties, Classical and Quantum.*

A symplectic variety is an algebraic variety with a closed, nondegenerate algebraic 2-form. Symplectic varieties appear naturally in many places in algebraic geometry and beyond: for example, in classical mechanics, representation theory, gauge theory, and quantum field theory. I will give a low-tech introduction, with examples, to symplectic algebraic varieties and survey how they arise in a wide variety of mathematical and physical contexts. I will then explain how quantizations of symplectic varieties have taken on a starring role in many recent developments in representation theory. Finally I will discuss how the powerful principles of Morse theory apply in (both ordinary, or "classical," and quantum) symplectic algebraic geometry and yield rich structural consequences. (Received August 17, 2016)

1123-14-131 **Steven Sperber***, sperber@math.umn.edu, and **Alan Adolphson**, alan.adolphson@okstate.edu. *Distinguished Root Formulas for Generalized Calabi-Yau Projective Hypersurfaces.* Preliminary report.

Let X be a non-singular projective hypersurface of degree d and dimension n. When n+2 is a multiple of d, say $n+2=(r+1)d$, the first non-vanishing hodge number in dimension n is $h^{r,n-r}=1$. If we work over the finite field of q elements, and write $Z(X,T)$ for the zeta function of X, it is known that $(Z(X,T)\prod_{i=0}^{n}(1-q^iT))^{(-1)^{n+1}}$ is a polynomial for general X with a (distinguished) unique reciprocal root u_X satisfying $\mathrm{ord}_q(u_X)=r$. In this work, we describe a formula for this unique reciprocal zero in terms of a distinguished p-adic solution to a particular A-hypergeometric system. (Received August 22, 2016)

1123-14-154 **Eric Katz*** (katz.60@gmail.com), 231 West 18th Avenue, Columbus, OH, 43210. *Okounkov bodies and linear systems on graphs.*

Tropical geometry and Okounkov bodies are generalizations of the theory of Newton polytopes in different directs: tropical geometry for higher codimensions; Okounkov bodies for non-toric ambient spaces. In this talk, we will discuss joint work with Stefano Urbinati which finds these two theories converging again. We will discuss the analogue of Okounkov bodies over discrete valuation rings. In the special case of semistable families of curves, the theory of linear systems on graphs makes an appearance. This gives some pointers to a higher dimensional theory of combinatorial linear systems. (Received August 24, 2016)

1123-14-187 **Jonathan Block**, **Julian Holstein** and **Zhaoting Wei*** (zwei3@kent.edu). *Twisted complexes and homotopy limits of dg categories.*

Descent data, in general, should be expressed in terms of a homotopy limit. In this talk we study the homotopy limits of some cosimplicial diagrams of dg-categories which arise in algebra and geometry: the homotopy limits are explicitly given by twisted complexes. I will give an informal introduction to twisted complexes and its applications in algebraic geometry. In particular the result can be applied in the study of equivariant dg-categories. This is a joint work with Jonathan Block and Julian Holstein. (Received August 25, 2016)

1123-14-290 **Mathew Bullimore**, **Tudor Dimofte**, **Davide Gaiotto**, **Justin Hilburn*** (jhilburn@math.upenn.edu) and **Hee-Cheol Kim**. *Monopoles, Vortices, and Vermas.*

Symplectic duality, as described by Braden-Proudfoot-Licata-Webster, is an equivalence of certain categories associated to a pair of conical symplectic singularities. Each such category is a subcategory of modules over a deformation quantization of functions on the corresponding singularity. The prototypical example is when the singularity is the nilpotent cone of a semi-simple Lie algebra $\mathfrak{g}$ in which case the corresponding category is the Bernstein-Gelfand-Gelfand Category $\mathcal{O}$ associated to $\mathfrak{g}$.

It is expected that all such dual pairs arise as Higgs and Coulomb branches of 3d $\mathcal{N}=4$ SUSY field theories. By examining a certain twist of this theory one can realize the action of a deformation quantization of the

Coulomb branch on a Verma module in terms of the action of monopole operators on the vortex moduli space. One can then use this to write the partition functions for 2d $\mathcal{N} = (2, 2)$ theories in terms of Whittaker vectors. This gives a physical formulation and generalization of the finite AGT conjecture which has been studied by Braverman, Finkelberg, Feigin, Frenkel, Kuznetsov, Nakajima, and Rybnikov in the case of a nilpotent orbit closure. (Received August 29, 2016)

1123-14-330 **Gretchen L. Matthews*** (gmatthe@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634-0975. *Codes with locality from quotients of Hermitian curves.*

In some applications, it is necessary to recover a single message or codeword symbol using only local information, meaning information from only a few other coordinates rather than the entire received word. More specifically, a code C with locality r has the property that given a received word w, component w_i can be recovered by accessing $w_{i_1}, \ldots, w_{i_r}$. As demonstrated by Barg et. al., a modification of an algebraic geometric construction allows for this. In this talk, we consider codes with locality constructed from quotients of Hermitian curves. (Received August 29, 2016)

15 ► Linear and multilinear algebra; matrix theory

1123-15-16 **Richard A Brualdi*** (brualdi@math.wisc.edu) and **Shi-Mei Ma**. *Centrosymmetric, and Symmetric and Hankel-symmetric Matrices.*

We formulate and solve existence questions concerning centrosymmetric matrices and symmetric, Hankel-symmetric matrices which are nonnegative, nonnegative and integral, and $(0, 1)$-matrices. (Received July 19, 2016)

1123-15-47 **Minerva Catral*** (catralm@xavier.edu), Department of Mathematics, Xavier University, 3800 Victory Parkway, Cincinnati, OH 45207, and **Minghua Lin**, **Dale Olesky** and **Pauline van den Driessche**. *Inverses and eigenvalues of diamond alternating sign matrices.*

An $n \times n$ diamond alternating sign matrix (ASM) is a $(0, +1, -1)$-matrix with ± 1 entries alternating and arranged in a diamond-shaped pattern. The explicit inverse (for n even) or generalized inverse (for n odd) of a diamond ASM is derived. The eigenvalues of diamond ASMs are considered and when n is even, the characteristic polynomial, which involves signed binomial coefficients, is determined. (Received August 10, 2016)

1123-15-60 **Jephian C.-H. Lin*** (chlin@iastate.edu). *Distance spectra of graphs.*

For a given graph G, the distance matrix of G is a symmetric matrix whose rows and columns are indexed by $V(G)$ and the i, j-entry is the distance between i and j in the graph G. Graham and Pollak use the distance matrix as a tool to design the "loop switching" scheme in a communication system. In this talk, we will discuss the spectral properties of distance matrices, and introduce open questions.

This is a joint work supported by Rocky Mountain-Great Plains Graduate Research Workshop in Combinatorics (GRWC) 2015. (Received August 12, 2016)

1123-15-63 **Kevin N. Vander Meulen***, Department of Mathematics, Redeemer University College, 777 Garner Road, Ancaster, Ontario L9K 1J4, Canada, and **Jonathan Earl** and **Adam Van Tuyl**. *Refined Inertially Arbitrary Patterns.*

This talk explores how the combinatorial arrangement of the entries of a matrix can affect the eigenvalues of a matrix. The particular focus will be the refined inertia of a matrix A, an ordered 4-tuple (a, b, c, d) with a (resp. b) the number of eigenvalues of A with positive (resp. negative) real part, c the number of zero eigenvalues, and d the number of purely imaginary eigenvalues. A combinatorial pattern is refined inertially arbitrary if the pattern does not restrict the possible refined inertias of a matrix with that pattern. Previous work by Deaett, Olesky and van den Driessche explored nonzero patterns, patterns which specify each matrix entry as either zero or nonzero. In this talk we will focus on zero patterns, patterns which specify where entries are zero and where entries can be any real number. (Received August 13, 2016)

1123-15-77 **Pauline van den Driessche*** (pvdd@math.uvic.ca). *Refined inertias of strongly connected orientations of the Petersen graph.*

The 18 non-isomorphic strongly connected orientations of the Petersen graph give rise to matrix patterns in which nonzero entries can be taken to be strictly positive, of arbitrary sign, or of fixed sign. The allowed refined inertias, in which the number of zero eigenvalues are split from others on the imaginary axis, are considered for some of these matrix patterns to illustrate the following results. Each nonnegative pattern has unique refined

inertia determined by the number of required zero eigenvalues. For zero-nonzero patterns, the allowed refined inertias are determined for each orientation. One particular sign pattern allows only two distinct refined inertias out of a possible 161 for a sign pattern of order 10. [Joint work with G.J. Culos and D.D. Olesky] (Received August 16, 2016)

1123-15-95 **Travis Peters*** (tpeters319@gmail.com), **Michael Young** and **John Goldwasser**. *LIGHTS OUT! on Cartesian Products.* Preliminary report.

The game *LIGHTS OUT!* is played on a 5×5 square grid of buttons; each button may be on or off. Pressing a button changes the on/off state of the light of the button pressed and of all its vertical and horizontal neighbors. Given an initial configuration of buttons that are on, the object of the game is to turn all the lights out. The game can be generalized to arbitrary graphs. We investigate graphs of the form $G\Box H$, where G and H are arbitrary finite, undirected graphs. In particular, we provide conditions for which $G\Box H$ is universally solvable (every initial configuration of lights can be turned out by a finite sequence of button presses) using both closed neighborhood switching and open neighborhood switching. (Received August 19, 2016)

1123-15-143 **Steve Kirkland*** (stephen.kirkland@umanitoba.ca). *On Random Walk Centrality.*

We consider a notion of random walk centrality for undirected graphs that has been proposed in the literature on complex networks. This notion is shown to be naturally related to an accessibility index for the states of a discrete-time, ergodic, homogenous Markov chain on a finite state space. We provide several characterisations of this accessibility index, investigate the behaviour of the accessibility index under perturbation of the transition matrix, and describe some examples that exhibit counter-intuitive behaviour. (Received August 23, 2016)

1123-15-231 **J Ding***, Department of Mathematics, Hattiesburg, MS 39406, and **Q Dong**. *Complete Commuting Solutions of a Class of Quadratic Matrix Equations.*

Given a nilpotent matrix A, we solve the quadratic matrix equation $AXA = XAX$, sometimes called the Yang-Baxter-like matrix equation, to find all the commuting solutions. The strategy is to use the Jordan form J of A and then solve a simplified quadratic matrix equation $JYJ = YJY$. (Received August 27, 2016)

1123-15-233 **Wei Fang**, **Wei Gao**, **Fei Gong**, **Yubin Gao**, **Guangming Jing** and **Zhongshan Li***, zli@gsu.edu, and **Yanling Shao** and **Lihua Zhang**. *Convex polytopes and minimum ranks of nonnegative sign pattern matrices.*

A sign pattern (matrix) $\mathcal{A}$ is a matrix whose entries are from the set $\{+, -, 0\}$. A nonnegative sign pattern is a matrix whose entries are from the set $\{0, +\}$. The qualitative class of $\mathcal{A}$ is $Q(\mathcal{A}) = \{B \in M_n(\mathbb{R}) \mid \operatorname{sgn}(B) = \mathcal{A}\}$. The minimum rank (resp., rational minimum rank) of a sign pattern matrix $\mathcal{A}$ is the minimum of the ranks of the matrices (resp., rational matrices) whose entries have signs agreeing with the corresponding entries of $\mathcal{A}$. Using a correspondence between sign patterns with minimum rank r and point-hyperplane configurations in $\mathbb{R}^{r-1}$ and Steinitz's theorem on the rational realizability of 3-polytopes, we show that for every nonnegative sign pattern of minimum rank at most 4, the minimum rank and the rational minimum rank are equal. We show that every k-polytope corresponds to a nonnegative sign pattern with minimum rank $k + 1$ that has a $(k + 1) \times (k + 1)$ triangular submatrix with all diagonal entries positive. Some bounds on the entries of the integer matrices achieving the minimum ranks of nonnegative sign patterns with minimum rank 3 or 4 are established. (Received August 27, 2016)

1123-15-246 **Craig Erickson*** (cerickson@grandview.edu). *Upper triangular sign patterns that require eventual exponential nonnegativity.*

A real square matrix A is eventually exponentially nonnegative if there exists a positive real number t_0 such that for all $t \geq t_0$, e^{tA} is an entrywise nonnegative matrix, where $e^{tA} = \sum_{k=0}^{\infty} \frac{t^k A^k}{k!}$. A sign pattern $\mathcal{A}$ is a matrix having entries in $\{+, -, 0\}$ and its qualitative class is the set of all real matrices A for which $\operatorname{sgn}(A) = \mathcal{A}$. Sign pattern $\mathcal{A}$ requires eventual exponential nonnegativity if every matrix in the qualitative class of $\mathcal{A}$ is eventually exponentially nonnegative. In this talk, we discuss a characterization of upper triangular sign patterns that require eventual exponential nonnegativity. Our proof of the sufficiency of this result makes use of König digraphs to investigate the Hermite interpolating polynomial of e^{tA}. (Received August 28, 2016)

1123-15-308 **Xavier Martinez-Rivera*** (xaviermr@iastate.edu). *The epr-sequence over a field of characteristic 2.*

The enhanced principal rank characteristic sequence (epr-sequence) of an $n \times n$ symmetric matrix over a field $\mathbb{F}$ was recently defined as $\ell_1 \ell_2 \cdots \ell_n$, where ℓ_k is either `A`, `S`, or `N` based on whether all, some (but not all), or none of the order-k principal minors of the matrix are nonzero. There is no known characterization of the epr-sequences that are attainable by symmetric matrices over the real or any other field of characteristic *not* 2. However, for a

field of characteristic 2 such a characterization is now known, and it is presented in this talk. (Received August 29, 2016)

1123-15-317 **Louis Deaett*** (louis.deaett@quinnipiac.edu) and **Colin Garnett**. *Algebraic and combinatorial conditions on spectrally arbitrary patterns.* Preliminary report.

The *zero-nonzero pattern* of a matrix specifies precisely which of its entries are nonzero. Imagine we have fixed some $n \times n$ zero-nonzero pattern and some field k. We may ask if there exists a matrix with this pattern and entries in k realizing each possible characteristic polynomial with coefficients in k. If so, the pattern is said to be *spectrally arbitrary* over k. The so-called $2n$ Conjecture states that the number of nonzero entries in such a pattern must be at least $2n$. We discuss combinatorial and algebraic conditions which imply that a given zero-nonzero pattern cannot be spectrally arbitrary over any field k. Using such conditions, we verify that the $2n$ Conjecture in fact holds for $n \leq 6$, over every field. (Received August 29, 2016)

1123-15-327 **H. Tracy Hall*** (h.tracy@gmail.com) and **Simone Severini**. *Separation of potentially unitary patterns by (skew) field.*

A square pattern of zero and nonzero entries is called *potentially unitary* if there exists a unitary matrix conforming to the pattern. When this can be accomplished while restricting the entries to be real or rational, respectively, the pattern is called *potentially orthogonal* or *potentially rational orthogonal.* In the other direction, a pattern allowing the same over the quaternionic skew field is called *potentially hyperunitary.*

It is shown that the four classes of pattern are separated by strict inclusions. The proof relies on the rigidity properties of a particular pattern of size 7×7, which is potentially rational orthogonal but which is potentially hyperunitary only for all nonzero entries having the same magnitude. This allows the conversion of small rectangular orthogonal-column patterns that include additional equal-magnitude restrictions into considerably larger square patterns where the only restrictions are zero or nonzero.

Such a separation is interesting in a quantum dynamics context because such patterns give the transitions of a discrete quantum random walk. The publication of this work is in the physics literature under the title *Locality for quantum systems on graphs depends on the number field.* (Received August 29, 2016)

16 ► Associative rings and algebras

1123-16-75 **Alexandru Chirvasitu*** (chirva@uw.edu), Box 354350, Mathematics Department, University of Washington, Seattle, WA 98195, and **S. Paul Smith**. *Exotic elliptic algebras.*

In the course of his work on finding solutions to the Yang-Baxter equation arising from theta functions on elliptic curves, Sklyanin introduced his eponymous algebras. These are non-commutative deformations of polynomial rings in four variables, and are the most widely known examples of three-dimensional quantum projective spaces.

Many of the classical notions familiar from the study of projective algebraic varieties (lines and points in projective space, vector bundles on projective schemes, etc.) make sense in the non-commutative realm and provide important geometric information about the non-commutative graded rings underlying the non-commutative schemes being examined.

In this talk we discuss certain (further) deformations of Sklyanin algebras that in many ways exhibit generic behavior within the moduli space of quantum projective 3-spaces: they have the fewest number of points possible (namely 20), their schemes of lines are of minimal dimension (one) and generic degree (again 20), etc. All of this follows from a study of certain autoequivalences of various categories of representations for our twisted Sklyanin algebras. In turn, these autoequivalences arise as "quantum symmetries" via quantum group actions on the algebras.

(joint with S. Paul Smith) (Received August 16, 2016)

1123-16-136 **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 background will be given. This is a joint work with Linhong Wang and Xingting Wang. (Received August 22, 2016)

1123-16-162 **Ellen E. Kirkman*** (kirkman@wfu.edu), Wake Forest University, Box 7388 Reynolda Station, Winston-Salem, NC 27109, and **James J. Kuzmanovich** and **James J. Zhang**. *Dual reflection group coactions.*

Let k be a field of characteristic zero, and A be an Artin-Schelter regular k-algebra that is graded by a finite group G. We call G a *dual reflection group* for A if the identity component A_e of A is also AS regular. We consider necessary conditions on (G, A) for G to be a dual reflection group for A, construct some dual reflection groups, show some groups are not dual reflection groups and some algebras have no dual reflection groups. We prove that the covariant ring, $A^{cov} = A/I$ for $I = ((A_e)_{\geq 1})$, is Frobenius. The Hopf algebra $H = k^G$ associated to a dual reflection group can be regarded as a generalization of a reflection group, since under the action of H on A the invariant subring $A^H = A_e$ is AS regular, providing a generalization of the Shephard-Todd-Chevalley Theorem, where $A = k[x_1, \ldots, x_n]$, G is a reflection group, A^G is a polynomial ring, and $k[x_1, \ldots, x_n]/I$, for $I = (A^G{}_{\geq 1})$, is a complete intersection. (Received August 24, 2016)

1123-16-163 **Colin Ingalls** and **Charles Paquette***, charles.paquette@uconn.edu. *Global dimensions of idempotent subalgebras.* Preliminary report.

Consider a finite dimensional algebra A over a field and e an idempotent of A. Consider the algebra $\Gamma = (1-e)A(1-e)$. In general, A and Γ are very different from the homological point of view. One general goal is to find an A-module S_e that controls the relationship between the global dimensions of A and Γ. The semi-simple A-module $S_e = eA/\mathrm{rad}A$ is a good candidate for this. For e primitive, consider the following three conditions: (1) $\mathrm{gl.dim}A < \infty$; (2) $\mathrm{gl.dim}\Gamma < \infty$; (3) $\mathrm{Ext}^i_A(S_e, S_e) = 0$ for all $i > 0$. In a past project, we proved that any two of these conditions imply the third. If e is not primitive, then condition (3) needs to be replaced by another closely related condition (3'). In this talk, I will explain how (3') allows us to relate the global dimensions of A and Γ. I will also explain how to use this to get a reduction formula for the Cartan Determinant Conjecture. This is joint work with Colin Ingalls. (Received August 24, 2016)

1123-16-170 **Alex Martsinkovsky***, alexmart@neu.edu. *Injective torsion.*

Classical torsion was defined for modules over commutative domains. One possible extension of this notion to modules over noncommutative rings is the 1-torsion, defined as the kernel of the canonical map from a module to its double dual. When the module is finitely presented, the 1-torsion admits a cohomological description. Unfortunately, for infinite module over commutative domains, the classical torsion may be strictly contained in the 1-torsion. The goal of this talk is to remove this limitation by introducing a new notion of torsion over arbitrary rings and show that: 1) over commutative domains it coincides with the classical torsion, even for infinite modules, and 2) for finitely presented modules, it coincides with the 1-torsion. (Received August 25, 2016)

1123-16-174 **Karin Baur**, **Eleonore Faber**, **Sira Gratz**, **Khrystyna Serhiyenko*** (khrystyna.serhiyenko@berkeley.edu) and **Gordana Todorov**. *Mutation of A_n friezes.*

A frieze is a grid of positive integers with a finite number of infinite rows satisfying a certain rule. Introduced in 1970's, friezes gained fresh interest in the last decade in relation to cluster theory. In particular, there exists a bijection between friezes and cluster-tilted algebras of type A. An operation called mutation is the key notion in cluster theory, and we study mutations of friezes which are compatible with mutations of the associated cluster-tilted algebras.

We also provide an explicit formula for the number of submodules (up to isomorphisms) of a given module over a cluster-tilted algebra of type A. In this case, it coincides with the specialized Caldero Chapoton map applied to a given module, which in turn provides a way to pass from a cluster-tilted algebra to the associated frieze. (Received August 25, 2016)

1123-16-179 **Calin I Chindris*** (chindrisc@missouri.edu), University of Missouri, 202 Math Sciences Building, 810 E. Rollins Str, Columbia, MO 65211. *On the invariant theory for special biserial algebras.* Preliminary report.

This talk is based on joint work with Andy Carroll, Ryan Kinser, Amelie Schreiber, and Jerzy Weyman. It is about studying modules of finite-dimensional algebras via invariant theory. The goal here is to find characterizations of the tameness (more generally, Schur-tameness) of an algebra in terms of its moduli spaces of modules. In this talk, we show that under certain assumptions, the irreducible components of any moduli space of modules of a special biserial algebra are just products of projective spaces. Along the way, we also describe several reduction techniques for studying moduli spaces of modules of arbitrary finite-dimensional algebras. (Received August 25, 2016)

1123-16-228 **Iva Halacheva*** (i.halacheva@lancaster.ac.uk), **Joel Kamnitzer**, **Leonid Rybnikov** and **Alex Weekes**. *Cacti, crystals, and monodromy of the shift of argument algebras.* Preliminary report.

The cactus group $J_{\mathfrak{g}}$ is a cousin of the braid group and can be defined for any finite-dimensional, complex, reductive Lie algebra $\mathfrak{g}$. We describe a combinatorial action of $J_{\mathfrak{g}}$ on any $\mathfrak{g}$-crystal using Schützenberger involutions. On the other hand, there is a family of maximal commutative subalgebras in $U(\mathfrak{g})$, known as the shift of argument algebras, which act with simple spectrum on any highest weight, irreducible $\mathfrak{g}$-representation V. These subalgebras are indexed by points in a certain De Concini-Procesi moduli space, and so induce a covering on it for a fixed V. We show that the corresponding monodromy action, at least in type A and as work in progress for other types, agrees with the combinatorial action of the cactus group on the crystal corresponding to V. Skew Howe duality relates this result to an analogous construction for the Gaudin algebras. (Received August 27, 2016)

1123-16-244 **Frauke M Bleher*** (frauke-bleher@uiowa.edu), University of Iowa, Department of Mathematics, 14 MLH, Iowa City, IA 52242. *Universal deformation rings and self-injective Nakayama algebras.* Preliminary report.

Let k be a field and let Λ be a finite dimensional k-algebra such that there is a stable equivalence of Morita type between Λ and a self-injective split basic Nakayama algebra over k. I will show that every indecomposable Λ-module has a universal deformation ring and describe the possible isomorphism types of these rings. This is joint work with D. Wackwitz. (Received August 28, 2016)

1123-16-248 **Alex Sistko***, 14 MacLean Hall, Iowa City, IA 52242-1419, and **Miodrag Iovanov**, 14 MacLean Hall, Iowa City, IA 52242-1419. *Maximal Subalgebras of Finite-Dimensional Algebras.* Preliminary report.

Let B be a finite-dimensional algebra over a field k. Then is it natural to ask which k-algebras A can appear as maximal subalgebras of B, and which ring-theoretic/representation-theoretic properties of A are inherited from B. We focus on the cases where B is either semisimple or a quiver algebra. For the former case we provide a classification of maximal subalgebras. In attempting to answer the latter we are naturally led to split-by-nilpotent extensions, which have appeared in various other contexts in representation theory. We discuss examples where the extension $A \subset B$ is split-by-nilpotent, how to reduce to this case in a generic way, and what we might do when this reduction significantly alters the algebras A and B. Joint work with Miodrag Iovanov. Work in progress. (Received August 28, 2016)

1123-16-297 **Henry Kvinge*** (hkvinge@math.ucdavis.edu), **Anthony Licata** and **Stuart Mitchell**. *A surprising connection between Khovanov's Heisenberg category and the asymptotic representation theory of symmetric groups.*

Khovanov introduced a remarkable monoidal category $\mathcal{H}$, known as the Heisenberg category. $\mathcal{H}$ is defined via a calculus of planar diagrams and conjecturally categorifies the Heisenberg algebra. We will show how certain structures related to the asymptotic representation theory of symmetric groups appear naturally in the center of this category. This provides us with a new diagrammatic framework with which to understand these structures. (Received August 29, 2016)

1123-16-336 **David C Meyer*** (meyerdc@missouri.edu), University of Missouri, 217 Mathematical Sciences Building, 810 E. Rollins Street, Columbia, MO 65201. *Universal deformation rings and finite subgroups of $Gl_2(\mathbb{C})$.*

Universal deformation rings convey information about the characteristic 0 representations associated to characterstic p representations of an algebra. Let Γ be a finite group, and let V be an absolutely irreducible $\mathbb{F}_p\Gamma$-module. We consider the function which assigns to V its universal deformation ring $R(\Gamma, V)$. When this function is non-constant, we can use its graph to determine information about the internal structure of the group Γ. Specifically, we connect the fusion of certain subgroups N of Γ, to the kernels of those representations whose corresponding modules are a level set of the function $V \to R(\Gamma, V)$. We consider groups Γ which are extensions of finite irreducible subgroups of $Gl_2(\mathbb{C})$ by elementary abelian p-groups of rank 2. (Received August 29, 2016)

1123-16-370 **Kiyoshi Igusa**, **Gordana G. Todorov*** (g.todorov@neu.edu) and **Jerzy Weyman**. *Picture groups for Dynkin quivers and cohomology in type A_n.* Preliminary report.

For every quiver of finite representation type we define a finitely presented group called a picture group. This group is very closely related to the cluster theory of the quiver. For example, positive expressions for the Coxeter element in the group are in bijection with maximal green sequences. The picture group is derived from the semi-invariant picture for the quiver. We use this picture to construct a finite CW complex which is a K(π,1) for this

group, i.e. has this group as its fundamental group. The cells are in bijection with cluster tilting objects. For example, in type An there are a Catalan number of cells. The main result of this paper is the computation of the cohomology ring of all picture groups of type An with any orientation and any coefficient ring. (Received August 30, 2016)

1123-16-391 **Kosmas Diveris**, **Marju Purin*** (purin@stolaf.edu) and **Peter Webb**. *Bounded Derived Category of Incidence Algebras of Posets.* Preliminary report.

This is joint work with Kosmas Diveris and Peter Webb. We study the bounded derived category of incidence algebras of posets. We introduce 'clamping theory'- a technique that allows us to determine Auslander-Reiten quiver components in the derived category by examining embedded intervals in the posets. Using clamping theory we introduce a construction to generate posets that give rise to piecewise hereditary algebras. As an example, we may construct incidence algebras of finite representation type that are derived equivalent to hereditary algebras of wild representation type. (Received August 30, 2016)

1123-16-407 **Emily Barnard**, **Andrew T Carroll*** (andrew.carroll@depaul.edu), **Gordana Todorov** and **Shijie Zhu**. *Minimal inclusions of torsion classes.*

We investigate the lattice of torsion classes over a finite-dimensional associative algebra (viewed as a set ordered by inclusion). We start by showing that each cover in this lattice can be encoded by an indecomposable module over the algebra. We then show that there is a one-to-one correspondence between completely join-irreducible torsion classes in this lattice and indecomposable Schur modules over the algebra. In case the algebra is of finite representation type, this correspondence can be leveraged to describe the canonical join representation of any torsion class. In arbitrary representation type, it can be used to describe the canonical join representation of any torsion class that covers at least two other torsion classes. (Received August 30, 2016)

1123-16-408 **Calin Chindris**, **Ryan Kinser**, **Amelie Schreiber** and **Jerzy Weyman***, Department of Mathematics, University of Connecticut, 341 Mansfield Rd., Storrs, CT. *Moduli of Special Biserial Algebras.* Preliminary report.

I will report on the joint work with Calin Chindris, Ryan Kinser and Amelie Schreiber on moduli of special biserial algebras. (Received August 30, 2016)

17 ► Nonassociative rings and algebras

1123-17-172 **Ian M Musson*** (musson@uwm.edu), Department of Mathematical Sciences, UW-Milwaukee, Milwaukee, WI 53211. *Šapovalov elements and the Jantzen sum formula for contragredient Lie superalgebras.*

If $\mathfrak{g}$ is a contragredient Lie superalgebra and γ is a root of $\mathfrak{g}$, we prove the existence and uniqueness of Šapovalov elements for γ and give upper bounds on the degrees of their coefficients. Then we use Šapovalov elements to define some new highest weight modules. If X is a set of orthogonal isotropic roots and $\lambda \in \mathfrak{h}^*$ is such that $\lambda + \rho$ is orthogonal to all roots in X, we construct a highest weight module $M^X(\lambda)$ with character $\epsilon^\lambda p_X$. Here p_X is a partition function that counts partitions not involving roots in X. The main results are analogs of the Šapovalov determinant and the Jantzen sum formula for $M^X(\lambda)$ when $\mathfrak{g}$ has type A.

For the proof of the main results it is enough to study the behavior for certain relatively general highest weights. Using an equivalence of categories due to Cheng, Mazorchuk and Wang, the information we require is deduced from the behavior of the modules $M^X(\lambda)$ when $\mathfrak{g} = \mathfrak{gl}(2,1)$ or $\mathfrak{gl}(2,2)$. These low dimensional cases are studied in detail. (Received August 25, 2016)

1123-17-204 **Ryan E Grady*** (ryan.grady1@montana.edu), **Dylan Butson**, **Brian Williams** and **Philsang Yoo**. *Algebras and modules from boundary quantum field theory.* Preliminary report.

We report on a program to study quantum observables in the BV formalism on manifolds with boundary. Such observables are described in terms of (structured) factorization algebras. In examples, several familiar representation theoretic objects are recovered, including the Kac-Moody vertex algebra, affine W-algebras, and the quantum group (as an E_3 algebra). Moreover, as the boundary observables obtain a module structure over the bulk observables, we hope to describe potentially new relationships between quantum groups and affine W-algebras. Our formalism can also be applied to certain AKSZ type theories, including the Poisson sigma model and the Courant sigma model; we will sketch these constructions if time permits. (Received August 26, 2016)

1123-17-241 **K. Diveris*** (diveris@stolaf.edu), **M. Purin** and **P. Webb**. *Combinatorial Restrictions on the Tree Class of the Auslander-Reiten Quiver of a Triangulated Category.*

We show that if a connected, Hom-finite, Krull-Schmidt triangulated category has an Auslander-Reiten quiver component with Dynkin tree class then the category has Auslander-Reiten triangles and that component is the entire quiver. This is an analogue for triangulated categories of a theorem of Auslander, and extends a previous result of Scherotzke. (Received August 27, 2016)

1123-17-292 **Jie Sun*** (sjie@mtu.edu), Mathematical Sciences, Michigan Technological University, Houghton, MI 49931. *Twisted current algebras and their universal central extensions.*

Twisted current algebras are fixed point subalgebras of tensor products of Lie algebras and associative algebras under finite group actions. Examples of twisted current algebras include multiloop Lie algebras, twisted forms and equivariant map algebras. In this talk, central extensions of twisted current algebras are constructed and conditions are found under which the construction gives universal central extensions of twisted current algebras. (Received August 29, 2016)

1123-17-388 **Darlayne Addabbo***, addabbo2@illinois.edu. *Q-systems and Generalizations in Representation Theory.*

We discuss tau-functions given as matrix elements for the action of $\widehat{GL_2}$ on two-component fermionic Fock-space and explain how to see that they satisfy an $A_{\infty/2}$ Q-system. Q-systems are discrete integrable systems that are of interest in various places in mathematics, so it is natural to ask what relations are satisfied by analogous tau-functions given as matrix elements for the action of $\widehat{GL_3}$ on three-component fermionic Fock space. We will define these new tau-functions and the relations that they satisfy. If time permits, a generalization of this work will be discussed. (Joint with Maarten Bergvelt.) (Received August 30, 2016)

18 ► Category theory; homological algebra

1123-18-148 **Shawn X. Cui**, **César Galindo**, **Julia Plavnik*** (julia@math.tamu.edu) and **Zhenghan Wang**. *On gauging symmetry of modular categories.*

In this talk, we will first give some basic definitions and examples of modular categories. These categories appear in many mathematical subjects such as topological quantum field theory, conformal field theory, representation theory of quantum groups, von Neumann algebras, and vertex operator algebras. In addition to the mathematical interest, a motivation for pursuing a classification of modular categories comes from their application in condensed matter physics and quantum computing

Gauging is a well-known theoretical tool to promote a global symmetry to a local gauge symmetry. In this talk, we will also present a mathematical formulation of gauging in terms of higher category formalism. Roughly, given a unitary modular category (UMC) with a symmetry group G, gauging is a 2-step process: first extend the UMC to a G-crossed braided fusion category and then take the equivariantization of the resulting category. This is usefull tool to construct new modular categories from given ones.

We will show through two concrete examples which are the ingredients involved in this process and we will explain the mathematical structures associated to it. (Received August 23, 2016)

1123-18-195 **Robert Laugwitz***, Department of Mathematics, Rutgers University, 110 Frelinghuysen Rd., Piscataway, NJ 08854-8, and **Vanessa Miemietz**. *2-Representation Theory of p-DG 2-Categories.* Preliminary report.

This talk is a report on joint work in progress with V. Miemietz (UEA). Cell 2-representations for k-linear 2-categories with certain finiteness conditions were defined and studied in a series of papers by Mazorchuk–Miemietz and were inspired by Kazhdan–Lusztig cell modules for Hecke algebras. We adapt the construction of these 2-cell representations to a p-DG enriched setting. This links to the categorification of small quantum at roots of unity by Elias–Qi which uses techniques from Hopfological algebra developed by Khovanov–Qi. (Received August 26, 2016)

1123-18-267 **Yu Tsumura*** (tsumura.2@osu.edu), 100 Math Tower 231 West 18th Avenue, Columbus, OH 43210. *The dihedral type subcategory of a metaplectic category.* Preliminary report.

A metaplectic modular category is a unitary modular category with the same fusion rules as $\mathrm{SO}(N)_2$ for some odd $N > 1$. A metaplectic category contains a subfusion category whose fusion rules are the same as the dihedral group of order $2N$. We study this subcategory in the hope that the information of this subcategory can be used to effectively compute some topological invariant defined using a metaplectic category. This is a joint work with Thomas Kerler and Yilong Wang. (Received August 28, 2016)

1123-18-268 **Thomas Goodwillie** and **Kiyoshi Igusa*** (igusa@brandeis.edu). *Higher Franz-Reidemeister torsion of G-bundles.* Preliminary report.

If a finite group G acts fiberwise on a complex vector bundle over a simply connected space, the higher Franz-Reidemeister (FR)-torsion invariants with coefficients in any Mackey functor on the category of finite G-sets are defined and can be computed. The topological and algebraic contributions can be separated in the formula and in this talk I will concentrate on the algebraic component. Roughly speaking, higher FR-torsion of G-bundle naturally lives in a module over the Burnside ring A_G of G and many of the fundamental properties of FR-torsion can be expressed in terms of this action of A_G. I will review the definitions of Mackey functors and the Burnside ring and explain how they relate to the topology. The main application is a generalization of "Hatcher's construction" to G-bundles. (Received August 28, 2016)

19 ► K-theory

1123-19-61 **Dan Li*** (li1863@purdue.edu), 150 N University St, West Lafayette, IN 47907. *Index theory of topological insulators.*

Topological insulators are new materials observed in nature that behave like insulators in the bulk but have conducting edge states on the boundary. In fact, time reversal invariant topological insulators can be characterized by a $\mathbb{Z}_2$-valued invariant, which will be understood in the framework of index theory and K-theory. In particular, the bulk-boundary correspondence is the key to understanding the topological $\mathbb{Z}_2$ invariant. (Received August 12, 2016)

20 ► Group theory and generalizations

1123-20-173 **Yo'av Rieck*** (yoav@uark.edu), 301 SCEN (MATH), University of Arkansas, 1 University Dr, Fayetteville, AR 72701, and **Yasushi Yamashita**. *Stable Rips Sela canonical representatives in geometric small cancelation groups.*

Rips and Sela constructed canonical representatives for torsion free hyperbolic groups. Their construction has been very useful and influential, in particular in Sela's solution for the isomorphism problem for torsion free hyperbolic groups (which gives, using Mostow, an algorithm to decide when closed hyperbolic n-manifolds are homeomorphic). They showed that in certain geometric small cancelation groups their construction can be improved to give *stable* canonical representatives, and asked if stable canonical representatives exist in all torsion free hyperbolic groups.

In this talk we will define stable canonical representative, explain their relation to the isomorphism problem, and show a new construction of stable canonical representatives that is valid in all geometric small cancelation groups. (Received August 25, 2016)

1123-20-181 **Christopher M Drupieski*** (c.drupieski@depaul.edu) and **Jonathan R Kujawa**. *Support varieties for Lie superalgebras.*

In the mid 1980s, Friedlander and Parshall developed the theory of cohomological support varieties for restricted Lie algebras. This theory (modeled on the support variety theory for finite groups developed by Jon Carlson and others in the early 1980s) associates to each representation of a restricted Lie algebra $\mathfrak{g}$ a corresponding affine algebraic variety, defined in terms of the cohomology of the restricted enveloping algebra $V(\mathfrak{g})$ of $\mathfrak{g}$. Friedlander and Parshall showed how the cohomological support variety of a restricted $\mathfrak{g}$-module V geometrically encodes interesting representation-theoretic information about V.

In this talk I will discuss recent and ongoing work with Jon Kujawa to investigate support varieties for (restricted) Lie superalgebras and other related graded objects. (Received August 25, 2016)

1123-20-182 **Michael Aaron Geline*** (mgeline@niu.edu), Department of Mathematical Sciences, Northern Illinois University, DeKalb, IL 60115, and **Florian Eisele**, **Radha Kessar** and **Markus Linckelmann**. *Morita equivalences between blocks preserve heights of Knörr lattices.*

An interesting class of p-adic representations of finite groups was introduced by Knörr in relation to Brauer's so-called height zero conjecture. This class of (indecomposable) lattices includes the absolutely irreducible lattices. We show that a Morita equivalence between two block algebras of finite groups sends Knörr lattices to Knörr lattices, and that the heights of corresponding lattices coincide. The case of absolutely irreducible lattices was established by Broué (Received August 25, 2016)

1123-20-312 **Nate Harman*** (nharman@mit.edu), Department of Mathematics, Massachusetts Institute of Technology, Cambridge, MA 02139. *Integer valued polynomials and stable representation theory.*

First we'll discuss a connection between the ring of integer valued polynomials and the limiting behavior of the representation theory of symmetric groups S_n as n goes to infinity, verifying a prediction of Deligne about representations in positive characteristic. We will then discuss recent progress on q-deforming this entire picture, giving new results and predictions about the asymptotic behavior of the representation theory of finite general linear groups and Iwahori-Hecke algebras. (Received August 29, 2016)

1123-20-318 **Tom Halverson**, **Arun Ram** and **Nathaniel Thiem*** (thiemn@colorado.edu). *Flavors of q-partition algebras.* Preliminary report.

The partition algebra is a classical example of a diagram algebra that contains many of the other famous combinatorial centralizer algebras as subalgebras. The search for a q-analogue of these algebras leads to an investigation of the various coincidences that make the partition algebra combinatorially tractable. This talk introduces numerous q-analogue candidates and analyzes which desirable characteristics of the partition algebra break or become obscured in each case. (Received August 29, 2016)

1123-20-326 **Tim Susse*** (tsusse2@unl.edu), **Mark Brittenham** and **Susan Hermiller**. *Algorithms and dynamical systems for closed 3-manifold groups, II.*

A bounded flow function is a discrete dynamical system on a finitely presented group, mapping the set of paths in the Cayley graph into itself, such that path lengths increase in a bounded way and iteration eventually maps every path into a fixed maximal tree. If the flow function can be computed by a finite state automaton (FSA), the group is called autostackable and the FSA can be used to solve the word problem for the group. In this talk I will discuss relationships between geometry and dynamics that produce autostackable structures. In particular, I will discuss autostackability for closed 3-manifold groups. This is joint work with Mark Brittenham and Susan Hermiller. (Received August 29, 2016)

1123-20-349 **Mark Brittenham** (mbrittenham2@unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130, **Susan Hermiller*** (hermiller@unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130, and **Tim Susse** (tsusse2@unl.edu), Department of Mathematics, University of Nebraska, Lincoln, NE 68588-0130. *Algorithms and dynamical systems for closed 3-manifold groups, I.* Preliminary report.

A bounded flow function is a discrete dynamical system on a finitely presented group, mapping the set of paths in the Cayley graph into itself, such that path lengths increase in a bounded way and iteration eventually maps every path into a fixed maximal tree. If the flow function can be computed by a finite state automaton (FSA), the group is called autostackable and the FSA can be used to solve the word problem for the group. In this talk I will discuss relationships between geometry and dynamics that produce autostackable structures. In particular,I will discuss autostackability for closed 3-manifold groups. This is joint work with Mark Brittenham and Tim Susse. (Received August 29, 2016)

22 ► Topological groups, Lie groups

1123-22-229 **Cheng-Chiang Tsai*** (chchtsai@mit.edu), 2-246C, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139. *Uniform bounds on orbital integrals.*

Let G be an unramified reductive p-adic group and let f be the characteristic function of $G(\mathcal{O})$. An application of a result of Harish-Chandra says that there is a uniform bound on normalized orbital integral of f for all regular semisimple orbits. Using inductive property of orbital integrals and Shalika germs, we show that (assuming p large enough) the bound can be made independent of the base local field but only depending on the absolute root datum of G. (Received August 27, 2016)

1123-22-232 **Sam Evens*** (sevens@nd.edu), Department of Mathematics, University of Notre Dame, Notre Dame, IN 46556. *The Gelfand-Zeitlin system for gl(n) and so(n).*

I will give an overview of recent joint work with Mark Colarusso on the Gelfand-Zeitlin system for the Lie algebras g=gl(n,C) and g=so(n,C) introduced by Kostant and Wallach. This is a completely integrable system defined by the maximal Poisson commutative family given by invariants for g together with invariants for all smaller subalgebras of the same type. A point in g is called strongly regular if this collection of invariants have

linearly independent differentials, and flows through these points are flows of maximal dimension. The case of gl(n) is partly accessible via linear algebra, but we explain how to use structural results from algebraic groups (due to Knop, Luna, and others) in order to better understand the situation for gl(n), but also to extend many known results for gl(n) to the orthogonal case. (Received August 27, 2016)

1123-22-263 **Jessica Fintzen*** (fintzen@math.harvard.edu), Department of Mathematics, UMich, 2074 East Hall, 530 Church St, Ann Arbor, MI 48109. *On the Moy-Prasad filtration and supercuspidal representations.*

The Moy-Prasad filtrations of p-adic groups play an important role in the representation theory of p-adic groups. We will introduce the Moy-Prasad filtration and its quotients and indicate how they form representations over the residue field. We will then present new descriptions of these Moy-Prasad filtration representations that are in some sense independent of the residue field characteristic. As an application, we will explain how these results lead to new supercuspidal representations. (Received August 28, 2016)

1123-22-369 **Mark Colarusso*** (colaruss@uwm.edu). *Geometry of Complex Gelfand-Zeitlin Systems II.* Preliminary report.

We explain in more detail our results concerning the geometry of the Gelfand-Zeitlin (GZ) integrable systems outlined in the talk "Geometry of the Complex Gelfand-Zeitlin Systems I" given by S. Evens. We describe how the nilfibre of the partial Kostant-Wallach map can be understood using the theory of orbits of a symmetric subgroup on the flag variety. Using this description of the nilfibre along with the Luna slice theorem, we obtain a simple description of partial Kostant-Wallach map fibres and the so-called partially strongly regular set. We use these results to understand the geometry of the full strongly regular set and construct components of Kostant-Wallach map fibres over the strongly regular set. If time permits, we will briefly discuss our approach to understanding the geometry of the GZ systems away from the strongly regular set using the theory of flat deformations of schemes. (Received August 30, 2016)

26 ► Real functions

1123-26-238 **Amalia Culiuc*** (amalia@math.gatech.edu), Georgia Tech Mathematics Department, 686 Cherry St NW, Atlanta, GA 30308. *Two weight estimates with matrix measures for well-localized operators.*

We discuss two weight estimates for well localized operators acting on vector-valued function spaces with matrix weights. We will show that the Sawyer-type testing conditions are necessary and sufficient for the boundedness of this class of operators, which includes Haar shifts and their various generalizations. More explicitly, we will show that it is sufficient to check the estimates of the operator and its adjoint only on characteristic functions of cubes. This result generalizes the work of Nazarov-Treil-Volberg in the scalar setting and is joint work with K. Bickel, S. Treil, and B. Wick. (Received August 27, 2016)

31 ► Potential theory

1123-31-329 **M. A. Snipes*** (snipesm@kenyon.edu). *Calculating harmonic measure in doubly connected domains.*

Harmonic measure is a natural measure on the boundary of a planar domain that reflects the accessibility of a portion of the domain by a Brownian particle released from some basepoint in the domain. Harmonic measure is invariant under conformal maps, so for simply connected domains, one can use the Riemann map to calculate the harmonic measure of subsets of the boundary. For multiply-connected domains, the problem becomes more complex. In this talk, we will describe (and compare) several approaches to calculating harmonic measure for doubly-connected domains, focusing on the example of the doubly-slit plane. This is joint work with J. Aarao, B.L. Walden, and L.A. Ward. (Received August 29, 2016)

33 ► Special functions

1123-33-38 **Gopala Krishna Srinivasan*** (gopal@math.iitb.ac.in), Department of Mathematics, Indian Institute of Technology Bombay, Powai, Mumbai, 400076, India. *On Integral Representations of Mellin Barnes and Ramanujan.*

Integral Representations of Meijer G-functions of which the Mellin Barnes integrals as well as some integrals of Ramanujan are increasingly playing an important role in the modern theory of special functions. We shall discuss a new approach to these via the theory of distributions of L. Schwartz. Certain formulas used by Fritz John in connection with problems in wave propagation and generalized by Lars Hormander provide a clear and transparent method of arriving at these integral representations. (Received August 06, 2016)

35 ► Partial differential equations

1123-35-24 **Xavier Ros-Oton*** (ros.oton@math.utexas.edu), 105 W 51st St Apt 1406, Austin, TX 78751. *Obstacle problems for integro-differential operators.*

We study obstacle problems for integro-differential operators of order $2s$, with $s \in (0,1)$.

Our main result establishes the regularity of the free boundary near regular points. Namely, we show that the set of regular free boundary points is open and that the free boundary is $C^{1,\alpha}$ near those points. Furthermore, we give a fine expansion for the solution at those points.

These results were only known for the fractional Laplacian and are completely new for more general integro-differential operators. The methods we develop are purely nonlocal, and do not rely on any monotonicity formula.

This is joint work with L. Caffarelli and J. Serra. (Received August 02, 2016)

1123-35-27 **Greg Faye**, **Matt Holzer** and **Arnd Scheel***, 206 Church St SE, School of Mathematics, Minneapolis, MN 55455. *Invasion and Resonance.*

I will present recent work on characterizations of invasion speeds in dissipative equations. The key observation is that spreading into unstable state can be understood as a resonant interaction between spatio-temporal modes through linear or nonlinear terms. Other than invasion by "pushed" fronts, speeds are determined by the linearization, only. The mechanism requires the presence of resonant coupling terms, but is independent of the strength. We illustrate our results near a Turing-steady-state mode interaction in a neural field model. (Received August 03, 2016)

1123-35-32 **Pablo Raúl Stinga*** (stinga@iastate.edu), Department of Mathematics, Iowa State University, 396 Carver Hall, Ames, IA 50011. *Extension problem for fractional powers of parabolic operators and applications.*

We show that the fractional powers of any uniformly parabolic operator with time-dependent coefficients can be realized as a Dirichlet-to-Neumann map through a parabolic extension problem in one more dimension. In particular, the fractional powers of the heat operator are considered. Using this characterization we obtain regularity estimates for nonlocal space-time equations, like the master equation from continuous time random walks, as the one considered by L. Caffarelli and L. Silvestre. These results are based on a joint work with J. L. Torrea. As a particular case, we recover the extension problem for the Marchaud fractional derivative, which was previously obtained in joint work with A. Bernardis, F. J. Martín-Reyes and J. L. Torrea. (Received August 03, 2016)

1123-35-39 **Nestor Guillen*** (nguillen@math.umass.edu) and **Russell Schwab** (rschwab@math.msu.edu). *Min-max formulas for elliptic operators.*

We investigate nonlinear, Lipschitz operators that satisfy the global comparison property – i.e. those that preserve the global ordering of input functions at any points where their graphs may touch, often called "elliptic" operators. In particular, we show that all such operators can be written as a min-max over linear operators that are a combination of drift-diffusion and integro-differential parts. The result applies to operators acting on complete Riemannian manifolds; its proof is based on a finite dimensional approximation –involving large finite graphs that converge to the manifold– and it uses tools from non smooth analysis, like the Clarke subdifferential, and also the Whitney extension.

These results have a number of implications. On one hand, they open up the study Dirichlet-to-Neumann mappings for fully nonlinear equations as integro-differential operators on the boundary. On the other hand, they

suggest that certain free boundary problems can be studied as nonlinear degenerate parabolic integro-differential equations. Based on joint work with Russell Schwab. (Received August 07, 2016)

1123-35-69 **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 15, 2016)

1123-35-74 **Hector A Chang-Lara*** (changlara@math.columbia.edu), New York, NY 10027, and **Nestor Guillen**. *Regularity for the Free Boundary of Hele-Shaw by Approximation.*

We propose a method to determine the smoothness for the free boundary of sufficiently flat solutions of one phase Hele-Shaw problems. We notice that under a flatness assumption the free boundary–represented by the hodograph transform of the solution–solves a nonlinear integro-differential equation. This nonlinear equation can be linearized to a (nonlocal) parabolic equation with bounded measurable coefficients, for which regularity estimates are available. (Received August 16, 2016)

1123-35-80 **Nicola Garofalo*** (rembrandt54@gmail.com) and **Xavier Ros-Oton**. *Structure and regularity of the singular set in the obstacle problem for the fractional Laplacian.* Preliminary report.

I will present some new results on the structure and regularity of the singular free boundary in the obstacle problem for the fractional Laplacian. One essential ingredient is a new one-parameter family of Monneau type monotonicity formulas. This is joint work with Xavier Ros-Oton. (Received August 18, 2016)

1123-35-97 **Chenchen Mou*** (muchenchen@math.ucla.edu), 520 Portola Plaza, Math Sciences Building 6364, Los Angeles, CA 90095-1555, and **Andrzej Swiech** (swiech@math.gatech.edu), 686 Cherry Street, Skiles 117, Atlanta, GA 30332-0160. *Schauder estimates for nonlocal Hamilton-Jacobi-Bellman equations.*

In this talk, we study Schauder estimates for viscosity solutions of second order nonlocal Hamilton-Jacobi-Bellman equations, where the nonlocal operators are of Lévy-Itô form. (Received August 19, 2016)

1123-35-99 **Blair Davey*** (bdavey@ccny.cuny.edu), 160 Convent Avenue, New York, NY 10031. *Recent progress on Landis' conjecture.*

In the late 1960s, E.M. Landis made the following conjecture: If u and V are bounded functions, and u is a solution to $\Delta u = Vu$ in $\mathbb{R}^n$ that decays like $|u(x)| \leq c\exp(-C|x|^{1+})$, then u must be identically zero. In 1992, V. Z. Meshkov disproved this conjecture by constructing bounded functions $u, V : \mathbb{R}^2 \to \mathbb{C}$ that solve $\Delta u = Vu$ in $\mathbb{R}^2$ and satisfy $|u(x)| \leq c\exp(-C|x|^{4/3})$. The result of Meshkov was accompanied by qualitative unique continuation estimates for solutions in $\mathbb{R}^n$. In 2005, J. Bourgain and C. Kenig quantified Meshkov's unique continuation estimates. These results, and the generalizations that followed, have led to a fairly complete understanding of the complex-valued setting. However, there are reasons to believe that Landis' conjecture may be true in the real-valued setting. We will discuss recent progress towards resolving the real-valued version of Landis' conjecture in the plane. This talk covers joint work with Carlos Kenig and Jenn-Nan Wang. (Received August 19, 2016)

1123-35-121 **Wenhui Shi*** (wenhui.shi@hcm.uni-bonn.de). *Higher regularity for the fractional thin obstacle problem.*

We study the higher regularity of the regular free boundary in the fractional thin obstacle problem. Our strategy is to use a partial hodograph-Legendre transformation to fix the free boundary, and reduce the problem to the study of higher regularity of solutions to a degenerate elliptic fully nonlinear PDE. We show that this nonlinear PDE is a perturbation of a weighted Baouendi-Grushin Laplacian. By using an implicit function theorem argument, we show that the regular free boundary is smooth (real analytic) if the given obstacle is smooth (real analytic). This is a joint work with Herbert Koch and Angkana Rüland. (Received August 22, 2016)

1123-35-140 **Ariel E Barton*** (aeb019@uark.edu). *The Neumann problem for symmetric higher order elliptic differential equations.*

Second-order equations of the form $\nabla \cdot A\nabla u = 0$, with A a uniformly elliptic matrix, have many applications and have been studied extensively. A well-known foundational result of the theory is that, if the coefficients A are real-valued, symmetric, and constant along the vertical coordinate (and merely bounded measurable in the horizontal coordinates), then the Dirichlet problem with boundary data in L^2 or $\dot{W}^2_1$ and the Neumann problem with boundary data in L^2 are well-posed in the upper half-space.

The theory of higher-order elliptic equations of the form $\nabla^m \cdot A\nabla^m u = 0$ is far less well understood. In this talk we will generalize well-posedness of the L^2 Neumann problem in the half-space to the case of higher-order equations with real symmetric vertically constant coefficients. (Received August 23, 2016)

1123-35-141 **Jeanne Clelland*** (jeanne.clelland@colorado.edu), Dept. of Mathematics, 395 UCB, University of Colorado, Boulder, CO 80309-0395, and **Taylor Klotz** and **Stephen Preston**. *Beltrami fields with non-constant proportionality factor via moving frames.* Preliminary report.

A Beltrami field on an open set in $\mathbb{R}^3$ is a vector field $\mathbf{u}$ satisfying the conditions

$$\operatorname{curl} \mathbf{u} = f\mathbf{u}, \qquad \operatorname{div} \mathbf{u} = 0$$

for some function f. When f is constant, local solutions depend on 2 arbitrary functions of 2 variables. For non-constant f, Encisco and Peralta-Salas have shown that solutions are rare; in fact, there are no solutions at all unless f satisfies an explicit differential equation.

In this work, we study Beltrami fields via a moving frames approach. For local solutions near any point where $\nabla f \neq 0$ we show that:

(1) If the level surfaces of f are open subsets of planes or spheres, there are no solutions unless the level sets of f are contained in parallel planes or concentric spheres, in which case solutions depend on 2 functions of 1 variable.

(2) Otherwise, there is at most a 3-dimensional space of solutions.

Unfortunately, the question of precisely which functions f admit solutions remains computationally intractable. A Cartan-Kähler argument suggests that such functions f should depend on 3 functions of 2 variables, so the question remains: which functions f admit solutions, and how many solutions does each such function admit? (Received August 23, 2016)

1123-35-145 **Mark Allen*** (allen@mathematics.byu.edu), Department of Mathematics, Brigham Young University, 275 TMCB, Provo, UT 84604. *Holder continuity for nondivergence equations involving a nonlocal time derivative of Marchaud or Caputo type.*

This talk concerns differential equations involving a generalized Marchaud derivative of nondivergence type. We show Holder continuity for these differential equations. We then apply these results to obtain Holder continuity for nondivegence parabolic equations with a generalized nonlocal time derivative of Marchaud or Caputo type. (Received August 23, 2016)

1123-35-164 **Vladimir Sverak*** (sverak@umn.edu). *Dynamics of some PDEs modelling aspects of fluids.*

We consider several models equations which share some interesting properties with the fundamental equation of incompressible fluid mechanics (Euler and Navier-Stokes). (Received August 25, 2016)

1123-35-188 **J. Arbunich*** (jarbun2@uic.edu) and **C. Sparber**. *Rigorous derivation of Nonlinear Dirac equations describing wave dynamics in Honeycomb lattices.*

We present recent work on the weakly nonlinear wave dynamics occurring in cubic nonlinear Schrödinger equations with a periodic honeycomb lattice potential. Using a semiclassical scaling, we rigorously derive an effective macroscopic model of nonlinear Dirac type. To this end we employ a multi-scale asymptotic expansion together with rigorous error estimates in certain scaled Sobolev spaces. If time permits, we shall also discuss the case of a non-local Hartree nonlinearity. (Received August 26, 2016)

1123-35-192 **Nicola Garofalo**, **Arshak Petrosyan**, **Camelia A. Pop** and **Mariana Smit Vega Garcia***, mariana.vega-smit@uni-due.de. *The obstacle problem for the fractional Laplacian with drift.*

We present the $C^{1,\alpha}$ regularity of the regular part of the free boundary in the obstacle problem defined by the fractional Laplacian operator with gradient perturbation, in the subcritical regime ($s \in (1/2, 1)$). More specifically, we consider

$$\min\{Lu, u - \varphi\} = 0,$$

where we denote $Lu := (-\Delta)^s u + \langle b(x), \nabla u\rangle + c(x)u$.

Our proof relies on a new Weiss-type monotonicity formula and an epiperimetric inequality. Both are generalizations of the ideas of G. Weiss, used in the classical obstacle problem for the Laplace operator, to our framework of fractional powers of the Laplace operator with drift. (Received August 26, 2016)

1123-35-209 **Jessica Lin*** (jessica@math.wisc.edu), 480 Lincoln Dr., Department of Mathematics, Madison, WI 53703-2463, and **Andrej Zlatos**. *Stochastic Homogenization of Reaction-Diffusion Equations.*

We consider heterogeneous reaction-diffusion equations in stationary-ergodic media with both ignition and KPP-type nonlinearities. Under certain hypotheses on the environment, we prove the existence of asymptotic, deterministic speeds of propagation for solutions with both spark-like and front-like initial data. This leads to a general stochastic homogenization result which shows that on average, the large-scale large-time behavior is governed by a deterministic Hamilton-Jacobi equation modeling front propagation. This talk is based on joint work with Andrej Zlatos. (Received August 26, 2016)

1123-35-234 **Jiayin Jin*** (jin@math.gatech.edu), School of Mathematics, Georgia Institute of Technology, 686 Cherry ST, Atlanta, GA 30332, and **Zhiwu Lin** and **Chongchun Zeng**. *Invariant Manifolds of the Solitary Waves of the Supercritical gKDV Equation.*

It is well known that the solitary waves of the supercritical gKDV equation are linearly unstable. By using the Hamiltonian structure of the linearized gKDV equation, one can show that at each solitary wave, the energy space can be linearly decomposed into unstable space, stable space and center space. Based on the linear decomposition, we construct stable manifolds, unstable manifolds, center-stable manifolds, center-unstable manifolds and center manifolds of the orbits of the whole family of solitary waves. The construction of these invariant manifolds is nontrivial, because the nonlinearity contains a loss of derivative. (Received August 27, 2016)

1123-35-236 **Mark E Fels*** (mark.fels@usu.edu), Department of Mathematics and Statistics, Utah State University, Old Main Hill, Logan, UT 84321. *The Generalized Inverse Problem in the Calculus of Variations and Bi-Hamiltonian Systems.*

Associated to every system of evolution equations $u^i_t = f^i(t, x, u, u_x, \ldots, u_n)$ is it's corresponding variational bi-complex. A particular component of the cohomology of this bi-complex can detect, in an invariant manner, the variational nature of the equation. I will show how this occurs, and apply this theory to compatible bi-Hamiltonian systems. (Received August 27, 2016)

1123-35-252 **Benoit Pausader*** (benoit.pausader@math.brown.edu) and **Nikolay Tzvetkov**. *Growth of Sobolev norms for cubic NLS on product spaces.*

We consider the cubic NLS on $\mathbb{R}\times\mathbb{T}^2$ and we show that for $s > 1/2$, there are solutions whose H^s-Sobolev norm grow unboundedly. This is joint work with N. Tzvetkov (following earlier joint work with Z. Hani, N. Tzvetkov and N. Visciglia). (Received August 28, 2016)

1123-35-254 **Jiayin Jin**, **Shasha Liao** and **Zhiwu Lin*** (zlin@math.gatech.edu). *Nonlinear modulatioal instability of dispersive wave models.*

Modulational instability (also called side band instability, Benjamin-Feir instability) is an important instability mechanism in lots of physical models, including 2D water waves and model equations such as KDV, BBM, and Whitham equations. It leads to the breakdown of periodic traveling wave pattern in these modes and the formation of stable structures such as envelope solitons. In the literature, such instability had been studied a lot from the linearized equation, i.e., the spectra of the linearized operator. With Shasha Liao and Jiayin Jin, we prove nonlinear modulational instability for lots of dispersive models including nonlinear Schrodinger equation, BBM, and KDV type equations (KDV, Benjamin-Ono, Whitham etc). The nonlinear instability is proved for both periodic and localized perturbations. The two main ingredients in the proof are: for the linear step, the semigroup estimates are obtained by using the Hamiltonian structures of the linearized PDEs; for the nonlinear step, the loss of derivative in the nonlinear term is overcome by the construction of higher order approximation solutions. (Received August 28, 2016)

1123-35-256 **Gabriela Jaramillo***, gjaramillo@math.arizona.edu, and **Shankar Venkataramani**, shankar@math.arizona.edu. *2-D array of oscillators with nonlocal coupling.* Preliminary report.

We study a toy model describing a 2-d array of oscillators with nonlocal diffusive coupling, and with a nonlocal nonlinearity. The assumptions on the type of coupling and nonlinearity help draw comparisons to an eikonal equation which models the phase of oscillatory chemical reactions. Guided by the results obtained for the eikonal

equation and using the Fredholm properties of the linearization we show that a small patch of oscillators, modeled here as a localized perturbation, can lead to either target patterns or contact defects depending on the sign of the perturbation. (Received August 28, 2016)

1123-35-260 **Li Li** (lilihit@126.com), NO.2 Yikuang Street, Harbin, Heilongjia 150080, Peoples Rep of China, **Yanyan Li** (yyli@math.rutgers.edu), 110 Frelinghuysen Road, Hill Center for the Mathematical Sciences, Pisacataway, NJ 08854, and **Xukai Yan*** (xkyan@math.rutgers.edu), 28 Bartle Ct Apt D, Highland Park, NJ 08904.
(-1)-homogeneous solutions of stationary incompressible Navier-Stokes equations with singular rays.

In 1944, L.D. Landau first discovered explicit (-1)-homogeneous solutions of 3-d stationary incompressible Navier-Stokes equations (NSE) with precisely one singularity at the origin. These solutions, now called Landau solutions, are axisymmetric with no swirl. In 1998 G. Tian and Z. Xin proved that all solutions which are (-1) homogeneous, axisymmetric with one singularity are Landau solutions. In 2006 V. Sverak proved that Landau solutions are the only (-1)-homogeneous solutions with one singularity. Our work focuses on the (-1)-homogeneous solutions of 3-d incompressible stationary NSE with finite singularities on the unit sphere. In this talk we will first classify all (-1)-homogeneous axisymmetric no-swirl solutions of 3-d stationary incompressible NSE with one singularity at the south pole on the unit sphere as a 2-d solution surface. We will then present our results on the existence of a one parameter family of (-1)-homogeneous axisymmetric solutions with non-zero swirl emanating from the 2-d surface of axisymmetric no-swirl solutions. We will also present asymptotic behavior of general (-1)-homogeneous axisymmetric solutions in a cone containing the south pole with a singularity at the south pole on the unit sphere . (Received August 28, 2016)

1123-35-266 **Robert Buckingham*** (buckinrt@uc.edu), Department of Mathematical Sciences, 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 solutions asymptotically exhibit multiscale phenomena similar to that seen in the small dispersive behavior of nonlinear wave equations such as the KdV, NLS, and sine-Gordon equations. (Received August 29, 2016)

1123-35-270 **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 functional 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 29, 2016)

1123-35-305 **Rohit Jain*** (rohitjain19@gmail.com).
Regularity Estimates for the Stochastic Impulse Control Problem.

Stochastic impulse control problems are control problems that fall between classical diffusion control and optimal stopping problems. In these problems the controller is allowed to instantaneously move the state process by a certain amount every time the state exits the non-intervention region. This allows for the controlled process to have sample paths with jumps. There is an enormous literature studying stochastic impulse control models and many of these models have found a wide range of applications in electrical engineering, mechanical engineering, quantum engineering, robotics, image processing, and mathematical finance. Our aim is to study the resulting free boundary problem and consider regularity estimates for the solution and the free boundary of a fully nonlinear generalization of the problem. The free boundary we study is an obstacle-type problem admitting a non-local obstacle. (Received August 29, 2016)

1123-35-306 **Dat Cao**, **Tadele Mengesha** and **Tuoc Phan*** (phan@math.utk.edu), Department of Mathematics, University of Tennessee, 227 Ayres Hall, 1403 Circle Drive, Knoxville, TN 37996-1320.
Weighted-$W^{1,p}$ estimates for weak solutions of degenerate and singular elliptic equations.

Global weighted L^p-estimates are obtained for the gradient of solutions to a class of linear singular, degenerate elliptic Dirichlet boundary value problems over a bounded non-smooth domain. The coefficient matrix is

symmetric, nonnegative definite, and both its smallest and largest eigenvalues are proportion to a weight in a Muckenhoupt class. Under a smallness condition on the mean oscillation of the coefficients with the weight and a Reifenberg flatness condition on the boundary of the domain, we establish a weighted gradient estimate for weak solutions of the equation. A class of degenerate coefficients satisfying the smallness condition is characterized. A counter example to demonstrate the necessity of the smallness condition on the coefficients is given. Our $W^{1,p}$-regularity estimates can be viewed as the Sobolev's counterpart of the Hölder's regularity estimates established by B. Fabes, C. E. Kenig, and R. P. Serapioni in 1982. (Received August 29, 2016)

1123-35-352 **Chi Hin Chan**, **Magdalena Czubak*** (magda.czubak@colorado.edu) and **Marcelo M Disconzi**. *The formulation of the Navier-Stokes Equations on the Riemannian manifolds.*

There are inequivalent formulations of the Navier-Stokes equations on the Riemannian manifolds due to the different possibilities for the Laplacian operator acting on vector fields. In this talk, we present several distinct arguments that indicate that the form of the equations proposed by Ebin and Marsden in 1970 should be adopted as the correct generalization of the Navier-Stokes to the Riemannian manifolds. (Received August 30, 2016)

1123-35-361 **Jared C Bronski***, 1409 W Green St, Urbana, IL 61801. *Stability and Modulations for Quasiperiodic Traveling waves of Nonlinear Schrodinger type equations.*

We consider the stability of quasi-periodic traveling wave solutions to equations of Nonlinear Schrodinger type. We derive a normal form for the operator governing linearized stability in a neighborhood of the origin in the spectral plane. (Received August 30, 2016)

1123-35-367 **Stefania Patrizi*** (spatrizi@math.utexas.edu), 2515 Speedway, Austin, TX 78712, and **Serena Dipierro** and **Enrico Valdinoci**. *Chaotic Orbits for Systems of Nonlocal Equations.*

We consider a system of nonlocal equations driven by a perturbed periodic potential. We construct multibump solutions that connect one integer point to another one in a prescribed way. In particular, heteroclinic, homoclinic and chaotic trajectories are constructed. This is the first attempt to consider a nonlocal version of this type of dynamical systems in a variational setting and the first result regarding symbolic dynamics in a fractional framework. (Received August 30, 2016)

1123-35-372 **Andrea R Nahmod*** (nahmod@math.umass.edu). *Long time dynamics of random data for certain nonlinear PDE.*

In this talk we present some recent probabilistic well posedness results for the NLS, on $\mathbb{T}^d$ $(d = 3, 2, 1)$ (joint work with G. Staffilani). If time permits, we conclude by describing recent work on a nondeterministic approach to a 2D modified SQG equation (joint with Pavlovic, Staffilani and Totz). (Received August 30, 2016)

1123-35-374 **Deniz Bilman*** (bilman@umich.edu), 2074 East Hall, 530 Church St, Ann Arbor, MI 48109, and **Irina Nenciu** (nenciu@uic.edu), 851 S. Morgan St, Chicago, IL 60607. *On Hamiltonian perturbations of the Toda lattice.*

We present the results of an analytical and numerical study of the long-time behavior for certain Fermi-Pasta-Ulam (FPU) lattices viewed as perturbations of the completely integrable Toda lattice. Our main tools are the direct and inverse scattering transforms for doubly-infinite Jacobi matrices, which are well-known to linearize the Toda flow. We focus in particular on the evolution of the associated scattering data under the perturbed vs. the unperturbed equations. We find that the eigenvalues present initially in the scattering data converge to new, slightly perturbed eigenvalues under the perturbed dynamics of the lattice equation. To these eigenvalues correspond solitary waves that emerge from the solitons in the initial data. We also find that new eigenvalues emerge from the continuous spectrum as the lattice system is let to evolve under the perturbed dynamics. (Received August 30, 2016)

1123-35-379 **Robin Ming Chen**, **Samuel Walsh** and **Miles H. Wheeler*** (mwheeler@cims.nyu.edu). *Stratified solitary water waves.*

We consider traveling waves in a two-dimensional incompressible inviscid fluid bounded below by a horizontal bed and above by a free surface under constant pressure. Allowing the horizontal velocity and density to vary smoothly with depth at infinity instead of being constant, we introduce the possibility of front-like solutions as well as resonances between long and short waves. Nevertheless, we construct a continuous curve of solitary waves which are classical in that their profiles decrease monotonically on either side of a central crest as well as large in that their horizontal fluid velocity comes arbitrarily close to the wave speed. The construction depends on new qualitative results on the symmetry and speed of localized waves as well as the nonexistence of monotone fronts. (Received August 30, 2016)

1123-35-399 **Dana Mendelson***, dana@math.uchicago.edu. *Random data theory for nonlinear wave equations with null form nonlinearity.*

In this talk, I will discuss energy critical nonlinear wave equations with quadratic derivative null form nonlinearity on both the torus and Euclidean space. In certain cases, there are counterexamples to the usual estimates in Sobolev spaces. These yield a gap between the regularity on the initial data that is needed in order to obtain local well-posedness, and the desired result in the critical energy space. We will show that for suitably chosen random initial data, by exploiting the null structure of these equations, we are able to prove estimates for initial data of supercritical regularity in spite of the counterexamples. In particular, this suggests that the geometry underlying certain evolution flows imposes a nonlinear structure which is suitable for the implementation of a more probabilistic approach. I will also highlight some differences in the analysis and results between the periodic and Euclidean settings. This talk is based on work in progress with Chanillo, Czubak, Nahmod and Staffilani. (Received August 30, 2016)

1123-35-400 **Dana Mendelson***, dana@math.uchicago.edu. *Random data Cauchy theory for some nonlinear wave equations.*

I will discuss two problems on nonlinear wave equations with random initial data. The first, based on joint work with Luhrmann, focuses on nonlinear wave equations with defocusing energy-subcritical power-type nonlinearity on Euclidean space. The second problem, based on work in progress with Chanillo, Czubak, Nahmod and Staffilani, concerns energy critical nonlinear wave equations with null form nonlinearities in both the periodic and the Euclidean setting. I will present several almost sure well-posedness results for these equations and contrast the ways in which random data techniques can be exploited in these different contexts. (Received August 30, 2016)

1123-35-414 **Agnid Banerjee**, **Mariana Smit Vega Garcia** and **Andrew K Zeller*** (zellera@purdue.edu). *Higher regularity of the free boundary in the parabolic Signorini problem.*

We show that the quotient of two caloric functions which vanish on a portion of an $H^{k+\alpha}$ regular slit is $H^{k+\alpha}$ at the slit, for $k \geq 2$. In the case $k = 1$, we show that the quotient is in $H^{1+\alpha}$ if the slit is assumed to be space-time $C^{1,\alpha}$ regular. This can be thought of as a parabolic analogue of a recent important result of De Silva and Savin, whose ideas inspired us. As an application, we show that the free boundary near a regular point of the parabolic thin obstacle problem studied in a recent paper of Danielli, Garofalo, Petrosyan, and To with zero obstacle is C^∞ regular in space and time. (Received August 30, 2016)

37 ► Dynamical systems and ergodic theory

1123-37-88 **Zhaohu Nie*** (zhaohu.nie@usu.edu), Department of Mathematics and Statistics, Utah State University, Logan, UT 84322-3900. *Toda field theories and integral curves of standard differential systems.*

We will talk about three relations between the Toda field theory associated to a simple Lie algebra and the integral curves of the standard differential system on the corresponding complete flag variety.

First, we establish an isomorphism concerning regular functions on the jet space and on the unipotent subgroup in the setting of a simple Lie group.

Using this result, we then show that in the sense of differential systems, after restricting one independent variable to a constant the Toda field theory becomes the system for integral curves of the standard differential system on a complete flag variety.

Finally, we establish that, in terms of differential invariants, the Toda field theory is the quotient of the product of two such systems by a natural group action. (Received August 18, 2016)

1123-37-202 **Mary Silber*** (msilber@uchicago.edu), Dept. of Statistics, 5747 S. Ellis Avenue, University of Chicago, Chicago, IL 60637, **Kaitlin Hill** (k-hill@u.northwestern.edu), Dept. of Engineering Sciences & Applied Math, Northwestern University, Evanston, IL 60208, and **Dorian Abbot** (abbot@uchicago.edu), Dept. of Geophysical Sciences, University of Chicago, Chicago, IL 60637. *A piecewise-smooth dynamical systems analysis of an Arctic sea ice loss model: what we learn from bifurcations when we remove albedo smoothing.*

Smoothing of nonlinearities in dynamical systems can remove bifurcations, bistability, and hysteresis loops associated with nonlinear dynamical systems. This presents challenges for using simple models to gain insight into the impact of feedbacks, and possible tipping point behavior associated with them, especially since the

smoothing parameters are not well constrained. We analyze a simple Arctic energy balance model, proposed by Eisenman and Wettlaufer, in a limiting case where a smoothing parameter associated with ice-albedo feedback is set to zero, which makes the system piecewise-smooth. We demonstrate that certain qualitative bifurcation behaviors of the smooth system can have nonsmooth counterparts. We also focus on some features, unique to the non-smooth system, which, surprisingly, turn out to give us insights into how model parameters affect the bifurcation structure of the smoothed problem. We use this perspective to systematically search parameter space, and this analysis provides an alternative perspective on how parameters of this simple conceptual model affect bifurcation behavior. In addition, we have examined a version of this model with additive stochastic forcing, and some preliminary results related to that problem will be presented. (Received August 26, 2016)

1123-37-276 **Quang-Nhat Le*** (qnhatle@math.brown.edu). *A family of projectively natural discrete flows on the space of polygons.*

Polygon iterations, which can be thought of as discrete flows on the space of polygons, provide an abundance of interesting discrete 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 August 29, 2016)

41 ► Approximations and expansions

1123-41-271 **Robert Buckingham*** (buckinrt@uc.edu), Department of Mathematical Sciences, University of Cincinnati, Cincinnati, OH 45221, and **Thomas Bothner**. *Asymptotic analysis of a deformed Tracy-Widom distribution.*

The Tracy-Widom probability distribution describing the largest eigenvalue of a GUE random matrix can be written as a Fredholm determinant. We consider an integrable deformation of this determinant related to a thinned GUE process and orthogonal polynomials with discontinuous weights. We use Riemann-Hilbert analysis to study the asymptotic behavior of the deformed process over a range of parameter values. (Received August 29, 2016)

42 ► Fourier analysis

1123-42-40 **Lesley A. Ward*** (lesley.ward@unisa.edu.au), School of Info Tech & Math Sci, University of South Australia, Mawson Lakes, SA 5095, Australia. *Product Hardy spaces associated to operators with heat kernel bounds on spaces of homogeneous type.*

Much effort has been devoted to generalizing the Calderón–Zygmund theory from Euclidean spaces to metric measure spaces, or spaces of homogeneous type. Here the underlying space $\mathbb{R}^n$ with Euclidean metric and Lebesgue measure is replaced by a set X with general metric or quasi-metric and a doubling measure. Further, one can replace the Laplacian operator that underpins the Calderón–Zygmund theory by more general operators L satisfying heat kernel estimates.

I will present recent joint work with P. Chen, X.T. Duong, J. Li and L.X. Yan along these lines. We develop the theory of product Hardy spaces $H^p_{L_1,L_2}(X_1 \times X_2)$, for $1 \le p < \infty$, defined on products of spaces of homogeneous type, and associated to operators L_1, L_2 satisfying Davis–Gaffney estimates. This theory includes definitions of Hardy spaces via appropriate square functions, an atomic Hardy space, a Calderón–Zygmund decomposition, interpolation theorems, and the boundedness of a class of Marcinkiewicz-type spectral multiplier operators. (Received August 07, 2016)

1123-42-110 **Jill Pipher*** (jill_pipher@brown.edu). *Boundary value problems for elliptic and parabolic equations with non-smooth coefficients.*

There is a certain natural condition on the coefficients of an elliptic or parabolic equation in divergence form which can be expressed in terms of Carleson measures. We give some background in the case of real coefficients, and sketch some work-in-progress when the coefficients are complex valued. (Received August 20, 2016)

1123-42-115 **Virginia Naibo*** (vnaibo@math.ksu.edu), Mathematics Department, 138 Cardwell Hall, Kansas State University, Manhattan, KS 66506. *On certain commutator estimates.* Preliminary report.

We will present various commutator estimates in the settings of Lebesgue, variable Lebesgue, Triebel-Lizorkin and Besov spaces. The commutators to be discussed include those involving bilinear pseudodifferential operators and pointwise multiplication by Lipschitz functions, fractional derivatives and pointwise multiplication, and Littlewood-Paley operators and vector fields. The talk is based on respective collaborations with Arpad Benyi, David Cruz-Uribe and Jarod Hart. (Received August 21, 2016)

1123-42-257 **Shahaf Nitzan***, shahaf.nitzan@math.gatech.edu, and **Jan-Fredrik Olsen** and **Oscar Nilsson**. *Finite dimensional Balian-Low type theorems.*

The classical Balian-Low theorem states that if both a function and it's Fourier transform decay too fast then the Gabor system generated by this function (i.e. the system obtained from this function by taking integer translations and modulations) cannot be an orthonormal basis, nor can it be a Riesz basis.

Though it provides for an excellent 'thumbs–rule' in time-frequency analysis, the Balian–Low theorem is not adaptable to many applications. This is due to the fact that in realistic situations information about a signal is given by a finite dimensional vector rather then by a function over the real line.

In this work we obtain an analog of the Balian–Low theorem in the finite dimensional setting, as well as analogs to some of its extensions. In particular, we will note that the classical Balian–Low theorem can be derived from these finite dimensional analogs. (Received August 28, 2016)

1123-42-415 **Heekyoung Woo*** (heekyoung@choicerg.com), Choice Research Group, Cresskill, NJ 07626, and **Richard Kyung** (nycrick@gmail.com), Choice Research Group, Cresskill, NJ 07626. *Modeling the Bowed Violin to Effectively Produce an Accurate Violin Sound Using Mathematical and Physical Analysis.*

The equation for the energy of a wavelength for a violin bow is complicated than the energy of a wavelength composed of a single frequency. Through Fourier Analysis however, one can accurately calculate the exact power necessary to successfully produce a complex violin wave, by breaking it down into its constituent simple frequencies. In this paper, a more formal explanation of this proof was presented after a relevant strategy and program were set up determining the Fourier series that can be used to represent a bowed violin. Since a note played on violin exponentially dampens in decibels until it no longer can be heard, the dampening of a wave composed of a Fourier series can be modeled as the series multiplied by exponential function. By analyzing the time it takes a wave to dampen to the point in which it's no longer audible, a dampening effect was inserted into the model of the bowed violin to effectively produce an accurate violin sound. (Received August 30, 2016)

43 ► Abstract harmonic analysis

1123-43-34 **Theresa C Anderson*** (tcanderson@math.wisc.edu), WI , 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 August 04, 2016)

46 ► Functional analysis

1123-46-331 **Ralph M Kaufmann**, Dept. of Mathematics, Purdue University, West Lafayette, IN 47907, **Sergei Khlebnikov**, Dept. of Physics and Astronomy, Purdue University, West Lafayette, IN 47907, **Dan Li**, Dept. of Mathematics, Purdue University, West Lafayette, IN 47907, and **Birgit Wehefritz-Kaufmann*** (ebkaufma@math.purdue.edu), Dept. of Mathematics, and Dept. of Physics and Astronomy, Purdue University, West Lafayette, IN 47907. *Topology and Matter.*

The theory of topological properties of materials or condensed matter systems has become increasingly sophisticated. The most prominent has been Kitaev's "periodic table" for topological insulators. The main idea is that there are topological invariants, which dictate the behavior of the system. The tools include Chern-classes and K-theory in various flavors. We will give an overview of these tools and explain how they can be used in concrete situations. (Received August 29, 2016)

47 ► Operator theory

1123-47-142 **Seyed M Zoalroshd*** (szoalros@mail.usf.edu), MO. *Some remarks on a conjecture of Polya and Szego.*

The long standing conjecture of Polya and Szego states that the minimizer of the least eigenvalue of the Dirichlet Laplacian on the set of n-gonal domains of fixed area is the regular n-gon. Polya and Szego proved the conjecture for triangles and quadrilaterals. Surprisingly, the problem is still open for $n \geq 5$. We give some new evidence for Polya-Szego conjecture. (Received August 23, 2016)

1123-47-259 **Maria Cristina Pereyra*** (crisp@math.unm.edu), Department of Mathematics and Statistics, MSC01 1115, 1 University of New Mexico, Albuquerque, NM 87131. *Quantitative inequalities for the dyadic paraproduct.*

In this talk we present quantitative two weight L^2 estimates for the dyadic paraproduct associated to a function b. Our conditions on the pair of weights (u, v) are a joint A_2 and a Carleson condition (both necessary and sufficient for the boundedness of the dyadic square function) and an additional Carleson condition involving the weights and b that we call $Carl_{u,v}$. We compare our results to those of Holmes, Lacey, and Wick for the paraproduct where the weights are assumed to be in A_2 and b in Bloom's BMO. This is joint work with Oleksandra Beznosova, Jean Moraes, and Daewon Chung. (Received August 28, 2016)

49 ► Calculus of variations and optimal control; optimization

1123-49-280 **Rob Kusner*** (profkusner@gmail.com), Geometry, Analysis, Numerics & Graphics: GANG, Department of Mathematics & Statistics, University of Massachusetts, Amherst, MA 01003. *Critical Configurations of Hard Disks on S^2.* Preliminary report.

We study the *injectivity radius* or *thickness* function r on the configuration space $C(N, S^2)$ of N distinct points on the unit 2-sphere. Criticality for maximizing r is equivalent to the existence of a *balanced contact graph* of geodesic arcs whose vertices are (a subset of) the points in the configuration (often, but not always, the remaining points are "rattlers"). We also develop a Morse Lemma for the second order behavior of r near such a critical configuration: $r = q + p + o(2)$, where q is a quadratic function on the tangent space of $C(N, S^2)$, and where p is piecewise linear and concave. In general, such critical configurations comprise a semi-algebraic subvariety of $C(N, S^2)$ and the corresponding critical values are a finite subset of the interval $[\pi/N, \pi]$. For small values of N, we describe all the critical configurations and the corresponding Morse Complex; we also aim to understand special values of N, like $N = 12$, where some surprises occur. (This is part of a joint project with W. Kusner, J. Lagarias and S. Shlosman.) (Received August 29, 2016)

1123-49-304 **Almut Burchard*** (almut@math.toronto.edu), 40 St. George Street, R. 6290, Toronto, Ontario M5S 2E4, Canada. *On a non-local shape optimization problem related to swarming.*

I will discuss recent work with Rustum Choksi and Ihsan Topaloglu on a shape optimization problem where the energy functional is given by an attractive/repulsive interaction potential in power-law form. A natural conjecture is that balls minimize this energy for large mass, and minimizers fail to exist if the mass falls below a certain critical threshold. We have partial results that support this view. (Received August 29, 2016)

51 ► Geometry

1123-51-269 **Lihan Wang***, The department of Mathematics, UC Riverside, 900 University Ave., Riverside, CA 92527. *Symplectic Laplacians, cohomology and boundary conditions.*

New elliptic operators, called symplectic Laplcians, are introduced to study cohomology of symplectic manifolds. In this talk, we focus on the study of these operators on symplectic manifolds with boundary. In order to relate these operators to cohomology, we introduce so-called symplectic boundary conditions on forms. Properties and theorems about these boundary conditions, operators and cohomology will be discussed. This is a joint work with Li-Sheng Tseng. (Received August 28, 2016)

1123-51-373 **Hao Fang*** (hap-fang@uiowa.edu), 14 McLean Hall, Iowa City, IA 52245. *Curvature Pinching and Gromov Volume of conic 2-spheres.* Preliminary report.

In this talk we discuss some results on the geometry of conic 2-spheres. Super-critical conic 2-spheres, in the sense of Troynov, are examples of unstable Kahler manifolds, which do not have a constant curvature metric. Thus, it is interesting to understand their curvature properties. We will discuss the best curvature pinching properties and the best volume bound with a uniform curvature bound. We will also explore similar problems for higher dimensional examples. This is joint work with Mijia Lai. (Received August 30, 2016)

52 ► Convex and discrete geometry

1123-52-81 **Andrew Suk*** (suk@uic.edu), Andrew Suk, 322 Science and Engineering Offices (M/C 249), 851 S. Morgan Street, Chicago, IL 60607. *On the Erdos-Szekeres convex polygon problem.*

Let $ES(n)$ be the smallest integer such that any set of $ES(n)$ points in the plane in general position contains n points in convex position. In their seminal 1935 paper, Erdos and Szekeres showed that $ES(n) \leq \binom{2n-4}{n-2} + 1 = 4^{n-o(n)}$. In 1960, they showed that $ES(n) \geq 2^{n-2} + 1$ and conjectured this to be optimal. Despite the efforts of many researchers, no improvement in the order of magnitude has been made on the upper bound over the last 81 years. In this talk, we will sketch a proof showing that $ES(n) = 2^{n+o(n)}$. We will also discuss several related open problems including a higher dimensional variant, and on mutually avoiding sets. (Received August 18, 2016)

1123-52-89 **Arnaud Marsiglietti*** (arnaud.marsiglietti@ima.umn.edu), California Institute of Technology, 1200 E. California Blvd., Computing & Mathematical Sciences, Pasadena, CA 91125, and **Matthieu Fradelizi**, **Mokshay Madiman** and **Artem Zvavitch**. *Do Minkowski averages get progressively more convex?*

Let us define, for a compact set $A \subset \mathbb{R}^n$, the Minkowski averages of A:

$$A(k) = \left\{ \frac{a_1 + \cdots + a_k}{k} : a_1, \ldots, a_k \in A \right\} = \frac{1}{k}\Big(\underbrace{A + \cdots + A}_{k \text{ times}}\Big).$$

Shapley, Folkmann and Starr (1969) proved that $A(k)$ converges to the convex hull of A in Hausdorff distance as k goes to ∞. Bobkov, Madiman and Wang (2011) conjectured that when one has convergence in the Shapley-Folkmann-Starr theorem in terms of a volume deficit, then this convergence is actually monotone. More precisely, they conjectured that $|A(k)|$ is non-decreasing, where $|\cdot|$ denotes Lebesgue measure.

In this talk, we show that this conjecture holds true in dimension 1 but fails in dimension $n \geq 12$. We also consider whether one can have monotonicity when measured using alternate measures of non-convexity, including the Hausdorff distance, effective standard deviation, and a non-convexity index of Schneider.

(Joint work with Matthieu Fradelizi, Mokshay Madiman and Artem Zvavitch.) (Received August 18, 2016)

1123-52-105 **Liran Rotem***, Vincent Hall, University of Minnesota, Minneapolis, MN 55455. *Geometric means and geometric Banach limits.*

Last year I gave a seminar talk at the IMA about geometric means of convex bodies (which was joint work with Vitali Milman). In this talk I would give a short update about this subject.

More concretely, we will construct a geometric Banach limit, which is a self-consistent way to assign a limit to any uniformly bounded sequence of convex bodies. Surprisingly, this newly defined notion of geometric mean will play a role in this construction.

In the opposite direction, we will show how to use a geometric Banach limit in order to construct a variant of the geometric mean that has some desirable properties. We will also discuss the question of uniqueness. (Received August 20, 2016)

1123-52-117 **Ohad Giladi**, **Joscha Prochno** and **Carsten Schuett*** (schuett@math.uni-kiel.de), Universitaet Kiel, Mathematisches Seminar, Kiel, Germany, and **Nicole Tomczak-Jaegermann** and **Elisabeth Werner**. *On the geometry of projective tensor products.*

We study the volume ratio of projective tensor products $\ell_p^n \otimes_\pi \ell_q^n \otimes_\pi \ell_r^n$ where $1 \leq p \leq q \leq r \leq \infty$. As a consequence of the Bourgain-Milman upper estimate on the volume ratio of Banach spaces by the cotype 2 constant, we obtain information on the cotype of $\ell_p \widehat{\otimes}_\pi \ell_q \widehat{\otimes}_\pi \ell_r$. Our results naturally generalize to k-fold projective tensor products $\ell_{p_1}^n \otimes_\pi \cdots \otimes_\pi \ell_{p_k}^n$. (Received August 21, 2016)

1123-52-119 **Jay Kangel***, jay.kangel@gmail.com. *Using Extreme Subsets to Create and Topologize Closure Systems.*

The extreme subset relation for real vector spaces is abstracted to a binary relation on a set. This notion of extremity is used to construct topologies and closure systems for the underlying set. Conversely, given a closure system on the lattice of subsets of a set, we define a notion of extremity that will generate the given closure system. Additionally we construct a notion of extremity from a connected topological space.

As an application of this material recall that even in $\mathbb{R}$ there are sets whose minimal extreme subsets are not singletons. We provide necessary and sufficient conditions for a generalization of the Krein-Milman theorem that applies to closure systems and weakens most of the assumptions of that theorem. (Received August 22, 2016)

1123-52-160 **Galyna V Livshyts*** (glivshyts6@math.gatech.edu), Georgia Institute of Technology, 686, Cherry street NW, Atlanta, GA 30332. *On an extension of Minkowski's theorem for measures.*

The Minkowski theorem asserts that every centered measure on the unit sphere which is not concentrated on any great subsphere is the surface area measure of the (unique) convex body. L_p-Brunn-Minkowski theory has called for extensions of this theorem in which the surface area measure is replaced, for example, by cone volume measure of a convex body. Borozcky, Lutwak, Stancu, Saraglou, Yang, Zhang, and many others have contributed to the study of this topic.

In this talk we discuss another natural extension of Minkowski's theorem, in which the surface area measure is replaced by the surface area measure with respect to an underlying measure in $\mathbb{R}^n$, with certain concavity and homogeneity properties. This new theorem has several consequences. Firstly, it helps to establish uniqueness and existence of a solution of certain PDE in the class of even support functions of convex sets; this result is a weaker version of the Log-Minkowski conjecture. Secondly, we use this theorem to obtain an extension of the solution to Shephard's problem for some measures, after extending the notion of a projection appropriately. Thirdly, we prove an analogue of Aleksandrov's theorem about unique determination of a symmetric convex body with areas of its projections for certain measures. (Received August 24, 2016)

1123-52-177 **Ben Li*** (bxl292@case.edu), Cleveland, OH , and **Elisabeth Werner**. *Affine invariant points for functions.*

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

We introduce them for log-concave and s-concave functions. We give new examples of affine invariant points and mappings for functions, e.g., the John function, the Loewner function and the floating function. (Received August 25, 2016)

1123-52-245 **Kyle Leland Chapman*** (kyle.chapman.topology@gmail.com). *Randomly Generating Self Avoiding Polygons Off Lattice.*

We go through a method for generating off lattice polygons which account for the thickness of the polygonal fiber being modeled. We will start by outlining what can be done when we ignore the thickness constraint, using methods of symplectic geometry. We will then show a method for accounting for the thickness during the generation process. Finally, we will go through some of the resulting data about generation times and the resulting impacts of thickness. (Received August 28, 2016)

53 ► Differential geometry

1123-53-51 **Alessandro Arsie*** (alessandro.arsie@utoledo.edu), 2800 W. Bancroft St, MS 942, Toledo, OH 43606, and **Paolo Lorenzoni** (paolo.lorenzoni@unimib.it), Via Paolo Cozzi, 55, 20125 Milano, Italy. *Complex reflection groups, logarithmic connections and bi-flat F-manifolds.*

We show that bi-flat F-manifolds can be interpreted as natural geometrical structures encoding the almost duality for Frobenius manifolds without metric.

Using this framework, we extend Dubrovin's duality between orbit spaces of Coxeter groups and Veselov's $\vee$-systems, to the orbit spaces of exceptional well-generated complex reflection groups of rank 2 and 3.

On the Veselov's $\vee$-systems side, we provide a generalization of the notion of $\vee$-systems that gives rise to a dual connection which coincides with a Dunkl-Kohno-type connection associated with such groups.

In particular, this allows us to treat on the same ground several different examples including Coxeter and Shephard groups. Remarkably, as a byproduct of our results, we prove that in some examples basic flat invariants are not uniquely defined. As far as we know, such a phenomenon has never been pointed out before. (Received August 11, 2016)

1123-53-57 **Gary R Jensen*** (gary@math.wustl.edu), Math Dept, Campus Box 1146, Washington University, One Brookings Drive, St. Louis, MO 63130, and **Emilio Musso** and **Lorenzo Nicolodi**. *Surface immersions with unique Bonnet mate.* Preliminary report.

A Bonnet mate of an immersion $\mathbf{x} : M^2 \to \mathbf{R}^3$ is a non-congruent immersion $\tilde{\mathbf{x}} : M \to \mathbf{R}^3$ with the same induced metric, $d\tilde{\mathbf{x}} \cdot d\tilde{\mathbf{x}} = d\mathbf{x} \cdot d\mathbf{x}$, and the same mean curvature function $\tilde{H} = H$. If $\mathbf{x}$ possesses a Bonnet mate, it is called a Bonnet immersion. If it possesses more than one distinct mate, it is called a proper Bonnet immersion. Bonnet (1867) proved that umbilic free proper Bonnet immersions are isothermic. Graustein (1924) proved that if $\mathbf{x}$ is isothermic and Bonnet, then it is proper Bonnet. In this talk we prove that if $\mathbf{x}$ is totally non-isothermic (to be made precise) then it has a unique Bonnet mate. (Received August 12, 2016)

1123-53-70 **Michael R Benfield**, **Helge Kristian Jenssen** and **Irina A. Kogan*** (iakogan@ncsu.edu). *Jacobians with prescribed eignvectors.* Preliminary report.

We consider a problem of constructing all possible maps from an open subset $\Omega \subset \mathbb{R}^n$ to $\mathbb{R}^n$, such that the set of eigenvector fields of the Jacobian matrix of each of these maps contains a given set of $m \leq n$ independent vector fields on Ω. Our initial motivation for considering this problem comes from the geometric study of hyperbolic conservation laws. This problem is, however, of independent geometric interest and, in turn, leads to an interesting systems of overdetermined systems of PDEs, which can be studied via classical integrability theorems and their appropriate generalizations. (Received August 15, 2016)

1123-53-112 **Changzheng Qu*** (quchangzheng@nbu.edu.cn), No. 818, Fenghua Road, Jiangbei District, Ningbo, Zhejiang 315211, Peoples Rep of China. *Symplectic Invariants for Curves and Integrable Systems in Symplectic Grassmannian Space.*

In this talk, the symplectic invariants and invariant curve flows in symplectic Grassmannian homogeneous space are discussed. The Maurer-Cartan differential invariants for the Grassmannian curves are derived by developing the equivariant moving frame method. The Grassmannian natural frame are also constructed by a gauge transformation from the Serret-Frenet frame, relating to the hyperbolic natural frame by the local Lie group isomorphism. Using the natural frames, invariant curve flows in the Grassmannian and the hyperbolic spaces are studied. It is shown that certain intrinsic curve flows induce the matrix mKdV equation on the Maurer-Cartan differential invariants. It is also shown that the non-commutative mKdV bi-Hamiltonian structure can be obtained from the Grassmannian geometric poisson brackets. This is a joint work with Prof. Junfeng Song and Prof. Ruoxia Yao. (Received August 20, 2016)

1123-53-120 **Jason Cantarella*** (jason.cantarella@gmail.com), Department of Mathematics, University of Georgia, Boyd GSRC, Athens, GA 30602, and **Bertrand Duplantier**, **Clayton Shonkwiler** and **Erica Uehara**. *Sampling equilateral space polygons.*

A crucial background task in understanding random knotting is generating correct random ensembles of space polygons. In this talk, we'll present a surprisingly simple algorithm for equilateral polygon sampling based on the toric symplectic structure of equilateral polygon space. Some of the estimates involved in computing the runtime of the algorithm are of independent interest in the theory of polygon spaces. (Received August 22, 2016)

1123-53-127 **Arlo Caine*** (jacaine@cpp.edu) and **Berit Nilsen Givens** (bngivens@cpp.edu). *Classification of Toric Poisson structures.* Preliminary report.

We consider real Poisson structures on complex toric manifolds which are generically non-degenerate, invariant under the complex torus action, and of type (1,1). We show that such structures are in one-to-one correspondence with non-degenerate Hermitian quadratic forms on the dual of lie algebra of the torus. Furthermore, the complex torus action on the open symplectic leaf of such a Poisson manifold admits a complex torus-valued momentum map if and only if the corresponding form is integral with respect to the weight lattice of the torus. We will also discuss the Poisson cohomology of such structures on toric complex surfaces. (Received August 22, 2016)

1123-53-175 **Mohammed Abouzaid** and **Luis Diogo***, ldiogo@columbia.edu. *Monotone Lagrangians on cotangent bundles.* Preliminary report.

Take a monotone Lagrangian on the cotangent bundle of an odd dimensional sphere, whose Floer homology is not trivial. We show that this Lagrangian is not Hamiltonian displaceable from either the zero section or an element of a certain 1-parameter family of monotone Lagrangian tori. The proof involves a classification of modules over the wrapped Floer homology of a cotangent fiber. If time permits, we will discuss a possible generalization to other cotangent bundles. (Received August 25, 2016)

1123-53-208 **Abraham David Smith*** (smithabr@uwstout.edu), JHSW 227, MSCS Department, University of Wisconsin-Stout, Menomonie, WI 54751. *Progress Toward a Moduli Theory of Involutive Differential Equations.* Preliminary report.

This talk is an update on an ongoing project to answer the question "what is the geometry of the space of Involutive differential equations?"

Recent reinterpretations of Guillemin Normal Form have allowed explicit calculation of the ideal of involutive tableaux/symbols with *any* Cartan characters, and the space is ripe for exploration by students and faculty alike.

In this talk, I'll summarize the technique, and show some examples of these spaces, and—if time permits—state some preliminary results about how integrable systems fit into this framework. (Received August 26, 2016)

1123-53-222 **Weiwei Wu*** (mathwww@gmail.com) and **Cheuk-Yu Mak**. *Monotone Viterbo functoriality and subcritical handle attachments.*

We will explain a version of Viterbo functoriality in monotone symplectic manifolds for both the open and closed string cases. This implies the invariance of Fukaya category of an open monotone symplectic manifold under subcritical handle attachments. This is a joint work with Cheuk-Yu Mak. (Received August 26, 2016)

1123-53-242 **Bahar Acu*** (baharacu@ucla.edu). *The Weinstein Conjecture for Iterated Planar Open Books.*

The Weinstein conjecture states that, on a compact contact manifold, any Reeb vector field carries at least one periodic orbit. The conjecture was proven for all closed 3-dimensional manifolds by Taubes, but it is still open in higher dimensions. In this talk, we show that a $(2n+1)$-dimensional Weinstein fillable contact manifold supporting an iterated planar open book decomposition satisfies the Weinstein conjecture. (Received August 28, 2016)

1123-53-273 **Qingchun Ji** and **Ke Zhu*** (ke.zhu@mnsu.edu). *Solvability of Dirac type equations and automatic transversality of holomorphic curves.* Preliminary report.

We develop a weighted L^2-method for the (half)-Dirac equation. For Dirac bundles over Riemann surfaces, we give a sufficient condition for the solvability of the Dirac equation in terms of a curvature integral. Applying this to the Dolbeault-Dirac operator, we establish an automatic transversality criteria for holomorphic curves in Kahler manifolds. This is a joint work with Qingchun Ji. (Received August 29, 2016)

1123-53-278 **Chuu-Lian Terng**, Department of Mathematics, University of California at Irvine, Irvine, CA 92697, and **Zhiwei Wu*** (wuzhiwei@nbu.edu.cn), Faculty of Science, Ningbo University, Ningbo, Zhejiang 315211, Peoples Rep of China. *Isotropic curve flows on* $\mathbb{R}^{n+1,n}$.

In this talk, we will give a systematic way to construct hierarchies of isotropic curve flows, which give natural geometric interpretations of the KdV-type hierarchies associated to the affine Kac-Moody algebra $\hat{B}_n^{(1)}$ and $\hat{A}_{2n}^{(2)}$. Bi-Hamiltonian structures and conservation laws for isotropic curve flows are given. And we will also construct Bäcklund transformations for these curve flows and give an algorithm to construct infinitely many families of explicit solutions. (Received August 29, 2016)

1123-53-286 **Jason Cantarella**, **Thomas Needham** and **Clayton Shonkwiler*** (clay@shonkwiler.org), Department of Mathematics, Colorado State University, Campus Delivery 1874, Fort Collins, CO 80523, and **Gavin Stewart**. *What's the probability that a random triangle is obtuse? or: What the heck is a "random triangle", anyway?*

"Three Points are taken at random on an infinite Plane. Find the chance of their being the vertices of an obtuse-angled Triangle."

This is the text of Lewis Carroll's Pillow Problem #58, from 1884. Of course, the obvious probabilistic interpretation of the problem is invalid, since the uniform distribution on the plane is not a probability measure. Various authors have solved the problem when the points are taken from a Gaussian distribution, or uniformly from some bounded, convex domain, but this seems unnatural: surely the problem Carroll is getting at is that of choosing random *triangles*, not random points.

As Stephen Portnoy observed in 1994, the problem of choosing random triangles is problematic largely due to the apparent lack of a natural transitive group action on the set of triangles. In this talk, we show how to construct a measure on the set of triangles with exactly such an action by identifying triangle space with the projective plane. We can then give a precise answer to Carroll's question and indeed answer a number of related questions about planar n-gons. This approach also generalizes to random polygons in space, a subject near and dear to Ken Millett's heart. (Received August 29, 2016)

1123-53-288 **Ekaterina Shemyakova*** (shemyake@newpaltz.edu), 1 Hawk dr., SUNY New Paltz, Department of Mathematics, New Paltz, NY 12561. *Darboux transformations on the superline, Berezinians, and densities.* Preliminary report.

We consider differential operators on the superline, i.e., a supermanifold of dimension 1|1. We show that every non-degenerate operator can be written in terms of 'super Wronskians' (which are Berezinians). We apply this to prove that every Darboux transformation corresponds to an invariant subspace of the source operator and, upon a choice of a basis in this subspace, is expressed by a super-Wronskian formula. (On the way, we obtain non-trivial analogs of classical row and column expansions for Berezinians.) We also discuss a generalization to differential operators acting on the algebra of densities. (Received August 29, 2016)

1123-53-302 **Yi Lin*** (yilin@georgiasouthern.edu), 65 Georgia Ave. Room 2306, Statesboro, 30458. *Convexity properties of Hamiltonian transversely symplectic manifolds.*

In this talk, we introduce the notion of a Hamiltonian action on a transversely symplectic foliation. This provides a framework to study the Hamiltonian actions on many interesting singular (possibly non-Hausdorff) symplectic spaces, such as symplectic orbifolds, symplectic quasi-folds (by E. Prato), and the leaf spaces of characteristic Reeb foliations in contact and co-symplectic geometries. We explain that under reasonable conditions, the components of a moment map introduced by us are still Morse-Bott functions with even indexes. This in particular leads to a foliated version of the Atiyah-Guillemin-Sternberg-Kirwan convexity theorem. This talk is based on a joint work with R. Sjamaar. (Received August 29, 2016)

1123-53-328 **Jean Gutt*** (jgutt@uga.edu), Department of Mathematics, Boyd Graduate Studies Research Center, University of Georgia, Athens, GA 30602, and **Michael Hutchings** (hutching@math.berkeley.edu), Dept. of Mathematics, University of California, Berkeley, 970 Evans Hall #3840, Berkeley, CA 94720. *Symplectic capacities from positive S^1-equivariant symplectic homology.*

We use positive S^1-equivariant symplectic homology to define a sequence of symplectic capacities c_k for star-shaped domains in $\mathbb{R}^{2n}$. These capacities are conjecturally equal to the Ekeland-Hofer capacities, but they satisfy axioms which allow them to be computed in many more examples. In particular, we give combinatorial formulas for the capacities c_k of any "convex toric domain" or "concave toric domain". As an application, we determine optimal symplectic embeddings of a cube into any convex or concave toric domain. We also extend the c_k to functions of Liouville domains which are almost but not quite symplectic capacities. (Received August 29, 2016)

1123-53-339 **Thomas A Ivey*** (iveyt@cofc.edu) and **Annalisa Calini**. *Integrable Flows for Curves in the Pseudoconformal 3-sphere.* Preliminary report.

The pseudoconformal group $SU(2,1)$ preserves a mixed-signature Hermitian form on C^3, and thus acts on the projectivized null cone, which is diffeomorphic to S^3 and carries an invariant CR-structure. In this preliminary report, we develop pseudoconformal moving frames and curvatures for Legendrian curves in the sphere, and for curves transverse to the contact distribution. One may define an invariant arclength for generic curves of either class, and in each case we give general forms for non-stretching geometric evolution equations. Moreover, for

Legendrian curves we show that there is a sequence of local flows that induce the Kaup-Kuperschmidt hierarchy at the level of curvature.

This hierarchy was also realized in earlier work with Mari Beffa on curves in 3-dimensional centroaffine geometry (defined by the action of the related group $SL(3,R)$) as a special case of a family of flows inducing the Boussinesq hierarchy. Hence one expects the Boussinesq system to be realized in the pseudoconformal setting by a flow for transverse curves, which have a pair of functional invariants. In fact, we show that there exists at least one flow for such curves inducing an integrable evolution for the curvatures, but appearance of the Boussinesq is so far elusive. (Received August 29, 2016)

1123-53-347 **Victor Mouquin*** (mouquinv@math.toronto.edu). *The Fock-Rosly Poisson structure as defined by a quasitriangular r-matrix.*

The moduli space of flat G-connections over a Riemann surface Σ is well known to admit a natural Poisson structure. If one looks at principal G-bundles trivialized over finitely many points $v_1, ..., v_n$ lying in the boundary of Σ, Fock and Rosly have constructed a Poisson structure on the corresponding moduli space of flat connections which depends on the choice of an r-matrix for each point v_j. We show that this Fock-Rosli Poisson structure is defined by a quasitriangular r-matrix, and is an example of a so-called mixed product Poisson structure defined by actions of pairs of dual Lie bialgebras. (Received August 29, 2016)

1123-53-382 **H. Andersen*** (and02626@umn.edu). *Hard Lefschetz Property of Symplectic Structures on Compact Kähler Manifolds.* Preliminary report.

In 1996, B. Khesin and D. McDuff questioned whether or not there exists a path of symplectic forms $\{\omega_t\}$ such that the dimension $h^k_{hr}(M,\omega)$ of the space of symplectic harmonic k-forms varies along t. Recently, Y. Cho provided an answer by constructing a compact, simply-connected Kähler manifold (M, J, ω) of complex dimension 3, which possesses a symplectic form σ that does not satisfy the hard Lefschetz property yet is symplectically deformation equivalent to the Kähler form ω; the first example of its kind. We generalize the construction to complex dimension 4, and consider further applications. (Received August 30, 2016)

1123-53-390 **Jun Li***, 1070 27th Ave SE, Apt B, Minneapolis, MN 55414, and **Tian-Jun Li** and **Weiwei Wu**. *symplectomorphism gorup of rational 4-manifold.*

We study topology of symplectomorphism gorup of rational 4-manifold. In particular, connectedness results for Torelli group of 5 blow up of $\mathbb{C}P^2$ for a generic form is established. (Received August 30, 2016)

54 ► General topology

1123-54-37 **Alexander Y Grosberg*** (ayg1@nyu.edu), Department of Physics, New York University, 4 Washington Place, New York, NY 10003. *Unconcatenated unknots and their minimal surfaces.*

Statistical mechanics of unconcatenated unknots is speculated to have relevance in the physics of genome folding. We look at the problem from the point of view of one-sided minimal surfaces which we computationally span on the various unknots. We found that minimal surface area for a freely fluctuating isolated unknot scales as N^x, with $x \approx 1.25$, consistent with the idea that $x = 2\nu$, where $\nu \approx 0.588$ is the well known Flory exponent for self-avoiding walks, and $N \gg 1$ is the number of segments in the loop. By contrast, similar problem for many unconcatenated unknots sharing tigt volume (so called melt of rings) we find a significantly smaller area index, $x \approx 1$, consistent with the idea of a double folded contour forming an effective tree. (Received August 05, 2016)

1123-54-54 **Laura K. Plunkett*** (plunkett@hnu.edu), Holy Names University, 3500 Mountain Blvd., Oakland, CA 94619. *Size and knotting results for open chains, generated ergodically, with arbitrarily large excluded volume.* Preliminary report.

We will briefly describe a new algorithm, the reflection method, to generate off-lattice random walks of specified, though arbitrarily large, thickness in $\mathbb{R}^3$. We will describing the complex relationship between the presence and nature of knotting and size, thickness and shape of the random walk. We will extend the current understanding of excluded volume by expanding the range of analysis of how the squared radius of gyration scales with length and thickness. We will also show the profound effect of increasing thickness on the probability of knot formation. (Received August 12, 2016)

1123-54-189 **David A. B. Hyde*** (dabh@stanford.edu), 353 Serra Mall, Room 205, Stanford, CA 94305. *Quantifying the Complexity of Ideal Knots.*

In this talk, we review a recent paper (Hyde et al. 2015) that presents multiple ways to measure the complexity of ideal knots. We use disk matrices to define "knotting fingerprints" that provide fine-grained insights into the local knotting structure of ideal knots. From this fine structure and an analysis of the associated planar graph, one can define a measure of knot complexity using the number of independent unknotting pathways from the global knot type as the knot is trimmed progressively to a short arc unknot. A specialization of the Cheeger constant provides another measure of complexity as a measure of constraint on these independent unknotting pathways. Furthermore, the structure of the knotting fingerprint supports a comparison of the tight knot pathways to the unconstrained unknotting pathways of comparable length. (Received August 26, 2016)

1123-54-378 **Kathleen Hake*** (khake@math.ucsb.edu). *Polygonal Knot Space and Symplectic Geometry.* Preliminary report.

A n-sided polygon in $\mathbb{R}^3$ can be described as a point in $\mathbb{R}^{3n}$ by listing in order the coordinates of it vertices. In this way, the space of n-sided polygons embedded in $\mathbb{R}^3$ is a manifold in which points correspond to piecewise linear knots and paths correspond to isotopies which preserve the geometric structure of these knots. Restricting to polygons of unit edge length gives a submanifold consisting of equilateral knots. We will discuss some aspects of the topology of the space of equilateral hexagons as well as its symplectic structure. (Received August 30, 2016)

55 ► *Algebraic topology*

1123-55-72 **Hiro Lee Tanaka***, Math Department, 1 Oxford St, Cambridge, MA 02138. *Cobordism theory for Lagrangians and Homological mirror symmetry over spectra.*

We'll talk about a project to enrich homological mirror symmetry over the sphere spectrum. While there are at least three ways to do this, we'll talk about a way involving a symplectic and non-compact version of cobordism theory. A lot of new math comes up because this cobordism theory doesn't obviously yield to classical, Pontrjagin-Thom type methods. (Received August 15, 2016)

1123-55-82 **Charles Rezk*** (rezk@illinois.edu), Urbana, IL. *Looijenga line bundles and complex analytic elliptic cohomology.* Preliminary report.

We present some calculations, which (1) show how the moduli stack of complex analytic elliptic curves is encoded in the cohomology of the moduli space of smooth genus 1 surfaces equipped with a line bundle which admits a flat connection, and (2) show how certain natural line bundles over d-fold products of complex analytic curves (Looijenga's line bundles), are encoded in a similar way by moduli of $U(1)^d$-bundles with prescribed vanishing of a degree four characteristic class. Then we speculate recklessly on the relevance of these calculations to the construction of complex analytic elliptic cohomology, in the sense of Grojnowski. (Received August 18, 2016)

1123-55-90 **J. Javier Zúñiga*** (zuniga_jj@up.edu.pe), Centro de Investigación, Jr. Gral Sánchez Cerro 2050, Jesús María, Lima, Lima Lima21, Peru. *Semistable Graph Homology.* Preliminary report.

Using an orbicell decomposition of a Deligne-Mumford like compactificiation of the decorated moduli space of Riemann surfaces a chain complex based on semistable ribbon graphs is constructed which is an extension of Konsevich's graph homology and can provide a combinatorial solution to the Quantum Master Equation. (Received August 18, 2016)

1123-55-98 **Ben Knudsen*** (knudsen@math.harvard.edu), Department of Mathematics, Harvard University, 1 Oxford St, Cambridge, MA 02138. *Higher enveloping algebras.*

We provide Lie algebras with enveloping algebras over the operad of little n-dimensional disks for any choice of n, and we give two complementary descriptions of these objects. The first description is an abstract characterization by a universal mapping property, which witnesses the higher enveloping algebra as the value of a left adjoint in an adjunction, while the second is a result analogous to the classical Poincare-Birkhoff-Witt theorem, giving a concrete identification of this algebra in terms of Lie algebra homology. Our construction draws inspiration from the work of Beilinson-Drinfeld on chiral algebras and has applications to the study of configuration spaces. (Received August 19, 2016)

1123-55-129 **Kirsten Graham Wickelgren*** (kwickelgren3@math.gatech.edu), School of Math, Georgia Tech, 686 Cherry Street, Atlanta, GA 30332. *Arithmetic enrichments of curve counts.*

We prove that the local A1-Brouwer degree equals the quadratic form of Eisenbud–Khimshiashvili–Levine, answering a question posed by David Eisenbud in 1978. As an application, we investigate arithmetic enrichments of curve counts. This is joint work with Jesse Kass. (Received August 22, 2016)

1123-55-150 **Gabriel C. Drummond-Cole***, Mathematical Science Building Room 108, POSTECH, Cheongam-ro, Nam-gu, Pohang, Gyeongbuk 37673, South Korea, and **Ben Knudsen**, Department of Mathematics, Harvard University, 1 Oxford St., Cambridge, MA 02138. *Betti numbers for configuration spaces of surfaces.*

Explicit formulas will be given for the Betti numbers of unordered configurations of all surfaces of finite type. (Received August 23, 2016)

1123-55-166 **Nikita S. Markarian*** (nikita.markarian@gmail.com). *Factorization homology and the Kontsevich integral.*

I discuss how factorization homology of Weyl algebras may be used in calculations of the Kontsevich integral. (Received August 25, 2016)

1123-55-184 **Andrew Salch*** (asalch@math.wayne.edu). *Complex multiplication and homotopy.*

This talk will cover recent results in the theory of formal groups with complex multiplication: their moduli, their associated cohomological and L-function-theoretic data, and their applications to computational problems in the stable homotopy groups of spheres and other finite spectra. (Received August 25, 2016)

1123-55-203 **Ben C Ward*** (bward@math.su.se). *Six operations formalism for generalized operads.*

The first part of this talk will present an analogy between sheaves and (generalizations of) operads using the language of Feynman categories. This analogy suggests several novel constructions and relationships which we will realize in the second part of the talk. In particular we will establish intertwining theorems which explain how combinatorial operations on graphs influence respective notions of Koszul duality. (Received August 26, 2016)

1123-55-206 **Jordan S. Ellenberg**, **TriThang Tran** and **Craig Westerland*** (cwesterl@umn.edu). *Quantum shuffle algebras and the homology of braid groups.*

We study the homology of braid groups with coefficients in the exponential system coming from tensor powers of a Yetter-Drinfeld module V. One specific example of interest gives rise to the homology of Hurwitz moduli spaces of branched covers of the affine line. We identify these homology groups with the cohomology algebra $Ext_A(k,k)$ of the quantum shuffle algebra A coming from V. Furthermore, we give criteria for producing a soft exponential bound on the growth of these homology groups. (Received August 26, 2016)

1123-55-216 **Daniel Berwick-Evans*** (danbe@illinois.edu). *Equivariant elliptic cohomology and characters of loop group representations.* Preliminary report.

I'll describe a geometric model for equivariant elliptic cohomology with complex coefficients in terms of sections of line bundles on the moduli stack of G-bundles on 2|1-dimensional super tori. Path integral techniques from gauge theory pick out preferred sections of these bundles. Following the work of Looijenga and Grojnowski, I'll explain how to identify such sections with the characters of loop group representations. On the cohomological side, these sections define elliptic Euler classes for G-bundles. Time permitting, I'll comment on how this geometry is related to elliptic formal group laws and the string orientation of topological modular forms. This is joint work with Arnav Tripathy. (Received August 26, 2016)

1123-55-219 **Agnes Beaudry**, **Mark Behrens*** (mbehren1@nd.edu), **Prasit Bhattacharya**, **Dominic Culver**, **Doug Ravenel** and **Zhouli Xu**. *Perspectives on the telescope conjecture.* Preliminary report.

Mahowald-Ravenel-Schick attempted to disprove the telescope conjecture using the localized Adams spectral sequence, and described a very precise hypothesis. I will describe work, with Beaudry-Bhattacharya-Culver-Ravenel-Xu, where we consider what the unlocalized tmf-resolution, and the motivic localized Adams spectral sequence have to say about the telescope. While these tools alone don't seem to resolve the conjecture, they do make the MRS hypothesis eminently believable. (Received August 26, 2016)

1123-55-223 **David Gepner*** (dgepner@math.purdue.edu), 150 N University, West Lafayette, IN 47907.
On the elliptic cohomology of compact Lie groups. Preliminary report.

We will survey some known results and conjectures on the elliptic cohomology of compact Lie groups. (Received August 26, 2016)

1123-55-226 **Christopher L Rogers*** (chrisrogers@unr.edu), Department of Mathematics and Statistics, University of Nevada, Reno, 1664 N. Virginia Street, Reno, NV 89557, and **Chenchang Zhu** (chenchang.zhu@gmail.com), Mathematisches Institut, Georg-August-Universität Göttingen, Bunsenstraße 3–5, 37073 Göttingen, Germany.
Integrating quasi–isomorphisms between L_∞-algebras.

Lie ∞-groupoids are simplicial Banach manifolds which satisfy conditions similar to the "horn filling" conditions for Kan complexes in the theory of simplicial sets. Lie ∞-groupoids with only one object are called "Lie ∞-groups". These have been used to construct diffeo-geometric models for the higher stages of the Whitehead tower of the orthogonal group. With this goal in mind, A. Henriques developed a smooth analog of Sullivan's realization functor from rational homotopy theory which produces a Lie ∞-group from a finite type L_∞-algebra.

In this talk, I will describe joint work in progress with C. Zhu (Göttingen) in which we develop a user–friendly homotopy theory for Lie ∞-groups that is compatibile with the homotopy theory of L_∞-algebras. In particular, we show that Henriques' integration functor sends quasi-isomorphisms between finite–type L_∞-algebras to weak equivalences between their corresponding Lie ∞-groups. (Received August 27, 2016)

1123-55-394 **Zhen Huan*** (huan2@illinois.edu). *Quasi-elliptic cohomology.*

Quasi-elliptic cohomology is closely related to Tate K-theory. It can be interpreted by orbifold loop spaces and expressed in terms of equivariant K-theories. We formulate the complete power operation of this theory. Applying that we proved the finite subgroups of Tate curve can be classified by the Tate K-theory of symmetric groups modulo a certain transfer ideal. Moreover, we construct a G-orthogonal spectra weakly representing quasi-elliptic cohomology. Unfortunately, our construction does not arise from a global spectra; thus, we consider a new formulation of global stable homotopy theory that contains quasi-elliptic cohomology. (Received August 30, 2016)

1123-55-396 **Charles Rezk*** (rezk@illinois.edu), Department of Mathematics, 273 Altgeld Hall, MC-382, 1409 W. Green Street, Urbana, IL 61801. *On some approximations to homotopy theory.*

Homotopy theory arose as the study of continuous maps between spaces up to continuous deformation. It has surprisingly been found to be an essential concept in many new developments in algebra and geometry, under the guise of higher categories. However, the classical problems in topology remain. Many basic questions are difficult if not intractable: for instance, the problem of computing higher homotopy groups of spheres.

A better approach is to describe certain approximations to classical homotopy. One highly successful example is the "rational homotopy theory" of Quillen and Sullivan, which gives an effective method for computing homotopy groups modulo torsion; or equvialently, after inverting primes. There is a generalization of this point of view, called "chromatic homotopy theory" where instead of inverting primes, we invert classes of maps called "v_n-self maps". I'll give an introduction to some of these ideas, and explain some recent work (joint with Mark Behrens) which provides a chromatic analogue of some rational homotopy constructions. (Received August 30, 2016)

57 ► Manifolds and cell complexes

1123-57-22 **Jennifer Hom**, **Adam Simon Levine** and **Tye Lidman*** (tlid@math.ncsu.edu). *Concordance and 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)

1123-57-25 **Micah Chrisman*** (mchrisma@monmouth.edu). *Virtual Knot Concordance and the Band-Pass Move.*

Two long virtual knots are concordant if one may be obtained from the other by a finite sequence of extended Reidemeister moves, births b, saddles s, and deaths d such that $\#b - \#s + \#d = 0$. A long virtual knot is slice if it is concordant to the long unknot. It is ribbon if it has a concordance with the unknot containing no births.

Kauffman showed that every classical knot is band-pass equivalent to the unknot or the trefoil. All classical ribbon knots are band-pass equivalent to the unknot. We show that there are long virtual ribbon knots that are not band-pass equivalent to either the unknot or the trefoil. Further we establish some elementary facts about the long virtual knot concordance group. Some joint work with H. U. Boden and R. I. Gaudreau on slice virtual knots is also discussed. (Received August 03, 2016)

1123-57-42 **Kenneth C Millett*** (millett@math.ucsb.edu), Department of Mathematics, UCSB, Santa Barbara, CA 93106. *More knots in knots: a study of classical knot diagrams.*

The structure of classical minimal prime knot presentations suggests that there are often, perhaps always, sub segments that present either the trefoil or the figure-eight knot. In joint work with Alex Rich, we undertook a comprehensive study of the sub knots of the minimal prime knot presentations through 15 crossings and that shows that this is always the case for these knot presentations. Among this set of knots, there are only 109, or 0.3 percent, that do not contain a trefoil knot. On average, the 14 crossing prime knot presentations contain 9 percent trefoils and 3.5 percent figure-eight knots among the average of 27.4 distinct types of sub knots. We have identified several infinite minimal alternating prime knot families that do not contain trefoils but always contain figure-eight knots. We report the detailed statistics of sub knots of prime knots and, using knot presentation fingerprints, illustrate the complex character of the sub knots of these classic minimal prime knot presentations. (Received August 09, 2016)

1123-57-45 **David Bachman**, **Ryan Derby-Talbot*** (rdt@questu.ca) and **Eric Sedgwick**. *Computing Heegaard genus is NP-hard.* Preliminary report.

We show the problem of determining when a 3-manifold admits a Heegaard splitting of genus less than or equal to g is NP-hard. We do this by converting the calculation of the Heegaard genus of certain toroidal 3-manifolds into a satisfiability question for Boolean formulas in conjunctive normal form. The latter problem is known to be NP-complete. (Received August 09, 2016)

1123-57-55 **Scott A. Taylor***, scott.taylor@colby.edu, and **Maggy Tomova**. *Additive Invariants of Knots, Links, and Graphs in 3-manifolds.*

Bridge number is a classical knot invariant which is additive under connected sum. Tunnel number and Width are two other knot invariants which have a more complicated relationship to additivity. I'll describe two new families of knot (and link and graph) invariants, both related to bridge number, which are additive under connected sum, detect the unknot, and shed light on tunnel number and width. This is joint work with Maggy Tomova. (Received August 12, 2016)

1123-57-68 **Eric J Rawdon*** (ejrawdon@stthomas.edu), University of St. Thomas, 2115 Summit Ave, OSS 201, Saint Paul, MN 55105. *Supercoiling can help type II topoisomerases to unknot and unlink DNA.*

Type II topoisomerases have been shown to be 10 to 100 times more effective than random crossing changes in unknotting and unlinking DNA. The exact mechanism for such efficiency is a problem of modern curiosity. Buck and Zechiedrich proposed that type II topoisomerases might perform strand passage preferably at hooked juxtapositions. Simulations have shown that strand passage at such hooked juxtapositions on random knot configurations do preferably simplify knotting. Furthermore, Witz et al. showed that supercoiling induces a tightening of the knotted regions during simulations. In our work, we show how supercoiling creates special geometrical attributes in simulated knotted and linked DNA that could be identified by topoisomerases. This is joint work with Julien Dorier, Dusan Racko, Kenneth Millett, and Andrzej Stasiak. (Received August 15, 2016)

1123-57-87 **Candice R Price** and **Isabel K Darcy*** (idarcybiomath@gmail.com). *Application of a skein relation to difference topology experiments.*

The protein topoisomerase can change the knot type of circular DNA by breaking a segment of DNA, allowing a second segment to pass through the break before resealing the break. This results in a crossing change. Recombinases are another family of proteins which can knot circular DNA. Their operation is mathematically equivalent to smoothing a crossing. A skein quadruple is a set of four knot diagrams which differ at exactly one crossing. In the quadruple, (K_+, K_-, K_D, K_I), the knots K_+, K_- differ by a crossing change which may represent topoisomerase action. The knots K_D and $K_I$are obtained by the oriented and unoriented smoothings, respectively, of that crossing which represents recombinase action. Both recombinases and topoisomerases have been used in an experimental technique called difference topology to probe the topological conformation of DNA bound by proteins of interest. The types of knots produced by topoisomerase and recombinase will

differ depending on whether the DNA is bound by other proteins. This difference is used to solve for the shape of DNA bound by proteins of interest. The skein quadruple can be used to determine what is the most efficient experimental set-up for difference topology experiments. Two published experiments will be analyzed. (Received August 18, 2016)

1123-57-123 **Carolyn Otto*** (ottoa@uwec.edu), WI, and **Christopher Davis**, **Taylor Martin** and **Jung Hwan Park**. *Every Genus 1 Algebraically Slice Knot is 1-Solvable.*

In the 1990's Cochran, Orr, and Teichner introduced a filtration of knot concordance indexed by half integers called the solvable filtration. Since its introduction, this filtration has been a convenient setting for many advances in knot concordance. There are now many results in the literature demonstrating the difference between the n'th and (n.5)'th terms in this filtration, but none regarding the difference between the (n.5)'th and (n+1)'st. In this talk we will prove that every genus one (0.5)-solvable knot is 1-solvable. We will also provide a new sufficient condition for a high genus (0.5)-solvable knot to be 1-solvable and close with some possible candidates for knots which are (0.5)-solvable but not 1-solvable. (Received August 22, 2016)

1123-57-133 **Christian R Millichap*** (cmillich@linfield.edu), 1925 NE Hembree St., McMinnville, OR 97128, and **William Worden** (tue83379@temple.edu). *Commensurability classes of hyperbolic knot and link complements.*

In general, it is a difficult problem to determine if two manifolds are commnensurable, i.e., share a common finite sheeted cover. Here, we are interested in examining the commensurability class of a hyperbolic 3-manifold M: the set of all manifolds commensurable with M. In this talk, we will examine some combinatorial and geometric approaches to analyzing commensurability classes of hyperbolic 3-manifolds. In particular, we will discuss current work done with Worden to show that the only commensurable hyperbolic 2-bridge link complements are the figure-eight knot complement and the 6_2^2 link complement. (Received August 22, 2016)

1123-57-137 **Mark Brittenham***, Department of Mathematics, Avery 203, University of Nebraska, Lincoln, NE 68588-0130. *Determining unknotting numbers.* Preliminary report.

We discuss the implementation of a random search for the unknotting numbers of knots in the 3-sphere, using the notion of knot adjacency. We also consider the implications of this search for knots whose unknotting numbers have not (yet) been determined in this way. (Received August 22, 2016)

1123-57-152 **Charles Frohman***, Department of Mathematics, The University of Iowa, Iowa city, IA 52245, and **Joanna Kania-Bartoszynska** and **Thang Le**. *The Unicity Conjecture for the Kauffman bracket skein algebra.*

Let F be finite type surface (including closed surfaces). Let ζ be a root of unity. The Kauffman bracket skein algebra of F at ζ, $K_\zeta(F)$, is an algebra built out of the vector space whose basis is isotopy classes of framed links in $F \times I$, modulo the Kauffman bracket skein relations, with the variable A set equal to ζ. An irreducible representation of $K_\zeta(F)$ is an onto algebra homomorphism $\phi : K_\zeta(F) \to M_n(\mathbb{C})$, where $M_n(\mathbb{C})$ is the algebra of $n \times n$ matrices with coefficients in the complex numbers for some n. Bonahon and Wong prove that such a representation has a **classical shadow** which consists of a trace equivalence class of homomorphisms $\rho : \pi_1(F) \to SL_2(\mathbb{C})$ and a choice of a complex number for each puncture of the surface. They conjecture that there is a generic set of shadows for which the representation is determined up to equivalence by its shadow. We prove this to be the case.

Our approach is structural, and it follows from the fact that the Kauffman bracket skein algebra is **almost Azumaya**. That is there is $c \neq 0$ the center of $K_\zeta(F)$ so that the result of localizing $K_\zeta(F)$ at the powers of c is an Azumaya algebra. (Received August 24, 2016)

1123-57-158 **Stu Whittington*** (swhittin@chem.utoronto.ca), University of Toronto, Toronto, Ontario M5S 3H6, Canada. *Counting self-entangled surfaces.* Preliminary report.

Just as simple closed curves can be knotted in 3-space and arcs can have self- entanglement complexity, so surfaces can be self-entangled in various ways. If a surface has a boundary that boundary can be knotted in 3-space. 2-spheres can be knotted in 4-space and 2-manifolds without boundary can show various kinds of entanglement complexity depending on the dimension of the ambient space. Several rigorous results – some old and some new – will be presented. This is joint work with Mashid Atapour, Chris Soteros, De Witt Sumners and Buks van Rensburg. (Received August 24, 2016)

1123-57-165 **Seungwon Kim*** (skim2@gradcenter.cuny.edu). *A topological characterization of toroidally alternating knots.* Preliminary report.

We extend Howie's characterization of alternating knots to give a topological characterization of toroidally alternating knots, which were defined by Adams. We provide necessary and sufficient conditions for a knot to be toroidally alternating. We also give a topological characterization of almost-alternating knots which is different from Ito's recent characterization. (Received August 30, 2016)

1123-57-180 **J. Scott Carter*** (carter@southalabama.edu), Department of Mathematics and Statistics, Mobile, AL 36688. *Using globular to study higher dimensional knottings.* Preliminary report.

The program globular is an implementation of higher categorical principles to a geometric context. So for example the 2-category of 2-tangles can be studied via knotted surfaces. In addition surface braids, and 3-dimensional braids can be created. In this talk, I will demonstrate several examples of the use of globular, the implementation of the movie moves, and the implementation of the braid movie moves. (Received August 25, 2016)

1123-57-190 **Sumeyra Sakalli*** (sakal008@umn.edu). *The new symplectic 4-manifolds with positive signature.* Preliminary report.

We will construct new symplectic 4-manifolds with positive signature by using line arrangements in $\mathbb{CP}^2$. On the way, we will remind the basic features of the Galois coverings. If time permits, we will also provide new minimal, symplectic 4-manifolds between the Noether and half Noether lines. This is a joint work with A. Akhmedov. (Received August 26, 2016)

1123-57-205 **Anar Akhmedov*** (akhmedov@umn.edu), Minneapolis, MN 55455, and **Weiyi Zhang**. *New symplectic 4-manifolds with $b_2^+ = 1$.* Preliminary report.

We will discuss the topology of symplectic 4-manifolds with $b_2^+ = 1$ and provide various constructions of symplectic 4-manifolds and Lefschetz fibrations with $b_2^+ = 1$ and prescribed c_1^2. This talk is based on two separate joint works Weiyi Zhang and Naoyuki Monden. (Received August 26, 2016)

1123-57-213 **Keiko Kawamuro***, 14 MacLean Hall, Iowa City, IA 52242, and **Tetsuya Ito**. *Positive factorizations of symmetric mapping classes.*

We study a question by Etnyre and Van Horn-Morris; whether a symmetric mapping class admitting a positive factorization is a lift of a quasi-positive braid. We give an affirmative answer for certain mapping classes. (Received August 26, 2016)

1123-57-215 **Josef G Dorfmeister*** (josef.dorfmeister@ndsu.edu). *Existence and Stability of Symplectic Configurations.*

Pseudoholomorphic curve techniques have been very successful at producing symplectic submanifolds (or configurations thereof) in particular for GW-effective classes. However, when considering curves of negative self-intersection, in particular in rational and ruled manifolds, many of these techniques are not applicable.

In this talk I will describe some recent results for negative curves in symplectic 4-manifolds. (Joint work with Tian-Jun Li and Weiwei Wu) (Received August 26, 2016)

1123-57-218 **Yuanan Diao**, **Pengyu Liu*** (pliu10@uncc.edu) and **Gabor Hetyei**. *The braid index of homogeneous braids.* Preliminary report.

It is well known that any link can be represented by the closure of a braid. The minimum number of strands needed in a braid whose closure represents a given link is called the braid index of the link. In an earlier paper, the authors showed that if a link has a reduced alternating diagram which is also the closure of a braid on n strands, then the braid index of the link is exactly n. In this talk we present a new result that generates the above result to the class of homogeneous braids. (Received August 26, 2016)

1123-57-225 **Anar Akhmedov*** (akhmedov@umn.edu), Minneapolis, MN 55455, and **Naoyuki Monden** (monden@isc.osakac.ac.jp). *Genus two Lefschetz fibrations via lantern substitution.* Preliminary report.

We will construct a family of genus two Lefschetz fibrations $X(n)$ over two sphere by applying a single lantern substitution to the twisted fiber sums of Matsumoto's genus two Lefschetz fibration. We will compute the fundamental group of $X(n)$ and show that it is isomorphic to the trivial group if $n = -3, -1$, $\mathbb{Z}$ if $n = -2$, and $\mathbb{Z}_{|n+2|}$ for all integers $n \neq -3, -2, -1$. This is a joint work with Naoyuki Monden. (Received August 27, 2016)

1123-57-264 **Nur Saglam*** (sagla004@umn.edu), 1173, Fifield Avenue, S1, St. Paul, MN 55108. *Constructions of new Lefschetz fibrations using cyclic group actions.* Preliminary report.

Using the cyclic group actions, we construct the families of Lefschetz fibrations over $\mathbb{S}^2$. We also obtain more families of Lefschetz fibrations gluing these examples. This is a joint work with Anar Akhmedov. (Received August 28, 2016)

1123-57-295 **Amey Kaloti*** (amey-kaloti@uiowa.edu), 14 Maclean Hall, Iowa City, IA 52242, and **Bulent Tosun** (btosun@uiowa.edu). *Hyperbolic 3 manifolds not admitting fillable contact structures.*

We exhibit an infinite family of hyperbolic rational homology 3-spheres which do not admit any fillable contact structures. We also note that most of these manifolds do admit tight contact structures. Joint work with Bulent Tosun. (Received August 29, 2016)

1123-57-298 **Uta Ziegler*** (uta.ziegler@wku.edu), Bowling Green, KY 42101, and **Y Diao**, **C. Ernst** and **E. Rawdon**. *Geometric Properties of Knotted Random Polygons in Confinement.*

In this talk we study the properties of geometric quantities such as total curvature, total torsion, average crossing number and writhe, of random polygons in confinement. Specifically, while some of results fall in line with what has been observed in the studies of the unconfined random polygons, a few surprising results have emerged from our study, showing some properties that are unique due to the effect of confinement. (Received August 29, 2016)

1123-57-299 **Jennifer Schultens*** (jcs@math.ucdavis.edu), Dept of Math, UC Davis, 1 Shields Ave, Davis, CA 95616. *The Kakimizu complexes of select 3-manifolds.*

The Kakimizu complex of a knot is fairly well understood. It's vertices consist of isotopy classes of minimal genus Seifert surfaces; it's edges consist of pairs of vertices with disjoint representatives; if the 1-skeleton of an n- simplex lies in the complex, then the n-simplex must also lie in the complex (i.e., it's flag). Moreover, as proved by Johnson-Pelayo-Wilson, the Kakimizu complex of a knot is quasi-Euclidean with dimension equal to the number of tori in the JSJ decomposition of the knot complement.

The Kakimizu complex of a 3-manifold is less well understood. Given a primitive relative second homology class, it's vertices consist of isotopy classes of weighted multi-surfaces that represent the class; edges are defined in terms of disjointness of lifts to the canonical cover associated with the class; like the Kakimizu complex of a knot, it is also a flag complex. However, there exist 3-manifolds with hyperbolic Kakimizu complexes.

We will discuss concrete examples of 3-manifolds and their Kakimizu complexes. (Received August 29, 2016)

1123-57-301 **Christopher K Atkinson*** (catkinso@morris.umn.edu), University of Minnesota, Morris, Division of Science and Mathematics, 600 E 4th Street, Morris, MN 56267, and **Jessica Mallepalle**, **Joseph Melby**, **Shawn Rafalski** and **Jennifer Vaccaro**. *Guts and volume for a simple family of hyperbolic* 3*–orbifolds.* Preliminary report.

If a hyperbolic 3–orbifold $\mathcal{O}$ contains an orbifold incompressible 2–suborbifold S, one obtains a lower bound on the volume of $\mathcal{O}$ in terms of the guts of the path metric completion of $\mathcal{O} \setminus S$ by applying work of Agol, Storm, and W. Thurston. For a simple family of hyperbolic 3–orbifolds, we show how to explicitly compute this volume bound in terms of the topology of a incompressible 2–suborbifold and the singular locus of the orbifold. (Received August 29, 2016)

1123-57-310 **Daniel Rodman*** (daniel-rodman@uiowa.edu). *Critical Bridge Spheres.* Preliminary report.

The concept of a critical surface has been a fruitful tool in the context of Heegaard splittings. We adapt this idea to link complements in the 3-sphere and prove that critical bridge spheres exist. (Received August 29, 2016)

1123-57-334 **Jason Parsley***, 1834 Wake Forest Rd., Box 7388, Winston-Salem, NC 27109-7388, and **Hao Chen**, NC. *Petal Links.* Preliminary report.

A petal diagram of a knot or link consists of a center point surrounded by n non-nested loops; it represents n strands of the link at various heights which all project onto the same center point. Though every knot has a petal diagram, extremely few links have petal diagrams. The goal of this project is to characterize and enumerate which links do. First, we tabulate all petal links of 2-5 components. We then show all petal links arise as circle graphs – the intersection graph of a set of chords of a circle. This establishes lower bounds on the number of petal links and allows us to conjecture upper bounds. We then discuss using petal diagrams to model certain classes of knots and links. (Received August 29, 2016)

1123-57-338 **Nick Castro**, **David Gay** and **Juanita Pinzon-Caicedo*** (jpinzon@uga.edu).
Diagrams of Relative Trisections.

In 2012 Gay and Kirby introduced trisections, a new decomposition of 4–manifolds and described diagrams for closed 4–manifolds. In joint work with Gay and Castro, we extended the diagramatic approach to include the relative case. In this talk I will define trisection diagrams for 4–manifolds with boundary, describe a few (families of) examples, and explain how to "read" the open book decomposition of the boundary from a trisection diagram. (Received August 29, 2016)

1123-57-340 **Claus Ernst*** (claus.ernst@wku.edu), WKU, Department of Mathematics, Bowling Green, KY 42101. *Coherent and incoherent nullification of torus knots.* Preliminary report.

Nullification is a basic move used to simplify a knot. A nullification move which does (not) change the number of components of the given knot diagram is called a coherent (incoherent) nullification move. While for torus knots the coherent nullification number has been determined, the incoherent nullification number is an open question. This talk uses a combinatorial argument applied to braids to establish upper bounds on the incoherent nullification number of torus knots. (Received August 29, 2016)

1123-57-344 **Azer Akhmedov***, 1210 Albrecht Boulevard, Department of Mathematics, North Dakota State University, Fargo, ND 58102, and **Cody Martin**, 1210 Albrecht Boulevard, Department of Mathematics, North Dakota State University, Fargo, ND 58102. *On non-embeddability of knot groups into the group of analytic diffeomorphisms of the interval.* Preliminary report.

Every knot group is known to be left-orderable thus it embeds in $\mathrm{Homeo}_+(I)$ - the group of orientation preserving homeomorphisms of the interval $I = [0, 1]$. By far, not every knot group is bi-orderable. The bi-orderability of a knot group has interesting topological consequences for a Dehn filling of the knot.

Embedding a group into $\mathrm{Diff}^{\omega}_+(I)$ - the group of orientation preserving analytic diffeomorphisms of the interval would imply its bi-orderability. Thus the question of which knot groups embed into $\mathrm{Diff}^{\omega}_+(I)$ becomes interesting.

In a joint work with M.Cohen, the first author has classified all RAAGs which embed in $\mathrm{Diff}^{\omega}_+(I)$. By extending the techniques of this work, we provide an answer to the embeddability question for the knot groups. (Received August 29, 2016)

1123-57-346 **Helen M Wong*** (hwong@carleton.edu), 1 N College St, Northfield, MN 55057, and **Francis Bonahon**. *Representations of the Kauffman bracket skein algebra.* Preliminary report.

The Kauffman bracket skein algebra of a surface was originally defined as a generalization of the Jones polynomial, but it was later realized to have connections with hyperbolic geometry. We discuss recent results concerning representations of the Kauffman bracket skein algebra of a surface and their relationship with hyperbolic geometry, particularly the SL_2-character variety of the fundamental group. (Received August 29, 2016)

1123-57-354 **Mario Eudave-Muñoz*** (mario@matem.unam.mx), Instituto de Matematicas, Universidad Nacional Autonoma de Mexico UNAM, Ciudad Universitaria, 04510 Mexico, D.F., Mexico. *Knotted handlebodies and knots with a half-integral toroidal surgery.* Preliminary report.

Many years ago I gave a construction of an infinite family of hyperbolic knots, denoted $k(l, m, n, p)$, which have a half-integral toroidal surgery. The construction was made by using tangles and double branched covers. Later, Gordon and Luecke showed that this family contains all knots with a half-integral toroidal surgery. Recently, Koda and Ozawa have given a description of all genus two knotted handlebodies which contain an essential annulus or Möbius band in their exteriors; one of families described come from the knots $k(l, m, n, p)$. Now, we give an explicit construction of such knotted handlebodies, and then an explicit construction of the knots $k(l, m, n, p)$. (Received August 30, 2016)

1123-57-376 **Thomas Kindred*** (thomas-kindred@uiowa.edu), Department of Mathematics, 14 MacLean Hall, Iowa City, IA 52242. *Khovanov homology detects adequate homogeneous states.* Preliminary report.

Given an adequate homogeneous state of a link diagram, we construct a sum of this state's enhancements (in the sense of Viro) which is nonzero in Khovanov homology over $\mathbb{Z}/2\mathbb{Z}$. This talk is intended for a general audience and will assume no background knowledge beyond linear algebra and the definition of a link diagram. Expect lots of pictures. (Received August 30, 2016)

1123-57-395 **Patricia Cahn*** (pcahn@smith.edu) and **Alexandra Kjuchukova** (kjuchukova@math.wisc.edu). *Linking numbers of pseudo-branch curves in irregular dihedral covers.* Preliminary report.

Let M be a p-fold irregular dihedral branched cover along a knot K in S^3, and $f : M \to S^3$ the corresponding covering map. The linking numbers of the components of the branch set $f^{-1}(K)$ are simple but powerful knot invariants. Building on an algorithm of Perko, which computes these linking numbers, we describe an algorithm for computing linking numbers of preimages of arbitrary curves in the complement of K. We will also discuss the motivation for our work, namely the classification of branched covers between four-manifolds with singular branching sets. This is joint work with Alexandra Kjuchukova. (Received August 30, 2016)

58 ► Global analysis, analysis on manifolds

1123-58-66 **Luen-Chau Li*** (luenli@math.psu.edu), Department of Mathematics, Pennsylvania State University, University Park, PA 16802, and **Zhaohu Nie**. *On the Liouville integrability of the periodic Kostant-Toda flow on matrix loops of level k.*

In this work, we consider the periodic Kostant-Toda flow on matrix loops of level k, which correspond to periodic infinite band matrices with period n with lower bandwidth equal to k and fixed upper bandwidth equal to 1 with 1's on the first superdiagonal. We show that the coadjoint orbits through such matrix loops can be identified with those of a finite dimensional Lie group which appears in the form of a semi-direct product. We then characterize the generic coadjoint orbits and obtain an explicit global cross-section for such orbits. Finally we establish the Liouville integrability of the periodic Kostant-Toda flow on such orbits via the construction of action-angle variables. (Received August 15, 2016)

60 ► Probability theory and stochastic processes

1123-60-18 **John Harlim***, jharlim@psu.edu. *The Diffusion Forecasting Method.*

I will discuss a nonparametric modeling approach for forecasting stochastic dynamical systems on smooth manifolds embedded in Euclidean space. In the limit of large data, this approach converges to a Galerkin projection of the semigroup solution of the backward Kolmogorov equation of the underlying dynamics on a basis adapted to the invariant measure. This approach, which we called the "diffusion forecast", allows one to evolve the probability distribution of non-trivial dynamical systems with an equation-free modeling. If time permitted, I will also discuss a semi-parametric modeling framework to compensate for model error by learning an auxiliary dynamical model for the unknown parameters. (Received July 21, 2016)

1123-60-23 **Mokshay Madiman*** (madiman@udel.edu), UD Department of Mathematical Sciences, 501 Ewing Hall, Newark, DE 19716, and **James Melbourne** and **Peng Xu**. *Rogozin's convolution inequality for locally compact groups.*

An influential inequality of Rogozin for the essential supremum of a convolution of probability density functions on the real line is extended to arbitrary unimodular locally compact groups for two densities, and to Euclidean spaces for an arbitrary number of densities. Consequences include an inequality for the Rényi entropy of order infinity of sums of independent random vectors, providing an asymptotically sharp refinement of an inequality of Bobkov and Chistyakov, and a multidimensional generalization of results of Livshyts, Paouris and Pivovarov. (Received August 29, 2016)

1123-60-28 **Michele De La Chevrotiere*** (mdelachev@psu.edu), Penn State University Mathematics Dept., University Park, State College, PA 16802, and **John Harlim** (jharlim@psu.edu), Penn State University Mathematics Dept., University Park, State College, PA 16802. *A data-driven method for improving the correlation estimation in serial ensemble Kalman filters.*

Ensemble Kalman filters (EnKF) with small ensemble size tend to induce spurious long-range correlations in the ensemble approximation of the model covariance. The typical approach to this long standing issue consists of using space localization techniques that effectively reduce the spurious correlations. Many such techniques have been proposed, for instance with the tapering functions of Furrer and Bengtsson (2007) or the Gaspari and Cohn localization functions (1999). While these techniques have been very useful, they require exhaustive tuning and present challenges when applied to nonlinear observations. Recently, Anderson and Lei (2013) have introduced an approach based on empirical localization functions (ELF) that requires almost no tuning. However, ELF

are constructed in stages and have limitations when applied to large atmospheric models. Motivated by this approach, we present a data-driven method for improving the sample correlation estimation in the EnKF when small ensemble size is used. In particular, we find a linear map that takes the poorly estimated sample correlation in each EnKF cycle and transforms it into a sample of improved correlation. This talk will present an overview of the method and results obtained with the Lorenz-96 model. (Received August 03, 2016)

1123-60-67 **Panki Kim** and **Renming Song*** (rsong@illinois.edu), Department of Mathematics, University of Illinois at Urbana-Champaign, Urbana, IL 61801, and **Zoran Vondracek**.
Heat kernels of non-symmetric jump processes:beyond the stable case.

Let J be the Lévy density of a symmetric Lévy process in $\mathbb{R}^d$ with its Lévy exponent satisfying a weak lower scaling condition at infinity. Consider the non-symmetric and non-local operator

$$\mathcal{L}^\kappa f(x) := \lim_{\epsilon \downarrow 0} \int_{\{z\in\mathbb{R}^d : |z|>\epsilon\}} (f(x+z)-f(z))\kappa(x,z)J(z)\,dz\,,$$

where $\kappa(x,z)$ is a Borel measurable function on $\mathbb{R}^d\times\mathbb{R}^d$ satisfying $0<\kappa_0\le\kappa(x,z)\le\kappa_1$, $\kappa(x,z)=\kappa(x,-z)$ and $|\kappa(x,z)-\kappa(y,z)|\le\kappa_2|x-y|^\beta$ for some $\beta\in(0,1)$. We construct the heat kernel $p^\kappa(t,x,y)$ of $\mathcal{L}^\kappa$, establish its upper bound as well as its fractional derivative and gradient estimates. Under an additional weak upper scaling condition at infinity, we also establish a lower bound for the heat kernel p^κ. (Received August 15, 2016)

1123-60-118 **Sergey G Bobkov*** (bobkov@math.umn.edu), School of Mathematics, University of Minnesota, 127 Vincent Hall, 206 Church St. S.E., Miinneapolis, MN 55455. *Extended transport distances.*

We will be discussing one extension of the power (Kantorovich) transport distances from the space of probability distributions to the larger class of signed measures on the real line with total mass 1. This extension allows one to analyze an asymptotic behavior of such distances in the central limit theorem by virtue of Edgeworth expansions. (Received August 21, 2016)

1123-60-168 **Elizabeth Meckes** and **Mark Meckes*** (mark.meckes@case.edu). *Self-similarity in the spectra of random unitary matrices.*

I will present a rigorous result roughly stating that, for a range of mesoscopic scales, the eigenvalues of an $n\times n$ random unitary matrix are statistically indistinguishable from those of a $2n\times 2n$ matrix, suitably rescaled. This result is inspired by a conjecture made by Coram and Diaconis in a statistical study of the relationship between eigenvalues of large random unitary matrices and zeroes of the Riemann zeta function. (Received August 25, 2016)

1123-60-279 **Mokshay Madiman** and **James Melbourne*** (jamesm@udel.edu), 501 Ewing Hall, Newark, DE 19716, and **Peng Xu**. *Min-entropy power inequalities, bounds on marginal densities of product measures, and a theorem of Rogozin.*

Extensions of an inequality due to Rogozin for the essential supremum of a convolution of k probability density functions on the real line are considered. A weakened version of the theorem is put forth in the context of arbitrary unimodular locally compact groups when $k=2$. On $\mathbb{R}^d$ the result can combined with rearrangement inequalities for arbitrary k to recover a full generalization. As a consequence, we obtain an inequality for the Renyi entropy of order infinity for sums of independent random vectors, providing an asymptotically sharp refinement of an inequality of Bobkov and Chistyakov. The proof is elementary and relies on a characterization of extreme points of a class of probability measures in the general setting of Polish measure spaces. As other applications, we generalize bounds on marginal densities achieve Livshyts-Paouris-Pivovarov and Rudelson-Vershynin. (Received August 29, 2016)

1123-60-294 **Janna Lierl*** (janna.lierl@uconn.edu), Dept. of Mathematics, 341 Mansfield Road, Unit 1009, Storrs, CT 06269-1009. *Boundary Harnack principle and Dirichlet heat kernel estimates for nonsymmetric stable-like operators.* Preliminary report.

Consider the α-stable like operator

$$\Delta^{\frac{\alpha}{2},\kappa}u(x) := \mathcal{A}(d,-\alpha)\lim_{\epsilon\to 0}\int_{\{y\in\mathbb{R}^d:|x-y|>\epsilon\}}\frac{\kappa(x,y)(u(y)-u(x))}{|x-y|^{d+\alpha}}dy,\quad x\in\mathbb{R}^d,$$

where $d\ge 2$, $\alpha\in(0,2)$.

The existence of the heat kernel for this operator, as well as two-sided heat kernel estimates, have been proved in a recent work by Z.-Q. Chen and X. Zhang, under mild assumptions on κ. Namely, it suffices that κ is bounded between two positive constants, satisfies $\kappa(x,x+z)=\kappa(x,x-z)$ for all $x,z\in\mathbb{R}^d$, and $x\mapsto\kappa(x,x+z)$ is Hölder continuous of order β for some $\beta\in(0,1)$.

Under somewhat stronger assumptions on κ, I will show a boundary Harnack principle with explicit decay rate $\delta(x)^{\alpha/2}$ on bounded $C^{1,1}$-open sets in $\mathbb{R}^d$, where $\delta(\cdot)$ denotes distance to the boundary. Moreover, I will present two-sided estimates for the Dirichlet heat kernel on $C^{1,1}$-open sets. (Received August 29, 2016)

1123-60-311 **Xiaojun Yuan*** (xyuan@ldeo.columbia.edu), Lamont-Doherty Earth Observatory of, Columbia University, Palisades, NY 10964, and **Dake Chen**, **Cuihua Li**, **Lei Wang** and **Wanqiu Wang**. *Arctic Sea Ice Seasonal Prediction by a Linear Markov Model.*

A linear Markov model was developed to predict Arctic sea ice concentration (SIC) at the seasonal time scale. The model was built to capture co-variabilities in the atmosphere-ocean-sea ice system defined by SIC, sea and air surface temperatures. Multivariate empirical orthogonal functions of these variables served as building blocks of the model. A series of model experiments were carried out to determine model's dimension. The predictive skill was evaluated by anomaly correlation and root-mean-square errors in a cross-validated fashion. On average, the model is superior to the predictions by anomaly persistence, damped anomaly persistence and climatology. The model shows good skill in predicting SIC anomalies within the Arctic Basin during summer and fall. Long-term trends partially contribute to the model skill. However, the model still beats the anomaly persistence for all targeted seasons after linear trends are removed. The model predicts well the interannual variability of the total sea ice extent (SIE) but underestimates its long-term decline, resulting in a systematic model bias. The bias can be reduced by a linear regression bias correction, leading to an improved correlation skill of 0.92 for the two-month lead September SIE prediction. (Received August 29, 2016)

1123-60-409 **Daniel C Jerison** and **Lionel Levine***, 438 Malott Hall, Ithaca, NY 14850, and **John Pike**. *Mixing time and eigenvalues of the abelian sandpile Markov chain.*

The abelian sandpile model defines a Markov chain whose states are integer-valued functions on the vertices of a simple connected graph G. The eigenvalues and eigenvectors of this chain can be expressed in terms of 'multiplicative harmonic functions' on the vertices of G, which are complex-valued functions h satisfying

$$\prod_{y \sim x} \frac{h(y)}{h(x)} = 1$$

for all vertices x, where the product is over all neighbors y of x. If we fix $h(z) = 1$ for a sink vertex z, then there are finitely many such functions, equal in number to the spanning trees of G.

We show that the spectral gap of the sandpile chain is within a constant factor of the length of the shortest non-integer vector in the dual Laplacian lattice, while the mixing time is at most a constant times the smoothing parameter of the Laplacian lattice. We find a surprising inverse relationship between the spectral gap of the sandpile chain and that of simple random walk on G: If the latter has a sufficiently large spectral gap, then the former has a small gap! (Received August 30, 2016)

62 ► Statistics

1123-62-392 **Matthew Bowers*** (mcbowers@purdue.edu), West Lafayette, IN 47906, and **Wen-wen Tung** (wwtung@purdue.edu), West Lafayette, IN 47906. *Quantifying Uncertainty in Time Averages of Climate Signals with both Short- and Long-Range Dependence.*

Time averaging of observed or simulated data is a fundamental practice in climatology. Being an estimate of the underlying climate mean state, its uncertainty due to sampling variability is naturally characterized by the variance of its sampling distribution, which can be used to construct confidence intervals. Researchers have long recognized that the persistent serial correlations in climate signals necessitate modification of the classical Central Limit Theorem in order to compute accurate variances of time averages. Yet, these efforts have primarily focused on autoregressive or other short-range correlation structures. Here, we present a framework for estimating the variance of time averages of climate signals with short-, long-, or both short- and long-range dependence based on asymptotic results applicable to fractional ARIMA models and Monte Carlo simulations. We find that processes with even weak long-memory cause substantial underestimation of uncertainty in confidence intervals that assume pure short-range dependence. Yet given a sufficient sample size, confidence intervals accounting for long-memory perform well on processes with both short- and long-range dependence. (Received August 30, 2016)

65 ► Numerical analysis

1123-65-386 **Thomas Trogdon***, University of California, Irvine, Department of Mathematics, and **Deniz Bilman**, University of Michigan, Department of Mathematics. *Numerical inverse scattering for the Toda lattice.*

The Toda lattice is the prototypical discrete-space, continuous-time completely integrable Hamiltonian system. It was introduced by Morikazu Toda in 1967 and analyzed in detail by Flaschka in 1974. The bi-infinite Toda lattice can be solved with its associated inverse scattering transform (IST). The IST is closely tied to the interpretation of the flow as an isospectral deformation of a bi-infinite tridiagonal matrix. I will discuss the numerical computation of the IST for the Toda lattice by solving Riemann–Hilbert problems numerically. The numerical IST allows for the computation of the solution for all times, including the long-time regime. This is joint work with Deniz Bilman (U. of Mich.). (Received August 30, 2016)

1123-65-402 **Gideon Simpson*** (simpson@math.drexel.edu), Korman Center - Room 206, 33rd and Market Streets, Department of Mathematics, Philadelphia, PA 19104. *Adaptive Methods for Derivative Nonlinear Schrödinger Equations.* Preliminary report.

Numerical simulations of L^2 supercritical derivative nonlinear Schrödinger equations suggest the existence of finite time singularities. Thus far, the numerical studies have relied upon either integration of the original equation or the dynamic rescaling method. The first appraoch is limited because of the singularity, while the latter appraoch is limited by the hyperbolic character of the nonlinearity. Using locally adaptive meshing methods, we are able to overcome prior difficulties, integrating closer to the singularity time. (Received August 30, 2016)

68 ► Computer science

1123-68-10 **Narad Rampersad*** (n.rampersad@uwinnipeg.ca). *Decidable properties of automatic sequences.*

A k-automatic sequence is a sequence (of integers or just symbols) that can be generated by a finite automaton in the following sense: Each state of the automaton has an associated output and the n-th term of the sequence is obtained as the output of the state reached by the automaton after reading the digits of n written in base k. The prototypical example is the 2-automatic Thue-Morse sequence, whose n-th term is equal to the sum of the binary digits of n modulo 2. Some classical work of Buchi gives an equivalent definition of k-automatic sequences in terms of a certain extension of Presburger arithmetic. This extension remains decidable and in recent years many researchers (notably Shallit) have used the decidability of this theory to give entirely computerized proofs of many combinatorial properties of automatic sequences. For instance, a classical combinatorial property of the Thue-Morse sequence is that it does not contain the same sequence of terms three times in a row. This is an example of a combinatorial property that is provable by these automated techniques. We give a survey of this approach and mention some recent new results that have been proven by means of such techniques. (Received July 06, 2016)

1123-68-94 **Adam Case*** (adam.case@drake.edu), Drake University, Howard Hall, 2505 University Avenue, Des Moines, IA 50311. *Bounded Turing Reductions and Data Processing Inequalities for Sequences.*

A *data processing inequality* states that the quantity of shared information between two entities (e.g. signals, strings) cannot be significantly increased when one of the entities is processed by certain kinds of transformations. We prove the existence of several data processing inequalities for sequences, where the transformations are bounded Turing functionals and the quantity of shared information is measured by the lower and upper mutual dimensions between sequences. Specifically, we show that, for all sequences X, Y, and Z, if Z is computable Lipschitz reducible to X, then

$$mdim(Z : Y) \leq mdim(X : Y) \text{ and } Mdim(Z : Y) \leq Mdim(X : Y).$$

We also show how to derive other data processing inequalities by making adjustments to the computable bounds of the *use* and *yield* of a Turing functional. (Received August 25, 2016)

1123-68-362 **Fiona Knoll*** (fknoll@g.clemson.edu), **Shuhong Gao** (sgao@clemson.edu), **Yue Mao** (yuem@clemson.edu) and **Lin You** (mryoulin@gmail.com). *Explicit Johnson-Lindenstrauss projection of high dimensional data.*

Johnson and Lindenstrauss (1984) proved that any finite set of data in a high dimensional space can be projected into a low dimensional space with the Euclidean metric information of the set being preserved within any desired accuracy. Such dimension reduction plays a critical role in many applications with massive data. There have been extensive effort in the literature on how to find explicit constructions of Johnson-Lindenstrauss projections. In this presentation, we will show how algebraic codes over finite fields can be used for explicit and fast Johnson-Lindenstrauss projections of data in high dimensional Euclidean spaces. We will also give a brief overview on the lowest bound to which one can project data while preserving the Euclidean metric. (Received August 30, 2016)

1123-68-413 **Rob Scharein*** (rob@knotplot.com), 2116 West 6 Avenue, #211, Vancouver, BC V6K 1V6, Canada. *KnotPlot after 25 (or so) years.*

About a quarter century ago, a small group of mathematicians and other researchers began to study knots as physical objects, simulating their behaviour on a computer. One of the founders of this exciting new field was Ken Millett. Word of this activity reached this author by somewhat indirect means and eventually the software known as KnotPlot was born. Always a work in progress, it has occasionally proven useful in various studies of the physical and mathematical properties of knots, also finding applications in several other disciplines. In any event, KnotPlot was directly inspired by the work of Ken and his associates. This talk will be part review and part update, with some new directions to be revealed. (Received August 30, 2016)

76 ► Fluid mechanics

1123-76-31 **Samuel N. Stechmann***, University of Wisconsin-Madison, Department of Mathematics, 480 Lincoln Dr, Madison, WI 53706. *Stochastic PDEs for Tropical Weather and Climate.*

Our understanding of tropical weather and climate is less advanced than our understanding of weather and climate in the midlatitudes, where most of the United States is located. What is different about the tropics? One important difference is that clouds and rain appear not along fronts but in seemingly random clusters. As a result, one can imagine that tropical weather and climate could be modeled using stochastic partial differential equations (PDEs). In this talk, stochastic PDE models are presented for tropical rainfall and coupling with equatorial waves. Comparisons with observational data will be shown for several of the main features of tropical rainfall, such as the Madden-Julian oscillation and the distribution of cloud cluster sizes. Implications for long-range weather forecasting, for weeks or a month in advance, will also be discussed. (Received August 03, 2016)

1123-76-35 **Rafail V Abramov*** (abramov@math.uic.edu), 322 Science and Engineering Offices (M/C 249), 851 S. Morgan st., Chicago, IL 60607. *Diffusive Boltzmann equation and its fluid dynamics.*

We develop a diffusive modification of the Boltzmann equation. The corresponding diffusive fluid dynamics equations are then obtained in a standard way by closing the hierarchy of the moment equations using either the Euler, Navier-Stokes, or the Grad closure. In the numerical experiments with the Couette flow, we discover that the diffusive fluid dynamics equations may exhibit Knudsen-like velocity boundary layers. Additionally, we find that the diffusive Grad equations capture the heat flux component parallel to the direction of the flow, which is missing in the conventional fluid dynamics equations. We compare the simulations with the corresponding Direct Simulation Monte Carlo (DSMC) results. (Received August 04, 2016)

1123-76-44 **Dimitrios Giannakis*** (dimitris@cims.nyu.edu), 251 Mercer St, New York, NY 10012. *Extraction and Prediction Of Coherent Patterns In Incompressible Flows Through Space-Time Koopman Analysis.*

We discuss a method for detecting and predicting the evolution of coherent spatiotemporal patterns in incompressible fluid flows. The approach is based on a representation of the Koopman operator governing the evolution of observables in a smooth basis learned from velocity field data through the diffusion maps algorithm. This representation enables the detection of coherent flow patterns through Koopman eigenfunctions and simulation of the evolution of observables and probability densities under the flow map. We present applications in Gaussian vortex flows and chaotic flows generated by Lorenz 96 systems. (Received August 09, 2016)

1123-76-134 **Alexander Y Klimenko***, klimenko@mech.uq.edu.au. *Compensating mechanism in tornado-like flows and the associated power laws.*

This presentation gives a consistent treatment of axisymmetric flows with strong vorticity, such as in tornadoes, and discusses the associated asymptotic analysis. The analysis is used to introduce a compensating mechanism which, on one hand, generates tangential vorticity that is sufficient to stimulate and support the flow convergence but, on the other hand, prevents over-generation of the tangential vorticity, which would destabilize the flow. It is this mechanism that ultimately makes tornadoes and tornado-like vortices persistent and stable. The mechanism leads to the 4/3 power law (more accurately in the 4/3-3/2 power range) in an intermediate asymptotic region between the viscous core and the outer scales. The tornado-like vortices are continuously affected by atmospheric disturbances and the power laws tend to fluctuate around 4/3. Some examples of the power laws in tornadoes and hurricanes are presented. (Received August 22, 2016)

1123-76-149 **Pavel Belik** and **Doug Dokken*** (dpdokken@stthomas.edu), Dept. of Mathematics, University of St. Thomas, 2115 Summit Ave., St. Paul, MN 55106, and **Mikhail Shvartsman**, **Kurt Scholz** and **Corey Potvin**. *Applications of a vortex gas model to tornadogenesis and maintenance.* Preliminary report.

Processes related to the production of vorticity in the forward and rear flank downdrafts and their interaction with the boundary layer are thought to play a role in tornadogenesis. We apply a three- dimensional vortex gas model to supercritical vortices produced at the surface boundary layer possibly due to interactions of vortices brought to the surface by the rear flank downdraft and also to those related to the forward flank downdraft. The three-dimensional vortex gas model of Chorin, developed further by Flandoli and Gubinelli, is proposed as a model for intense small-scale subvortices found in tornadoes and in recent numerical studies by Orf et al. In this paper, the smaller scales are represented by intense, supercritical vortices, which transfer energy to the larger-scale tornadic flows. We address the formation of these vortices as a result of the interaction of the flow with the surface and a boundary layer. In a second part of this paper we use the fractal dimension of the cross sections of negative-temperature vortices to address the role supercritical vortices play in the increase of energy in the tornado vortex and in tornadogenesis and then use these ideas to interpret the power laws of Cai and Wurman. (Received August 23, 2016)

1123-76-210 **Pavel Belik**, **Douglas P Dokken**, **Kurt Scholz** and **Mikhail M Shvartsman*** (mmshvartsman@stthomas.edu), 2115 Summit Ave, Mail # OSS 201, Department of Mathematics, Saint Paul, MN 55105-1079. *Thermodynamics Equations in Tornado Layer.* Preliminary report.

We explore the energy balance in a thunderstorm, in particular, how energy is redistributed on a local level inside a vortex-like flow. The notions of non-equilibrium thermodynamics are used to describe the problem. We show that fluctuations on a macroscopic level play an especially important role in this model. (Received August 26, 2016)

1123-76-212 **Pavel Bělík*** (belik@augsburg.edu), **Aleksandr Lukanen**, **Douglas Dokken**, **Mikhail Shvartsman** and **Kurt Scholz**. *Equilibrium statistics of vortex filaments on a cubic lattice and entropy computation.* Preliminary report.

We present an extension of the results obtained by Chorin and others in the early 90s on the equilibrium statistics of the vortex filaments constrained to the cubic lattice. We present the pivot algorithm for generation of self-avoiding walks and its modification that allows to extend the computational results to a much wider range of temperatures, both positive and negative. We also discuss a way to reliably estimate the entropy of such filaments using the hypothetical scanning method of Meirovitch. (Received August 26, 2016)

1123-76-240 **Daozhi Han*** (djhan@iu.edu), Rawles Hall, 831 E 3rd St, Bloomington, IN 47405, and **Roger Temam** (temam@indiana.edu), Rawles Hall, 831 E 3rd St, Bloomington, IN 47405. *On the interaction of a vortex induced by a rotating cylinder with a plane.*

In this talk,we study theoretically and numerically the interaction of a vortex induced by a rotating cylinder with a perpendicular plane. We show the existence of weak solutions to the swirling vortex models by Hopf' extension method, and by an elegant contradiction argument, respectively. We demonstrate numerically that the model could produce phenomena of swirling vortex including boundary layer pumping and two-celled vortex that are observed in potential line vortex interacting with a plane and in a tornado. This work is joint with Roger Temam. (Received August 27, 2016)

1123-76-323 **Thijs Heus*** (t.heus@csuohio.edu), Cleveland, OH 44115. *On the interaction between the organization of clouds and climate variability.*

Cloud-aerosol interactions remain one of the largest uncertainties in climate modeling. The amount of aerosol in a cloud influences the amount of precipitation. If the precipitation exceeds a certain threshold, it will create feedback on the cloud field through cold pools and mesoscale organization. We study the sensitivity of trade wind cumulus clouds to perturbations in cloud droplet number concentrations. The transient behavior and the properties of the near-equilibrium cloud field depend on the microphysical state and therefore on the cloud droplet number density. The primary response of the cloud field is deepening of the cloud layer, and results in a shorter cloud life time. (Received August 29, 2016)

1123-76-365 **Marcus L Büker*** (ml-buker@wiu.edu), Dr. Marcus Büker, WIU - Deptartment of Geography, 1 University Circle, Macomb, IL 61455. *"Vortex interactions and superhelicity in tornadic supercell thunderstorms".*

This talk will focus on diagnostic methods for localized, barotropic vorticity evolution in tornadic supercell environments. These methods identify local maxima in vorticity tendency, and how these features relate to a quantity known as superhelicity, which is present whenever spatial gradients in horizontal vorticity (such as those associated with downdraft and updraft pulses) are orthogonal to a given background vorticity (such as in the vicinity of a mesocyclone). Using mobile Doppler radar retrievals from two observational cases featuring tornadic supercells, these diagnostic methods show promise for tracking coherent dynamical features related to surface vortex intensification, as well as potentially detecting signals of imminent tornadogenesis sooner than traditional vorticity tendency diagnostics. Furthermore, these methods may provide physical insight into vortex interactions and modes in the vicinity of the mesocyclone and flanking downdrafts. Numerical simulations will also illustrate these relationships through idealized vortex interactions. (Received August 30, 2016)

1123-76-417 **Gene S Kopp*** (gkopp@umich.edu), Department of Mathematics, 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *The arithmetic geometry of resonant Rossby wave triads.*

Linear wave solutions to the Charney-Hasegawa-Mima PDE with periodic boundary conditions have two physical interpretations: Rossby (atmospheric) waves, and drift (plasma) waves in a tokamak. These waves display resonance in triads: Linear combinations of three waves—with coefficients dependent on a slow time scale—satisfying the same (nonlinear) PDE. In the case of infinite Rossby deformation radius, the set of resonant triads may be described as the set of integer solutions to a particular homogeneous Diophantine equation.

We use elementary methods from algebraic geometry to determine the set of resonant triads as values of rational functions of three parameters. We then use more sophisticated number-theoretic methods to give a procedure for answering the question: For fixed $r \in \mathbb{Q}$, what are all wavevectors (x, y) that resonate with some wavevector (a, b) with $a/b = r$?

Finally, we illustrate the computational power of our approach. We find 463×24 resonant triads up to wavenumber bound $N = 5000$, improving on a calculation of Bustamante and Hayat. We also enumerate all resonant wavevectors of zonal group velocity zero up to the much higher bound $N = 10^{15}$. (Received August 30, 2016)

81 ► Quantum theory

1123-81-8 **Christof Sparber*** (sparber@uic.edu), Department of Mathematics, University of Illinois at Chicago, 851 South Morgan Street, Chicago, IL 60607. *Semiclassical quantum dynamics via Bohmian trajectories.*

We consider a linear, time-dependent Schrödinger equation describing a quantum particle under the influence of a (slowly varying) external potential. We focus on the question of how to obtain from it the associated Newtonian particle dynamics in the classical limit. To this end, we refer to David Bohm's reformulation of quantum mechanics. The latter allows one to rigorously define, for any given solution of Schrödinger's equation, an associated dynamical system yielding trajectories similar to the classical particle dynamics. This talk will report on recent results on the classical limit of these Bohmian trajectories for different choices of initial data. In particular, we shall see that for WKB initial data, these trajectories in general do not converge to the corresponding classical particle dynamics. In doing so, we will also study a family of phase-space measures, called Bohmian measures, which are seen to be equivariant with respect to the Bohmian flow and whose classical limit correctly incorporates the classical limit of the quantum mechanical position and the current densities. (Received May 27, 2016)

1123-81-73 **Boris Tsygan*** (b-tsygan@northwestern.edu), 2033 Sheridan Road, Lunt Building B4, Evanston, IL 60201. *A microlocal category of a symplectic manifold.*

To any symplectic manifold we associate a category enriched in infinity-local systems of modules over the Novikov ring.. We discuss some simple examples and relationships with other ways to construct a category for a given symplectic manifold, in particular with the Fukaya category and with Tamarkin's sheaf-theoretical category. (Received August 15, 2016)

1123-81-102 **Philsang Yoo*** (philsang@math.northwestern.edu). *Quantum Field Theories and Langlands Dualities.* Preliminary report.

In the first part of the talk, I will discuss a joint project with Chris Elliott on realizing the geometric Langlands correspondence as an instance of S-duality by careful analysis of Kapustin and Witten's work using derived algebraic geometry. In the second part of the talk, I will propose a program to simultaneously capture different instances of Langlands dualities in geometric representation theory through the lens of quantum field theories. (Received August 20, 2016)

1123-81-128 **Peter Koroteev*** (koroteev@ucdavis.edu), One Shields Drive, Davis, CA 95616. *Elliptic Algebras from Instanton Counting.*

We explore the correspondence between geometric representation theory, integrable systems, and supersymmetric gauge theories and string/M theory. In the example which will be presented we find intricate connections between representations of algebras (like double affine Hecke algebra, Ding Iohara algebra), quantization of integrable many-body systems (like Calogero-Moser, Ruijsenaars-Schneider), and instanton (vortex) counting of supersymmetric gauge theories of Seiberg-Witten type. Our results give rise to some new mathematical conjectures. (Received August 22, 2016)

1123-81-255 **Pavel Mnev*** (pmnev@nd.edu), 255 Hurley, Notre Dame, IN 46556. *Perturbative BV theories with Segal-like gluing.*

We will give an overview of the cohomolohical symplectic (BV-BFV) approach to perturbative quantization of gauge theories on manifolds with boundary. We present explicit examples where partition functions constructed within the BV-BFV framework combine the features of Atiyah-Segal partition functions (compatibility with gluing/cutting of manifolds) with features of effective Batalin-Vilkovisky actions (they satisfy a version of quantum master equation) and have a version of Wilsonian renormalization flow built into them. Partition functions are expressed in terms of the R-torsion and configuration space integrals and in some cases admit a combinatorial (cellular) presentation. This is a report on a joint work with Alberto S. Cattaneo and Nicolai Reshetikhin. (Received August 28, 2016)

1123-81-332 **John Terilla*** (jterilla@gc.cuny.edu). *Homotopy probability theory.*

Homotopy probability theory is a theory inspired by quantum field theory in which the vector space of random variables is replaced by a chain complex. (Received August 29, 2016)

1123-81-356 **Hisham Sati*** (hsati@pitt.edu). *M-theory and rational homotopy theory.*

M-theory has proven to be very rich from physics and mathematics points of view. We will show how the fields and their dynamics in M-theory can be captured naturally via constructions from rational homotopy theory. We explain how supersymmetric and differential extensions arise. We also comment on extensions beyond the rational level. (Received August 30, 2016)

82 ► Statistical mechanics, structure of matter

1123-82-19 **Tayyab Nawaz*** (tnawaz2@illinois.edu), Room 250, 1409 W. Greeen Street, Urbana, IL 61801, and **Kay Kirkpatrick**. *Some recent results on asymptotics of $O(N)$-model.*

I will discuss the mean-field classical N-vector models for $N \geq 1$, where N is an integer. I will discuss recent work with Kay Kirkpatrick on asymptotic behavior near the phase transition. We used large deviations, Stein's method and bounded properties of ratio of the modified bessel function of first kind to study the physical quantities such as susceptibility and magnetization. Some special cases are XY model ($N = 2$), Heisenberg model ($N = 3$) and Toy model of the Higgs sector($N = 4$). (Received July 22, 2016)

1123-82-78 **E J Janse van Rensburg*** (rensburg@yorku.ca), Department of Mathematics & Statistics, York University, Toronto, Ontario M3J 1P3, Canada. *Lee-Yang and Fishers zeros in Adsorbing Self-Avoiding Walks.*

Partition function or Fisher zeros play a fundamental role in the theory of phase transitions in classical lattice statistical mechanics. In this talk some results on the properties of partition and generating function zeros in models of adsorbing self-avoiding walk are presented. Theorems constraining the distribution of zeros in the complex plane, based on the distribution of polynomial zeros, will be given. These results show that partition function zeros are constrained to be located in annular regions with center at the origin in the complex plane. Results on the angular distribution of zeros will also be presented. Numerical results on the distribution of zeros will be shown, based on approximate enumeration of square lattice walks using the GAS algorithm. (Received August 17, 2016)

1123-82-161 **Christine Soteros*** (soteros@math.usask.ca). *Local and Non-local Knotting in Lattice Models of Confined Polymers.* Preliminary report.

Standard models for studying the effects of geometrical confinement on ring polymers use self-avoiding polygons constrained to lie in an infinite rectangular lattice tube, a sublattice of the simple cubic lattice. Such tube models have potential applications for modelling single DNA molecules in nanochannels, DNA under tight confinement, or protein configurations. Inspired by Ken Millett's observation that trefoil patterns in a 2 by 1 tube are not "local" knots, we have been using tube models to explore the concept of "local" versus "non-local" knotting in lattice polygons and to determine the effects of a stretching or compressing force on knotting probabilities. In this talk, I will present recent theoretical and numerical results related to this that were obtained in collaboration with Nick Beaton and Jeremy Eng. The numerical results are for small tube sizes and involve both exact and Monte Carlo generation of polygons using transfer matrix methods. (Received August 24, 2016)

1123-82-406 **Stephen D Levene*** (sdlevene@utdallas.edu), Department of Bioengineering BSB11, University of Texas at Dallas, 800 West Campbell Rd., Richardson, TX 75080-3021, and **Andreas Hanke** (hanke@phys.utrgv.edu), Department of Physics and Astronomy, University of Texas Rio Grande Valley, 80 Fort Brown, Brownsville, TX 78520. *Enhanced understanding of protein-mediated DNA looping, cyclization, and DNA topology through free-energy landscapes.*

Quantitative knowledge of free-energy changes is central to understanding protein and RNA folding, motion and energy transduction in molecular machines, macromolecule-ligand interactions, genome organization, and many other biological phenomena. We consider problems related to DNA tertiary structure and topology, especially loop-mediated interactions involving protein molecules bound to separate sites along DNA. Computing the free-energy cost of forming DNA or chromatin loops entails a delicate and length-scale-dependent balance of enthalpic and entropic contributions and is a challenging problem in statistical mechanics. Moreover, the effects of chromatin organization on such interactions are poorly understood. However, new insights can come from novel experimental approaches along with computational models of DNA flexibility and folding under geometric and/or topological constraints. We have developed a general method for computing free energy landscapes for DNA flexibility and folding across all length scales that is widely applicable to such problems. Applications to protein-mediated topological constraints and enzyme action will be discussed. (Received August 30, 2016)

86 ► Geophysics

1123-86-11 **Ian G Grooms*** (ian.grooms@colorado.edu). *A Gaussian-product stochastic Gent-McWilliams parameterization.*

The locally-averaged horizontal buoyancy flux by mesoscale eddies is computed from eddy-resolving QG simulations of ocean-mesoscale eddy dynamics. This flux has a very non-Gaussian distribution peaked at zero, not at the mean value. This non-Gaussian flux distribution arises because the flux is a product of zero-mean random variables: the eddy velocity and buoyancy.

A framework for stochastic Gent-McWilliams (GM) parameterization based around stochastic parameterization of the horizontal subgrid-scale density flux is presented. Within this context Gaussian random field models for subgrid-scale velocity and buoyancy are developed; these models are used to construct a stochastic horizontal subgrid-scale density flux as the core of a non-Gaussian stochastic GM parameterization. This new non-Gaussian stochastic GM parameterization is tested in an idealized box ocean model, and compared to a Gaussian approach that simply multiplies the deterministic GM parameterization by a Gaussian random field. The non-Gaussian approach has a significant impact on both the mean and variability of the simulations, more

so than the Gaussian approach. Future directions for development of the stochastic GM parameterization and extensions of the Gaussian-product approach are discussed. (Received July 11, 2016)

1123-86-101 **Leslie M Smith*** (lsmith@math.wisc.edu), Department of Mathematics, 480 Lincoln Dr, Madison, WI 53706. *Precipitating Convection with Fast Cloud Microphysics.*

Moist convection in the atmosphere directly impacts the formation and dynamics of cloud structures on many different horizontal length scales, from small-scale vortical hot towers, to intermediate-scale squall lines, to the merger of the polar and subtropical jets on large scales. Here we present a minimalist approach to the theory and modeling of precipitating convection, based on asymptotically fast cloud microphysics. Conservation laws for momentum, energy, moist entropy and total water are all retained, but have a simple nontrivial form. Performance and analysis of the model will be discussed for test cases on small and intermediate scales, as well as the systematic derivation of a precipitating quasi-geostrophic system to describe atmospheric large scales with dynamic phase changes. (Received August 19, 2016)

1123-86-125 **Amanda K O'Rourke*** (orourkea@umich.edu), **Brian Arbic** and **Stephen Griffies**. *Energetics of the Ocean Surface at Low Frequencies in GFDL's CM2-O Model Hierarchy.* Preliminary report.

Low frequency variability within the ocean surface can be excited by both external forcing, such as atmospheric exchanges of heat and momentum, as well as the nonlinear transfer of energy between ocean eddies. Recent studies have shown that nonlinear eddy interactions at short timescales can excite an energy transfer from high to low frequencies similar to the transfer of energy between spatial scales in two dimensional turbulence. As this energy exchange is sensitive to the existence of oceanic eddies, the process of energy exchange across frequencies may be sensitive to ocean resolution. We use GFDL's CM2-O hierarchy of fully coupled ocean-atmosphere models to address the transfer of surface kinetic energy and temperature variance between synoptic and decadal timescales utilizing a cross-spectrum diagnostic. One question related to this research is whether low frequency modes are primarily driven from internal mechanisms, such as nonlinearity, or external forces from the atmosphere. Diagnostics of energy flux and transfer within the frequency domain will be compared between three models at 1, 1/4th, and 1/10th degree ocean resolution to address the importance of eddy resolution in the driving of energy to low frequencies. (Received August 22, 2016)

91 ► Game theory, economics, social and behavioral sciences

1123-91-135 **Alexander Y Klimenko*** (klimenko@mech.uq.edu.au). *Complex cyclic behaviours in competitive systems and the ubiquitous nature of intransitivity.*

Many complex systems that involve competition in one form or another tend to evolve cyclically. Examples of cycles can be found in economics, history, biology, technology, science and almost any other area where elements, species or ideas compete against one another. This brief 10 minute presentation will outline an approach that may bring an explanation for persistence of these cycles and other patterns of complex behaviour (e.g. competitive cooperation) in systems that, seemingly, are radically different and belong to very different fields of science. The suggested approachis generic and based on randomly walking elements that compete according to a pre-selected set of rules. The analysis indicates that the common cause of complex behaviours is intransitivity of the competition rules. While intransitivity has been long argued as being illogical or irrational (conventional orders are transitive by definition), it seems that intransitivity is necessarily and ubiquitously present in nature. (Received August 22, 2016)

1123-91-146 **Mark D Flood** and **Jonathan Simon*** (jonathan-simon@uiowa.edu), Department of Mathematics, University of Iowa, Iowa City, IA 52240, and **Mathew Timm**. *Topological measures of financial network complexity.* Preliminary report.

Imagine a network of financial institutions trading some stock, or currency, or more elaborate derivatives. How complicated is the network? How much would it "cost" in time, effort, money, phone calls, anguish – to determine, at a given moment, who owns what, and who owes what to whom? We want to quantify this kind of complexity.

We work in the framework of finite graphs: models are simple graphs or allow orientations, edge weights, multiple edges or loops, as dictated by the application. We define several topologically based metrics, using the dealer network and its line graph. We start with network size and move on to: homology and simple cycles in the graphs; homology of a 2-complex defined by nettable cycles of obligations; and a mild form of persistent homology to visualize how edge weights and vertex degrees interact.

We have experiments showing our measures are sensitive to financially complicating behaviors such as collateral commingling and interdependent chains of obligations. Our measures, and correlations between them, can distinguish graph topologies, e.g. between random G(n,p) graphs and core-periphery graphs of the same size.

Our metrics give a new way to visualize the dynamics of the 2012 credit-default-swap event known as the "London Whale". (Received August 23, 2016)

1123-91-410 **Hyeonjo Jeong** (jeonghj.0114@gmail.com), Choice Research Group, Cresskill, NJ 07626, and **Richard Kyung*** (nycrick@gmail.com), Choice Research Group, Cresskill, NJ 07626.
Economic Solution of Homelessness.

In order to combat one of the critical social issues, homelessness, it is crucial to understand the trend of homelessness and other factors. In this paper, the fundamental relationship between GDP or operation budget and homelessness as indicators of the trend is used. In America especially, the cases vary significantly among different states. Although it is important to have an exact data for the homelessness, it is challenging to do so because it is hard to apply the same standard for people who became homeless for different reasons. Non-profit or voluntary community service programs, such as soup kitchens and shelters, can also affect the number and status of homeless. The distribution of the operating budget is also problematic. In order to study the current problems, this paper shows the trend of homelessness employing multi-factors using statistical analysis and computational tools. Majority of the resources are used to support the chronically homeless. Consequently, it is challenging to fund the newly homeless to help them bounce back to their regular lives. There is a trend that cities, such as, Los Angeles and New York that have a significant amount of homelessness cannot easily tackle the issue and reduce the number. (Received August 30, 2016)

1123-91-418 **Hyeonjo Jeong** (hyeonjo@choicerg.com), Choice Research Group, Cresskill, NJ 07626, **Jihyun Kim*** (jihyun@choicerg.com), Choice Research Group, Cresskill, NJ 07626, and **Richard Kyung** (nycrick@gmail.com), Choice Research Group, Cresskill, NJ 07626.
Economy and the Efficiency of the Spending on Homesess.

The efficiency of the amount of money spent on the homeless play an important role to solve the social problem. We used statistical analysis, computer programming, and many data including operating budget and homelessness to predict trends and plot percent difference in homelessness against the homelessness operating budget per capita of the 10 cities in America with the greatest homeless population. This research shows the way in which homelessness is approached which changes from city to city. Surprisingly, majority of the cities do not allocate much budget to combatting the homeless problem. LA, in particularly, has the second largest homeless population, but spends only a little money on funding them. Consequently, the homelessness keeps increasing. In many cities that spend a lot on homelessness, their efforts look quite unsuccessful in preventing an increase in homelessness depending on the regions. But unlike the fluctuating graph of GDP, there was a steady decreasing trend in the total homeless in the US. Total chronically and unsheltered homeless also shows steady decrease in its number. Although there were increase in the number of total homeless in some states, as a whole United States is experiencing a decrease in the number of homeless. (Received August 31, 2016)

92 ► Biology and other natural sciences

1123-92-363 **Eleni Panagiotou*** (panagiotou@math.ucsb.edu), South Hall, UCSB, Santa Barbara, CA 93106, and **Kenneth C Millett** and **Paul J Atzberger**. *Linking polymer entanglements with the viscoelastic mechanics of polymeric materials using topological analysis and computational simulations.*

We investigate how the entanglement of polymeric chains relates to bulk viscoelastic responses in polymeric materials. We show how the structure of the material can be analyzed using results from topology to develop new tools for entanglements. We develop three dimensional computational models to relate entanglement topology, polymer fiber mechanics, to bulk viscoelastic responses of the material. We study in particular woven polymer configurations having similar polymer densities but very different topologies varying from untangled to strongly entangled conformations. We also investigate the role of polymer density. Our approaches provide new mathematical tools for characterizing the origins of the rheological responses of polymeric materials. (Received August 30, 2016)

1123-92-393 **Seyed Mohammadhossein Tabatabaei Yazdi*** (tbtbyzd2@illinois.edu), 1308 W Main St, #125, Urbana, IL 61801, and **Han Mao Kiah** and **Olgica Milenkovic**. *Weakly Mutually Uncorrelated Codes.*

We introduce the notion of weakly mutually uncorrelated (WMU) sequences, motivated by applications in DNA based storage systems and synchronization protocols. WMU sequences are characterized by the property that no sufficiently long suffix of one sequence is the prefix of the same or another sequence. In addition, WMU sequences used in DNA-based storage systems are required to have balanced compositions of symbols and to be at large mutual Hamming distance from each other. We present a number of constructions for balanced, error correcting WMU codes using Dyck paths, Knuth's balancing principle, prefix synchronized and cyclic codes. (Received August 30, 2016)

94 ► Information and communication, circuits

1123-94-53 **John B Little*** (jlittle@holycross.edu), Department of Mathematics and CS, College of the Holy Cross, Worcester, MA 01610. *Codes from surfaces with small Picard number.* Preliminary report.

In 2007, Marcos Zarzar suggested that algebraic surfaces X over a finite field $\mathbb{F}_q$ with small Picard number (the rank of the Néron-Severi group over the finite field) might be used to produce good evaluation codes. His key idea was that limiting the Picard number of X puts restrictions on the irreducible curves on the surface that can appear as components of divisors in the hyperplane section divisor class (and this is important since reducible divisors often yield codewords of small weight in the associated evaluation codes). We study this idea and evaluate its potential. In particular, we point out that the sectional genus g of the surface also plays a key role and the cases of $g = 0, 1$ seem to be more favorable than higher g. We find bounds on the minimum distance in situations where we can control the irreducible components of the hyperplane sections. We also present several examples of such codes with minimum distance better than the best known examples in Grassl's tables. (Received August 12, 2016)

1123-94-76 **Jay A Wood*** (jay.wood@wmich.edu), Department of Mathematics, Western Michigan University, 1903 W Michigan Ave, Kalamazoo, MI 49008. *The Extension Theorem for Lee Weight.*

The extension theorem holds for the Lee and Euclidean weights over $\mathbb{Z}/p^k\mathbb{Z}$, p prime. That is, every isometry for those weights extends to a signed permutation. The proof involves showing a certain matrix is invertible. The determinant of this matrix equals a product of Fourier coefficients, each one of which is non-zero because of properties of generalized Bernoulli numbers and Dirichlet L-functions. This is joint work with Serhii Dyshko and Philippe Langevin. (Received August 16, 2016)

1123-94-93 **Jessica OShaughnessy*** (joshaugh@su.edu), Shenandoah University, 1460 University Drive, Winchester, VA 22601. *Group Ring Convolutional Codes: Constructions and Observations.*

A known isomorphism exists between elements of the group ring and matrices. This allows for interesting use of group ring matrices to construct codes. Constructions of convolutional codes using elements in the group ring, in particular units in the group ring, is explored. Observations on types of convolutional codes constructed using these methods are also presented. (Received August 19, 2016)

1123-94-153 **Steve Szabo*** (steve.szabo@eku.edu), Richmond, KY 40475. *Codes over Non-commutative Rings and Duality.*

In this talk we consider linear codes over non-commutative Frobenius rings and discuss issues concerning duality such as generalization of code size condition by Wood and duality preserving maps. (Received August 24, 2016)

1123-94-155 **Padmapani Seneviratne*** (padmapani.seneviratne@tamuc.edu), Texas A&M University - Commerce, 2600 South Neal St, Commerce, TX 75428. *A class of self-orthogonal three weight codes.* Preliminary report.

Recently ,there has been a growing interest in studying three weight codes due to their connections to three-class association schemes and cryptography. In this work, we construct a new class of self-orthogonal three-weight codes. Further, we determine the automorphism group and suitable PD-sets for permutation decoding of these codes. (Received August 24, 2016)

1123-94-183 **Felice Manganiello*** (manganm@clemson.edu), **Fiona Knoll**, **Gretchen Matthews** and **Shuhong Gao**. *Distributed storage systems from regular graphs.*

In this talk we look at distributed storage systems (DSSs) from a graph theoretic perspective. We focus on DSS which are constructed by means of the path decomposition of a 3-regular graph into P4 paths. The latter represents the disks of the DSS and the edges of the graph, the blocks. We deduce the properties of the DSS and show their optimality by studying its graph representation. (Received August 25, 2016)

1123-94-224 **Arya Mazumdar*** (arya@cs.umass.edu), 140 Governors Dr, College of Information and Computer Science, University of Massachusetts, Amherst, MA 01002. *Fundamental Limits of Locally Repairable Codes.*

Locally repairable codes (LRC) have recently been a subject of intense research due to theoretical appeal and their application in distributed storage systems. In an LRC, any coordinate of a codeword can be recovered by accessing only few other coordinates. For LRCs over small alphabet (such as binary), the optimal rate-distance trade-off is unknown. In this presentation we provide the tightest known bounds on the rate of LRCs of a given relative distance. (Received August 27, 2016)

1123-94-371 **Allison Beemer*** (allison.beemer@huskers.unl.edu). *Trapping and Absorbing Sets in SC-LDPC Codes.*

Spatially coupled low-density parity-check (SC-LDPC) codes have garnered widespread interest due to their capacity-approaching performance and superior density evolution thresholds on almost any channel. Furthermore, SC-LDPC codes may be decoded using a *windowed decoder* that slides along the code's Tanner graph, making them good candidates for applications such as streaming. However, SC-LDPC codes are still prone to error floors; we present strategies for SC-LDPC code design that seek to minimize the negative effects of the graphical substructures (*trapping sets* and *absorbing sets*) that characterize decoder failure at high signal-to-noise ratios. (Received August 30, 2016)

1123-94-380 **Katherine Morrison*** (katherine.morrison@unco.edu), 501 20th St CB 122, Greeley, CO 80639. *Algebraic Signatures of Convex and Non-Convex Neural Codes.*

The brain represents stimuli via patterns of neural activity. These activity patterns can be described by a neural code, i.e. a collection of indicator vectors showing which neurons co-fire in response to various stimuli. It is believed that the brain can infer many properties of the stimulus space purely from the intrinsic structure of the neural code, e.g. through the convex structure of receptive fields that give rise to convex neural codes. In this talk, we present algebraic techniques that enable us to determine if a given neural code is convex, and thus has additional structure that can be used to understand stimulus space structure. (Received August 30, 2016)

1123-94-384 **Jessalyn Bolkema*** (jessalyn.bolkema@huskers.unl.edu), **Katherine Morrison** and **Judy L. Walker**. *Structural Results on Factor Graphs of Polar Codes.*

Arikan's polar codes have been celebrated for their capacity-achieving performance since first presented in 2008. These codes are most often discussed from an information-theoretic point of view, but their algebraic properties are not as well understood. In this talk, we utilize factor graph realizations of polar codes as a framework to uncover underlying algebraic structures. We discuss graph-theoretic and algebraic properties of polar codes and explore the impact of these properties on code design and performance. (Received August 30, 2016)

00 ► General

1124-00-25 **Dirk R. H. Schlingmann*** (dschlingmann@uscupstate.edu), 800 University Way, Spartanburg, SC 29303.

Mathematics and Music.

I will present my work on how I use mathematics and technical computing software to analyze, manipulate, and create music. Musical pieces are available as Musical Instrument Digital Interface (MIDI) files. I will compare the work of well-known composers through statistical analysis, and will present variations of their compositions by performing geometrical transformations on their musical data. Furthermore, I will play musical creations that are entirely based on mathematical functions. (Received July 25, 2016)

1124-00-45 **John Risher*** (risherjt@email.sc.edu), 807 Hampton St., Walterboro, SC 29488.

Alternate Proofs for Two Inequalities with Geometric and Harmonic Means.

For sequences $\{a_i\}$, $\{b_i\}$, and $\{a_i + b_i\}$, let G_a, G_b, and $G_{(a+b)}$ be their geometric means respectively, and let H_a, H_b, and $H_{(a+b)}$ be their harmonic means respectively. Using our own method, we proved the two inequalities, $G_a + G_b \leq G_{(a+b)}$ and $H_a + H_b \leq H_{(a+b)}$, which were introduced by Hardy, Littlewood, and Polya in their book, *Inequalities*. We also generalized these two inequalities to the case of m-sequences: $G_{(a_1)} + \cdots + G_{(a_m)} \leq G_{(a_1+\cdots+a_m)}$, and $H_{(a_1)} + \cdots + H_{(a_m)} \leq H_{(a_1+\cdots+a_m)}$. (Received August 17, 2016)

1124-00-151 **He Feng*** (fenghe@vt.edu), 216 Robeson Hall, Department of Physics (MC 0435) Virginia Tech, 850 West Campus Drive, Blacksburg, VA 24061, and **Lara B. Anderson**.

New Evidence for (0,2) Target Space Duality.

In the context of (0,2) gauged linear sigma models, we explore chains of perturbatively dual heterotic string compactifications. The notion of target space duality originates in non-geometric phases and can be used to generate distinct GLSMs with shared geometric phases leading to apparently identical target space theories. To date, this duality has largely been studied at the level of counting states in the effective theories. We extend this analysis to the effective potential and loci of enhanced symmetry in dual theories. By engineering vector bundles with non-trivial constraints arising from slope-stability (i.e. D-terms) and holomorphy (i.e. F-terms) the detailed structure of the vacuum space of the dual theories can be explored. Our results give new evidence that GLSM target space duality may provide important hints towards a more complete understanding of (0,2) string dualities. (Received September 06, 2016)

1124-00-250 **Nicolas Garcia Trillos**, **Moritz Gerlach**, **Matthias Hein** and **Dejan Slepcev*** (slepcev@math.cmu.edu), Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15217.

Error estimates for the consistency of graph laplacians.

A number of machine learning tasks relies on spectral properties of the graph laplacian associated to the data. I will consider data points obtained as random samples of a measure on a manifold in a Euclidean space. I will discuss conditions under which the spectrum of the graph laplacians on a neighborhood graph spanned by the samples converges almost surely to the spectrum of appropriate weighted Laplace-Beltrami operators on the manifold, as the sample size increases and the neighborhood size shrinks to zero. I will present error estimates for the convergence that explicitly depend on the geometry of the manifold, the number of data points available and the size of the neighborhood used in the graph construction. (Received September 11, 2016)

1124-00-399 **Michael Chi**, 632CAB University of Alberta, Edmonton, Alberta T6G 2G1, Canada, **Francois Gay-Balmaz**, 24 Rhue Lhomond, 75231 Paris Cedex 05, France, **Vakhtang Putkaradze**, 632CAB University of Alberta, Edmonton, Alberta T6G 2G1, Canada, **Nima Fathi**, 1 University of New Mexico, MSC01 1150, Albuquerque, NM 87131, and **Peter Vorobieff***, 1 University of New Mexico, MSC01 1150, Albuquerque, NM 87131.

Flexible solar updraft towers: stability and control.

A major challenge of integrating renewable energy sources into the existing energy grid is presented by the variability of renewable power. One method to reduce such variability for solar power and to provide 24/7 baseline power is to use solar updraft towers, where solar energy heats the ground and the air underneath a large-area transparent collector roof and drives the updraft flow through a massive vertical chimney (solar tower). The large thermal mass of the facility makes it possible to power the turbine installed in the tower around the

clock. However, a traditional rigid design of the tower of desirable height (750–1500 m) makes the cost of the facility nearly prohibitive. We present a flexible inflatable tower design that could radically reduce the costs and complexity of the construction, as well as improve the survivability of the facility in case of extreme weather. Stability of the flexible tower under wind loading and control of its movement present an interesting problem, for which we developed analytical treatment. Experimental results confirm the premises of our theory. (Received September 13, 2016)

03 ► Mathematical logic and foundations

1124-03-100 **E. Todd Eisworth*** (eisworth@ohio.edu). *Coloring Theorems and the Mahlo Hierarchy.* Preliminary report.

We will discuss some recent results on coloring theorems obtained at cardinals lying quite high in the Mahlo hierarchy. (Received August 31, 2016)

1124-03-394 **Liwu Li*** (lwli@vt.edu), Dept of Biological Sciences, Virginia Tech, Blacksburg, VA 24061, and **Shuo Geng**. *Innate immunity memory dynamics in health and disease.* Preliminary report.

Low-grade inflammatory monocyte polarization may occur during chronic inflammation and deter effective wound repair. However, little is understood about the potential mechanisms of no-resolving monocyte polarization. We demonstrated that both murine and human monocytes can be programmed into a low-grade inflammatory state, as represented by the elevated population of CD11b+Ly6Chigh monocyte and sustained expression of CCR5, through continuous challenges with subclinical dose of bacterial endotoxin. Mechanistically, super-low dose endotoxin caused cellular stress, altered lysosome function and increased the transcription factor IRF5. TUDCA, a potent inhibitor of cellular stress, effectively blocked the monocyte polarization, and improved wound healing in mice injected with super-low dose endotoxin. Instead, prolonged challenges with higher dosages of LPS caused tolerance. The priming and tolerance dynamics can be manifested with TLR7 agonist in monocytes. In contrast, TLR3 agonist preferentially programs for the non-resolving inflammatory state of monocytes without inducing tolerance. Our data reveal systems dynamics of monocyte programming by distinct TLR agonists with varying signal strengths, underlying mechanisms, and pathological implications. (Received September 13, 2016)

05 ► Combinatorics

1124-05-24 **Ryan R Martin*** (rymartin@iastate.edu), 396 Carver Hall, Department of Mathematics, Iowa State University, Ames, IA 50011, 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 22, 2016)

1124-05-44 **Derrick Stolee*** (stolee@gmail.com). *Automated Discharging Arguments for Density Problems in Grids.* Preliminary report.

Discharging arguments demonstrate a connection between local structure and global averages. This makes it an effective tool for proving lower bounds on the density of special sets in infinite grids. However, the minimum density of an identifying code in the hexagonal grid remains open, with an upper bound of $\frac{3}{7} \approx 0.428571$ and a lower bound of $\frac{5}{12} \approx 0.416666$. We present a new, experimental framework for producing discharging arguments using an algorithm. This algorithm replaces the lengthy case analysis of human-written discharging arguments with a linear program that produces the best possible lower bound using the specified set of discharging rules.

We use this framework to present a lower bound of $\frac{23}{55} \approx 0.418181$ on the density of an identifying code in the hexagonal grid, and also find several sharp lower bounds for variations on identifying codes in several grids. (Received August 17, 2016)

1124-05-49 **Eva Czabarka**, **Laszlo A. Szekely*** (szekely@math.sc.edu) and **Stephan Wagner**.
Subtrees of trees.

There is continuing interest in the distribution of small subgraphs of graphs by isomorphism type. For trees, to avoid a trivial answer, one has to investigate the distribution of subtrees of a given small size. We proved the following conjecture of Bubeck and Linial: if in a sequence of trees, where the tree size goes to infinity, the proportion of k-vertex paths among k-vertex subtrees becomes negligible, then almost all k-vertex subtrees are stars. We also showed that the maximum number of non-isomorphic subtrees (of all sizes) of trees on n vertices is $\Theta(5^{n/4})$.

Another way of looking for subtrees is the following: in a rooted binary tree, any k leaves induce a rooted subtree. To obtain the induced rooted binary subtree of this leaf set, suppress non-root vertices of degree 2. Now the natural question is the distribution of the k-leaf induced rooted binary subtrees. Results on this problem led to a proof that a randomly and uniformly selected n-leaf tanglegram has tanglegram crossing number $\Theta(n^2)$ with near 1 probability. (Received August 18, 2016)

1124-05-52 **Eva Czabarka*** (czabarka@math.sc.edu), **Johannes Rauh**, **Kayvan Sadeghi**, **Taylor Short** and **Laszlo A Szekely**. *The maximum number of nonzero entries in a joint degree vector.*

The joint degree vector of an n-vertex graph gives the number of edges between vertices of degree i and degree j for $1 \leq i < j \leq n-1$. The number of nonzero entries of this graph provides an upper bound on the number of estimable parameters in the exponential random graph model with bidegree-distribution as its sufficient statistics. We find lower and upper bounds for this quantity as a function of n. (Received August 20, 2016)

1124-05-75 **Steve Butler*** (butler@iastate.edu). *Forest building process.* Preliminary report.

Consider the following process for a simple graph without isolated vertices: Order the edges randomly and keep an edge if and only if it contains a vertex which is not contained in some preceding edge. The resulting set of edges forms a spanning forest of the graph.

The probability of obtaining k components in this process for complete bipartite graphs is determined as well as a formula for the expected number of components in any graph. A generic recurrence and some additional basic properties are discussed.

Joint work with Zhanar Berikkyzy, Jay Cummings, Kristin Heysse, Paul Horn, Ruth Luo, and Brent Moran. (Received August 29, 2016)

1124-05-77 **Michael Young*** (myoung@iastate.edu), Ames, IA 50011. *Problems on Rainbow 3-term Arithmetic Progressions.*

A 3-term arithmetic progression is a sequence of the form $a, a+d, a+2d$, where a and d are nonnegative integers. Given a coloring of $[n]$, we say that an arithmetic progression is *rainbow* if no two elements of the arithmetic progression have the same color. An *anti-van der Waerden number* is the number of colors needed to guarantee that any coloring of $[n]$ using all the colors must contain a rainbow 3-term arithmetic progression. In this talk, we will discuss some known and new results about anti-van der Waerden numbers in $[n]$ and finite abelian groups. (Received August 29, 2016)

1124-05-88 **David C. Lax*** (dclax@vt.edu). *Order Filter Model for Minuscule Plücker Relations.*

The generalized Plücker relations are quadratic relations that define flag manifolds as projective varieties. We study the generalized Plücker relations for minuscule flag manifolds combinatorially and independent of Lie type. No geometric knowledge is necessary; the problem of finding these Plücker relations reduces to that of decomposing the symmetric square of a minuscule representation. We use Wildberger's combinatorial construction of minuscule Lie algebra representations that uses the colored partially ordered sets known as minuscule posets. We obtain, uniformly across Lie type, descriptions of the Plücker relations of "extreme weight". We show that these are supported by "double-tailed diamond" sublattices of minuscule lattices. From this, we obtain a complete set of Plücker relations for the exceptional minuscule flag manifolds. These extreme weight Plucker relations are straightening laws for their respective coordinate rings. (Received August 30, 2016)

1124-05-101 **Jerrold R Griggs*** (j@sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *On diamonds in the middle three layers.* Preliminary report.

: It interesting to study the maximum size of a family of subsets of an n-set that contains no (weak) copy of a given poset P, denote this $La(n, P)$. It is conjectured that $La(n, P)$ is asymptotic to $\binom{n}{\lfloor n/2 \rfloor}$ times some integer depending on P, as $n \to \infty$. While this has been proven for several posets P, it remains a tough challenge, even for the four-element diamond poset. Restricting attention to just the middle three levels, the no-diamond problem is that of bounding the largest size of a family of vertices in the middle three slices of the hypercube that induces no C_4. We discuss the current status of this problem, which remains open, and share ideas for the deeper understanding of the connections between the middle layers. This is in part joint work with Cliff Smythe. (Received August 31, 2016)

1124-05-102 **Matthew Yancey*** (mpyancey1@gmail.com). *A unique current-best algorithm to find a distance-approximating tree.*

The problem is simple: build a tree that models a fixed graph. An example application would be to build a phylogenetic tree from a list of pairs of related species. Given the original graph G and a proposed model T with a mapping $f : V(G) \to V(T)$, our objective function may be additive (minimize over T, f the value $\max_{u,v} \|d_G(u, v) - d_T(f(u), f(v))\|$) or multiplicative (minimize over T, injective f the value $\max_{u,v} \max\{d_G(u, v)/d_T(f(u), f(v)), d_T(f(u), f(v))/d_G(u, v)\}$). In either case the problem is NP-Hard. But there exists a single deterministic algorithm that constructs a model T and function f that is within a small constant of optimal for both the additive objective function and the multiplicative objective function.

In this talk we retrace the history of this algorithm, as it was discovered four distinct times in four distinct fields: (1) historical manuscripts, (2) hyperbolic geometry, (3) biology, and (4) computer vision. (Received August 31, 2016)

1124-05-107 **Ronald J Gould*** (rg@mathcs.emory.edu), Dept. 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, $sat(n, H)$, is the minimum number of edges in an H-saturated graph on n vertices. Of course, the well studied extremal number, $ext(n, H)$ is the maximum number of edges in an H saturated graph on n vertices. One question is now obvious: For what values of m, $sat(n, H) \leq m \leq ext(n, H)$ does there exist an H-saturated graph of order n with m edges? The set of all such values is called the saturation spectrum of H. In this talk we will explore this question for several families of graphs. (Received September 01, 2016)

1124-05-131 **Anant Godbole*** (godbolea@etsu.edu), **Thomas Grubb** (grubbtho@msu.edu), **Kyutae (Paul) Han** (kyutae.han93@gmail.com) and **Bill Kay** (bill.w.kay@gmail.com). *Threshold Progressions in Various Covering and Packing Contexts.* Preliminary report.

Using methods (due to Janson, Stein-Chen, and Talagrand) from probabilistic combinatorics, we explore the following general theme: As one progresses from each member of a family of objects $\mathcal{A}$ being covered by at most one object in a random collection $\mathcal{C}$, to being covered at most g times, to being covered at least once, to being covered at least g times, a hierarchy of thresholds emerge, which show when the required property holds with high or low probability. Moreover, the threshold is often multiplicative for packings, and additive for coverings. Examples will be from extremal combinatorics; set systems; combinatorical design theory; and additive number theory. This talk is based on joint work with Thomas Grubb (Michigan State University), Kyutae Han (UCLA) and Bill Kay (Emory University). (Received September 05, 2016)

1124-05-132 **Vladimir D Tonchev*** (tonchev@mtu.edu), 1400 Townsend Drive, Houghton, MI 49931. *On resolvable Steiner 2-designs and maximal arcs in projective planes.*

The topic of this talk is a combinatorial characterization of resolvable Steiner 2-designs embeddable as maximal arcs in projective planes. (Received September 05, 2016)

1124-05-157 **Hao Huang** and **Yi Zhao*** (yzhao6@gsu.edu). *Degree version of the Erdős-Ko-Rado Theorem.*

We use an algebraic method to prove a degree version of the celebrated Erdős-Ko-Rado theorem: given $n > 2k$, every intersecting k-uniform hypergraph H on n vertices contains a vertex that lies on at most $\binom{n-2}{k-2}$ edges. (Received September 06, 2016)

1124-05-159 **Gregory J Clark*** (gjclark@math.sc.edu), **Joshua Cooper**, **Jacob Folks**, **Seung Mok Lee**, **Andrew Mamroth**, **Sydney Miyasaki**, **Caleb Simmons** and **David Stewart**.
Splitting Numbers of Integer Tiles.

Janos Pach conjectured the following: there is a least integer N so that every covering of the plane by unit disks, such that each point is covered at least N times, has a two-coloring of the disks (say, by red and blue) where each point in the plane is covered by a red disk and a blue disk. In 2015, Pach and Palvolgyi showed the conjecture to be false. We explore questions similar to Pach's by restricting our attention to coverings of the integers by integer tiles. In particular, we show that for finite integer tiles a suitable N (which we define as the splitting number) always exists. In doing so we provide bounds on the splitting number of a finite tile and determine the splitting number for some families of tiles. We conclude by presenting a connection between computing the splitting number of an integer tile and two-coloring a uniform hypergraph. (Received September 06, 2016)

1124-05-161 **Amrita Acharyya*** (amrita.acharyya@utoledo.edu), University of Toledo, Toledo, OH, and **Jon M Corson** and **Bikash C Das**.
Profinite Fundamental Group and Universal Cover of Profinite Graphs.

We define a covering of a profinite graph to be a projective limit of a system of covering maps of finite graphs. With this notion of covering, we develop a covering theory for profinite graphs which is in many ways analogous to the classical theory of coverings of abstract graphs. For example, it makes sense to talk about the universal cover of a profinite graph and we show that it always exists and is unique. We define the profinite fundamental group of a profinite graph and show that a connected cover of a connected profinite graph is the universal cover if and only if its profinite fundamental group is trivial. (Received September 06, 2016)

1124-05-182 **Jacob D Baron*** (jabar@math.rutgers.edu) and **Jeff Kahn** (jkahn@math.rutgers.edu).
The cycle space of a random graph.

Write $\mathcal{C}(G)$ for the cycle space of a graph G, $\mathcal{C}_\kappa(G)$ for the subspace of $\mathcal{C}(G)$ spanned by the copies of C_κ in G, $\mathcal{T}_\kappa$ for the class of graphs satisfying $\mathcal{C}_\kappa(G) = \mathcal{C}(G)$, and $\mathcal{Q}_\kappa$ for the class of graphs each of whose edges lies in a C_κ. We prove that for every odd $\kappa \geq 3$ and $G = G_{n,p}$,

$$\max_p \Pr(G \in \mathcal{Q}_\kappa \setminus \mathcal{T}_\kappa) \to 0;$$

so the C_κ's of a random graph span its cycle space as soon as they cover its edges. For $\kappa = 3$ this was shown by DeMarco, Hamm and Kahn (2013). (Received September 07, 2016)

1124-05-193 **Axel Brandt*** (axbrandt@davidson.edu), **Michael Ferrara**, **Mohit Kumbhat**, **Sarah Loeb**, **Derrick Stolee** and **Matthew Yancey**.
I, F-partitions of sparse graphs.

A *star k-coloring* is a proper k-coloring such that the union of two color classes induces a star forest. While every planar graph is 4-colorable, not every planar graph is star 4-colorable. One method to produce a star 4-coloring is to partition the vertex set into a 2-independent set and a forest, where a 2-independent set is a set of vertices having pairwise distance more than 2. Such a partition is called an I, F-partition. We use the discharging method and other techniques to prove that every graph with maximum average degree less than $\frac{5}{2}$ has an I, F-partition, which is sharp and answers a questions of Cranston and West. This result implies that planar graphs of girth at least 10 are star 4-colorable, improving upon previous results of Bu, Cranston, Montassier, Raspaud, and Wang. (Received September 08, 2016)

1124-05-199 **James Haglund**, **Brendon Rhoades** and **Mark Shimozono*** (mshimo@math.vt.edu), Department of Mathematics, MC 0123, 460 McBryde Hall, Virginia Tech, 225 Stanger St., Blacksburg, VA 24061.
Ordered set partitions, generalized coinvariant algebras, and the Delta Conjecture.

The coinvariant algebra is a classical object that appears as the cohomology of the flag variety and as the ring of regular functions on the scheme-theoretic intersection of nilpotent matrices with diagonal matrices. We introduce graded algebras and symmetric group modules $R_{n,k}$ for $k \leq n$ such that $R_{n,n}$ is the coinvariant algebra. On the other hand, the shuffle algebra (also known as the elliptic Hall algebra, large rank spherical double affine Hecke algebra, and toroidal gl_1) acts naturally on symmetric functions (symmetric polynomial module). The Delta Conjecture of Haglund, Remmel, and Wilson, gives an explicit combinatorial formula for some values of this action. We show that when the Macdonald parameter t is set to zero, the HRW formula agrees with the graded Frobenius character of $R_{n,k}$ up to sign character twist and reversal of grading. (Received September 08, 2016)

1124-05-215 **Bernard Lidický** (lidicky@iastate.edu) and **Michelle Delcourt*** (delcour2@illinois.edu), Department of Mathematics, 1409 W Green St, Urbana, IL 61801, and **Luke Postle** (lpostle@uwaterloo.ca). *Star decompositions of random regular graphs.*

In 2006, Barát and Thomassen conjectured that the edges of every planar 4-regular 4-edge-connected graph can be decomposed into claws. Shortly afterward, Lai constructed a counterexample to this conjecture. Using the small subgraph conditioning method of Robinson and Wormald, Luke Postle and I showed that a.a.s. a random 4-regular graph has an edge decomposition into claws. I will also discuss more recent results edge decomposing regular graphs into stars; this is joint work with Bernard Lidický and Luke Postle. (Received September 09, 2016)

1124-05-219 **Craig Larson*** (clarson@vcu.edu), 4106 Harris Hall, 1015 Floyd Ave, Richmond, VA 23284. *Automated conjecturing for proof discovery.*

CONJECTURING is an open-source Sage program which can be used to make invariant-relation or property-relation conjectures for any mathematical object-type. The user must provide at least a few object examples, together with functions defining invariants and properties for that object-type. These invariants and properties will then appear in the conjectures.

Here we demonstrate how the CONJECTURING program can be used to produce proof sketches in graph theory. In particular, we are interested in finding a new proof of the Friendship Theorem: if every pair of vertices of a graph has a unique common neighbor, then the graph is a vertex adjacent to all other vertices.

We will discuss the program and give examples. This is joint work with Nico Van Cleemput (Ghent University). (Received September 09, 2016)

1124-05-239 **Junhua He**, **Louis A. Valentin**, **Xiaoyan Yin** and **Gexin Yu*** (gyu@wm.edu), College of William and Mary, Williamsburg, VA. *Extremal permutations in routing cycles.* Preliminary report.

Let G be a graph whose vertices are labeled $1, \ldots, n$, and π be a permutation on $[n] := \{1, 2, \cdots, n\}$. A pebble p_i that is initially placed at the vertex i has destination $\pi(i)$ for each $i \in [n]$. At each step, we choose a matching and swap the two pebbles on each of the edges. Let $rt(G, \pi)$, the routing number for π, be the minimum number of steps necessary for the pebbles to reach their destinations.

Li, Lu, and Yang proved that $rt(C_n, \pi) \leq n - 1$ for every permutation π on the n-cycle C_n and conjectured that for $n \geq 5$, if $rt(C_n, \pi) = n - 1$, then $\pi = 23 \cdots n1$ or its inverse. By a computer search, they showed that the conjecture holds for $n < 8$. We prove in this paper that the conjecture holds for all even $n \geq 6$. (Received September 10, 2016)

1124-05-258 **Martin Merker** (marmer@dtu.dk) and **Luke Postle*** (lpostle@uwaterloo.ca), 200 University Ave West, Waterloo, Ontario N2L 3G1, Canada. *Bounded Diameter Arboricity.*

We introduce the notion of bounded diameter arboricity. Specifically, the *diameter-d arboricity* of a graph is the minimum number k such that the edges of the graph can be partitioned into k forests each of whose components has diameter at most d. A class of graphs has *bounded diameter arboricity* k if there exists a natural number d such that every graph in the class has diameter-d arboricity at most k. We conjecture that the class of graphs with arboricity at most k has bounded diameter arboricity at most $k+1$. We prove this conjecture for $k \in \{2, 3\}$ by proving the stronger assertion that the union of a forest and a star forest can be partitioned into two forests of diameter at most 18. (Received September 11, 2016)

1124-05-260 **Paul Balister*** (pbalistr@memphis.edu), **Béla Bollobás** and **Karen Gunderson**. *Independence densities of hypergraphs.*

The independence density of a finite hypergraph is the probability that a subset of vertices, chosen uniformly at random contains no hyperedges. Independence densities can be generalized to countable hypergraphs using limits. We show that, in fact, every positive independence density of a countably infinite hypergraph with hyperedges of bounded size is equal to the independence density of some finite hypergraph whose hyperedges are no larger than those in the infinite hypergraph. This answers a question of Bonato, Brown, Kemkes, and Prałat about independence densities of graphs. Furthermore, we show that for any k, the set of independence densities of hypergraphs with hyperedges of size at most k is closed and contains no infinite increasing sequences. (Received September 11, 2016)

1124-05-270 **Emily Marshall*** (emarshall@lsu.edu) and **Guoli Ding**. *Minors in 3-connected planar nonhamiltonian graphs.* Preliminary report.

Hamilton cycles in graphs can be hard to find, and there is a large body of research that outlines sufficient conditions for the existence of such a cycle. For graphs on the plane, Whitney proved that all 4-connected triangulations are Hamiltonian and this result was later strengthened by Tutte to all 4-connected planar graphs. This talk approaches the problem from the other direction by looking instead at non-Hamiltonian graphs. It is known that not all 3-connected planar graphs are Hamiltonian and the Herschel graph is the smallest example. We focus on 3-connected planar non-Hamiltonian graphs and report on progress towards proving the existence of a Herschel minor in all such graphs with an initial restriction to triangulations. (Received September 11, 2016)

1124-05-274 **Vikram M Kamat*** (vkamat@vcu.edu), **Glenn Hurlbert** and **Eva Czabarka**. *On Chvátal's conjecture and Erdős–Ko–Rado graphs.* Preliminary report.

One of the fundamental results in extremal set theory, the Erdős–Ko–Rado theorem, finds a tight upper bound on the size of an intersecting family of r-subsets of $[n] = \{1, \ldots, n\}$ (when $r \leq n/2$) by proving that it is no bigger than the family of all r-subsets of $[n]$ containing a fixed element. A long-standing conjecture of Chvátal states that in every *downset*, i.e. a family of subsets $\mathcal{F}$ such that if $A \in \mathcal{F}$ and $B \subseteq A$, then $B \in \mathcal{F}$, this "EKR property" holds. We verify Chvátal's conjecture for any downset where every subset contains at most 3 elements.

We also discuss a closely-related graph-theoretic generalization that defines an EKR property for intersecting families of independent sets in a graph. We survey classes of graphs which have this property, and end with some open questions. (Received September 11, 2016)

1124-05-282 **Henry A. Kierstead**, **Alexandr V. Kostochka** and **Andrew McConvey*** (mcconve2@illinois.edu), Dept. of Mathematics, 250 Altgeld Hall, 1409 W. Green St., Urbana, IL 61801. *Strengthening theorems of Dirac and Erdős on disjoint cycles.* Preliminary report.

For an integer $k \geq 2$ and a graph G, let $H_k(G)$ be the set of vertices with degree at least $2k$ and $L_k(G)$ be the set of vertices of degree at most $2k-2$. In 1963, Dirac and Erdős proved that G contains k disjoint cycles whenever $|H_k(G)| - |L_k(G)| \geq k^2 + 2k - 4$. We improve this result, proving that a difference of at least $3k$ guarantees the existence of k disjoint cycles and, for small graphs, that this bound is the best possible. We also prove that when the order of G is large, a difference of at least $2k$ is sufficient for k disjoint cycles and is the best possible bound. (Received September 11, 2016)

1124-05-294 **James M Carraher*** (carraherjm2@unk.edu). *Minimum weight eulerian circuits.*

Let G be an eulerian digraph. For each vertex we are given a matrix A, where a_{ij} is a nonnegative integer representing the cost of moving from the (incoming) edge i to the (outgoing) edge j. A minimum weight eulerian circuit is an eulerian circuit that minimizes the total cost. We investigate when we can find minimum weight eulerian circuits. We show that in the case of weights of 0 and 1 that determining if there is a eulerian circuit of weight 0 is NP-complete. (Received September 12, 2016)

1124-05-309 **Ruth Luo*** (ruthluo2@illinois.edu), Dept. of Mathematics, 273 Altgeld Hall, 1409 W. Green St., Urbana, IL 61801, and **Zoltán Füredi** and **Alexandr Kostochka**. *A stability version for a theorem of Erdős on nonhamiltonian graphs.*

Let G be a nonhamiltonian graph on n vertices with minimum degree $\delta(G) \geq d$. In 1962, Erdős proved that G has at most $\max\{\binom{n-d}{2}+d^2, \binom{\lceil (n+1)/2 \rceil}{2} + \lfloor (n-1)/2 \rfloor^2\}$ edges, and there is a class of extremal examples $H_{n,d}$ for each n and $d < n/6$. We prove a stability version of this result: if G is a 2-connected nonhamiltonian graph on n vertices with minimum degree $\delta(G) \geq d$ and more than $\max\{\binom{n-(d+1)}{2} + (d+1)^2, \binom{\lceil (n+1)/2 \rceil}{2} + \lfloor (n-1)/2 \rfloor^2\}$ edges, then G must be a subgraph of the extremal graph $H_{n,d}$. This result is sharp. (Received September 12, 2016)

1124-05-312 **Sadegh Bolouki**, **Olgica Milenkovic**, **Gregory J. Puleo*** (gjp0007@auburn.edu) and **Vida Ravanmehr**. *Doubly Threshold Graphs.*

We introduce *doubly threshold graphs*, a class of graphs generalizing both threshold graphs and unit interval graphs. A graph G is doubly threshold if there are real numbers α, β and a vertex weight function w such that $uv \in E(G)$ if and only if $w(u) + w(v) \geq \alpha$ and $|w(u) - w(v)| \leq \beta$. We give a polynomial-time algorithm to determine whether a graph is doubly threshold, based on finding a special bipartition of the vertices of G. (Received September 12, 2016)

1124-05-314 **Jennifer Diemunsch**, **Nathan Graber**, **Lucas Kramer**, **Victor Larsen*** (vlarsen@kennesaw.edu), **Lauren Nelsen**, **Luke Nelsen**, **Devon Sigler**, **Derrick Stolee** and **Charlie Suer**. *Color-blind index in graphs of low degree.*

A not necessarily proper edge-coloring on a graph yields a color palette $\overline{c}(v) = \{a_i \ldots, a_k\}$ for each vertex v where a_i is the number of edges incident to v with color i. We reorder $\overline{c}(v)$ for every v in non-increasing order to obtain the *color-blind partition* $c^*(v)$. When the color-blind partition forms a proper vertex labeling, we say that the edge-coloring is *color-blind distinguishing*, and we let dal(G) be the smallest number of colors necessary for a color-blind distinguishing edge-coloring.

In this talk, we examine the problem of determining dal(G) for subcubic graphs, and show its connection with computational complexity theory and hypergraph coloring. We show that, for general graphs, determining dal(G) is NP-complete even when it is known that dal(G) $\in \{2, 3\}$. However, we can use known results from hypergraph coloring to help when working with regular bipartite graphs. (Received September 12, 2016)

1124-05-317 **Christopher Cox*** (cocox@andrew.cmu.edu) and **Derrick Stolee**. *Ramsey numbers on the Boolean lattice.*

We present an extension of Ramsey numbers, in particular the recently popular ordered Ramsey numbers, by considering graphs with a partial ordering on their vertices. In this context, we can use various families of posets in order to build host graphs for Ramsey problems, each having unique challenges. In this talk, we focus on Ramsey numbers of this kind which arise from Boolean lattices. We explore connections between 1-uniform Ramsey numbers and Turán problems on the Boolean lattice, and, in higher uniformities, find strong differences between Ramsey numbers on the Boolean lattice and ordered Ramsey numbers when the partial-orderings on the graphs have large antichains. (Received September 12, 2016)

1124-05-321 **Jon Cutler** and **Jamie Radcliffe*** (jamie.radcliffe@unl.edu). *Extremal problems for clique counts.*

I'll discuss a number of results, new and old, concerning the maximum or minimum number of cliques there can be in a graph that satisfies a range of natural conditions. These results form a strand of graph theory reaching from its earliest days to very recent problems.

I promise at least one open problem that will make you say "We don't know *that*?!". (Received September 12, 2016)

1124-05-338 **Michael Dairyko**, **Michael Ferrara*** (michael.ferrara@ucdenver.edu), **Bernard Lidicky**, **Ryan M. Martin**, **Florian Pfender** and **Andrew Uzzell**. *Ore and Chvátal-type Degree Conditions for Fast Bootstrap Percolation.*

Bootstrap percolation is a deterministic cellular automaton in which vertices of a graph G begin in one of two states "dormant" or "active". Given a fixed integer r, a dormant vertex becomes active if at any stage is has at least r active neighbors, and remains active for the duration of the process. Given an initial set of a active vertices A, we say that G r-percolates (from A) if every vertex in G becomes active after some number of steps. Let $m(G, r)$ denote the minimum size of a set A such that G r-percolates from A.

Here, we are concerned with degree-based density conditions than ensure $m(G, 2) = 2$. In particular, we give an Ore-type degree sum result that states if a graph G satisfies $\sigma_2(G) \geq n - 2$, then either $m(G, 2) = 2$ or G is one of several exceptional classes of graphs. We also give a Chv'atal-type degree condition: If G is a graph with degree sequence $d_! \leq d_2 \leq \cdots \leq d_n$ such that $d_i \geq i + 1$ or $d_{n-i} \geq n - i - 1$ for all $1 \leq i < \frac{n}{2}$, then $m(G, 2) = 2$. Both of these results are inspired by, and extend [D. Freund, M. Poloczek, and D. Reichman, Contagious sets in dense graphs, to appear in *European J. Combin.*] (Received September 12, 2016)

1124-05-351 **Jozsef Balogh**, **Andrew McDowell**, **Theodore Molla*** (molla@illinois.edu) and **Richard Mycroft**. *Triangle-tilings in graphs without large independent sets.*

We study the minimum degree necessary to guarantee the existence of perfect and almost-perfect triangle-tilings in an n-vertex graph G with sublinear independence number. In this setting, we show that if $\delta(G) \geq n/3 + o(n)$ then G has a triangle-tiling covering all but at most four vertices. Also, for every $r \geq 5$, we asymptotically determine the minimum degree threshold for a perfect triangle-tiling under the additional assumptions that G is K_r-free and n is divisible by 3. (Received September 13, 2016)

1124-05-352 **Tom Bohman*** (tbohman@math.cmu.edu). *Random greedy hypergraph processes.*

Let $\mathcal{H}$ be a D-regular, r-uniform hypergraph on n vertices. In this talk we consider the random greedy algorithms for producing matchings and independent sets on $\mathcal{H}$. The random greedy matching algorithm builds a matching by adding edges selected uniformly at random one at a time, subject to the condition that each selected edge does not intersect any previously selected edge. The random greedy independent set algorithm builds an independent

set by adding vertices one at a time which are chosen uniformly at random subject to the condition that the collection of selected vertices never contains an edge of $\mathcal{H}$. In this talk we survey some recent applications of these processes and discuss some open problems. (Received September 13, 2016)

1124-05-372 **Jessica Fuller*** (jessica.fuller@emory.edu) and **Ronald J. Gould**. *Saturation and Constructing $(K_t - e)$-saturated graphs.*

Given a graph H, we say a graph G is *H-saturated* if G does not contain H as a subgraph and the addition of any edge $e' \notin E(G)$ results in H as a subgraph. The question of the minimum number of edges of an H-saturated graph on n vertices, known as the *saturation number*, and the question of the maximum number of edges possible of an H-saturated graph, known as the Turán number, has been addressed for many different types of graphs. We are interested in the existence of H-saturated graphs for each edge count between the saturation number and the Turán number. We prove that $(K_4 - e)$-saturated graphs do not exist for small values of $|E(G)|$ and construct $(K_4 - e)$-saturated graphs with $|E(G)|$ in the interval $\left[2n - 4, \left\lfloor \frac{n}{2} \right\rfloor \left\lceil \frac{n}{2} \right\rceil - n + 6\right]$. We then extend the $(K_4 - e)$-saturated graphs to $(K_t - e)$-saturated graphs. (Received September 13, 2016)

1124-05-375 **Mohit Kumbhat**, **Kevin Moss*** (kmoss@iastate.edu) and **Derrick Stolee**. *Choosability with Union Separation.*

List coloring generalizes graph coloring by requiring the color of a vertex to be selected from a list of colors specific to that vertex. One refinement of list coloring, called choosability with separation, requires that the intersection of adjacent lists is sufficiently small. We introduce a new refinement, called choosability with union separation, where we require that the union of adjacent lists is sufficiently large. For $t \geq k$, a (k, t)-list assignment is a list assignment L where $|L(v)| \geq k$ for all vertices v and $|L(u) \cup L(v)| \geq t$ for all edges uv. A graph is (k, t)-choosable if there is a proper coloring for every (k, t)-list assignment. We explore this concept through examples of graphs that are not (k, t)-choosable, demonstrating sparsity conditions that imply a graph is (k, t)-choosable, and proving that all planar graphs are $(3, 11)$-choosable and $(4, 9)$-choosable. (Received September 13, 2016)

1124-05-377 **Joshua N Cooper***, 1523 Greene St, Columbia, SC 29208, **Wei Li**, Fuzhou, Fujian , Peoples Rep of China, and **An Chang**, Fuzhou, Fujian , Peoples Rep of China. *Analytic Connectivity of Uniform Hypergraphs.*

The second smallest eigenvalue of the Laplacian matrix of a 2-graph G, denoted $\lambda_2(G)$, is called the "algebraic connectivity" of G. This quantity plays an important role in spectral graph theory. Qi defined a the "Laplacian tensor" and a natural "analytic connectivity" $\alpha(H)$ of k-uniform hypergraphs H. We investigate upper and lower bounds on this parameter expressed in terms of the degree sequence, codegree sequence, vertex connectivity, isoperimetric number and diameter, and compute the the analytic connectivity of some special k-graphs. (Received September 13, 2016)

1124-05-378 **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 September 13, 2016)

1124-05-384 **Susan Margulies***, 121 Blake Road, 323 Chauvenet Hall, Annapolis, MD 21402, and **Chris Griffin**. *Combinatorial Optimization Problems via Hilbert's Nullstellensatz.*

Systems of polynomial equations often provide elegant and compact models of NP-complete problems. In this talk, we explore the results in this area, ranging from combinatorial interpretations of Hilbert's Nullstellensatz certificates of infeasibility, to identifying polynomial-solvable instances of NP-complete problems, to exploring combinatorial patterns within the Grobner basis of the underlying ideal. We will explore algebraic results on problems such as graph-k-colorability, partition, independent set and perfect matching. (Received September 13, 2016)

1124-05-403 **Kevin G Milans*** (milans@math.wvu.edu) and **Michael Wigal**. *Online coloring blowups of a known graph.* Preliminary report.

In the *G-coloring game of width w*, both G and w are known to the two players, who alternate turns. First, Spoiler places a new token at a vertex in G, and Algorithm responds by assigning a color to the new token. Algorithm must ensure that tokens on the same or adjacent vertices receive distinct colors. Spoiler must ensure

that the token conflict graph (in which two tokens are adjacent if and only if their distance in G is at most 1) has chromatic number at most w. Algorithm wants to minimize the number of colors used, and Spoiler wants to force as many colors as possible. The *value* of the G-coloring game of width w, denoted $f_G(w)$, is the minimum number of colors needed in an optimal Algorithm strategy.

A graph G is *online-perfect* if $f_G(w) = w$. We give a forbidden induced subgraph characterization of the class of online-perfect graphs. When G is not online-perfect, determining $f_G(w)$ seems challenging; we establish $f_G(w)$ asymptotically for some (but not all) of the minimal graphs that are not online-perfect. The game is motivated by a natural online coloring problem on the real line which remains open. This is joint work with Michael Wigal. (Received September 13, 2016)

08 ► General algebraic systems

1124-08-220 **Agnes Szanto*** (aszanto@ncsu.edu), Department of Mathematics, North Carolina State University, Campus Box 8205, Raleigh, NC 27695. *Certification of Approximate Roots of Exact Polynomial Systems.*

In this talk I will survey some of our recent work on certifying approximate roots of exact polynomial systems and will describe some applications. The difficulty lies in the fact that in many of the applications the polynomial system is overdetermined or singular, and consistency or singularity are not continuous properties, so traditional numerical certification techniques do not work. Our certification method is based on hybrid symbolic-numeric techniques. This is a joint work with Tulay Akoglu, Jonathan Hauenstein and Bernard Mourrain. (Received September 09, 2016)

11 ► Number theory

1124-11-105 **Frank Thorne***, thorne@math.sc.edu, and **Takashi Taniguchi**. *Levels of distribution for prehomogeneous vector spaces.*

I will describe a family of exponential sums over finite fields which arise in the study of prehomogeneous vector spaces and arithmetic statistics. I will give an overview of how they arise, how they are evaluated, how one can translate them into "level of distribution" estimates, and why one might care.

I will especially focus on describing how the algebraic and geometric structure of these sums leads quite directly to strong results in analytic number theory. (Received September 01, 2016)

13 ► Commutative rings and algebras

1124-13-26 **Imran Anwar*** (imrananwar@sms.edu.pk), 68 B New Muslim Town, LAHORE, Punjab 5400000, Pakistan. *GALLAI-SIMPLICIAL COMPLEXES.* Preliminary report.

In this talk, we discuss the newly introduced concept of Gallai-simplicial complex $\Delta_\Gamma(G)$ of a finite simple graph G. We will describe, how we use the concept of Gallai graph $\Gamma(G)$ of a planar graph G to introduce the Gallai-simplicial complex $\Delta_\Gamma(G)$. The buildup of Gallai-simplicial complexes from a planar graph is an abstract idea, somehow, similar to building an origami shape from a plane sheet of paper by defining a crease pattern. We will discuss the Cohen-Macaulayness of Stanley-Reisner ring of a Gallai simplicial complex associated to certain graphs. Moreover, we will discuss the non-pure shellability of Gallai simplicial complexes. (Received July 26, 2016)

1124-13-30 **Craig Huneke*** (huneke@virginia.edu). *Local cohomology over direct summands of regular rings.* Preliminary report.

This talk will report on joint work with Josep Alvarez-Montaner and Luis Nunez-Betancourt concerning the D-module structure of local cohomology modules with support in an arbitrary ideal in a direct summand of a polynomial or power series ring. We find that all such local cohomology have finite length as a D-module, and use this point of view to prove they have only finitely many associated primes. Other applications will be discussed as time permits. (Received August 05, 2016)

1124-13-43 **D. D. Anderson*** (dan-anderson@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa City, IA 52242, and **Erik Hasse**, Department of Matheamtics, The University of Iowa, Iowa City, IA 52242. *Putting or Reducing Fractions to Lowest terms.* Preliminary report.

Let D be an integral domain and let a,b,c,d,e be nonzero elements of D. The fraction c/d is in (strongest)lowest terms if gcd(a,b)=1 (lcm(a,b)=ab). The fraction a/b can be put in (strongest) lowest terms if a/b = c/d where c/d is in (strongest) lowest terms and can be reduced to (strongest) lowest terms if there is an e with c = a/e and d = b/e. We investigate when a fraction a/b can be put or reduced to (strongest) lowest terms and integral domains for which each fraction a/b can be put or reduced to (strongest) lowest terms. (Received August 16, 2016)

1124-13-55 **Thomas G Lucas***, Department of Mathematics & Statistics, University of North Carolina Charlotte, Charlotte, NC 28223. *Weakly Additively Regular Rings and Special Families of Prime Ideals.* Preliminary report.

A commutative ring R is weakly additively regular if for each pair of elements $f, g \in R$ with f regular, there is a pair of elements $s, t \in R$ such that $gs + ft$ is regular and $sR + fR = R$. Also R is a Marot ring if each regular ideal can be generated by a set of regular elements. Each weakly additively regular ring is Marot, but a Marot ring need not be weakly additively regular. Both of these properties can be defined with regard to the set of prime ideals that contain only zero divisors. Thus we introduce weakly additively regular families and Marot families of primes. A nonempty set of (nonzero) primes $\mathcal{P} = \{P_\alpha\}_{\alpha \in \mathcal{A}}$ is a weakly additively regular family if for $f, g \in R$ with $f \in R \backslash \bigcup P_\alpha$, there is a pair of elements $s, t \in R$ such that $gs + ft \in R \backslash \bigcup P_\alpha$ and $sR + fR = R$. Also $\mathcal{P}$ is Marot family if each ideal I that is not contained in $\bigcup P_\alpha$ can be generated by $I \cap S$ where $S = R \backslash \bigcup P_\alpha$. If $\mathcal{P}$ is a weakly additively regular family and there are only finitely many maximal ideals that are not contained in $\bigcup P_\alpha$, then each invertible ideal that is not contained in $\bigcup P_\alpha$ is principal. (Received August 22, 2016)

1124-13-65 **Andrew R. Kustin***, kustin@math.sc.edu. *The equations defining blowup algebras of height three Gorenstein ideals.*

We find the defining equations of Rees rings of linearly presented height three Gorenstein ideals. To prove our main theorem we use local cohomology techniques to bound the maximum generator degree of the torsion submodule of symmetric powers in order to conclude that the defining equations of the Rees algebra and the special fiber ring have the same image in the symmetric algebra. We show that this image is the unmixed part of the ideal generated by the maximal minors of a matrix of linear forms which is annihilated by a vector of indeterminates, and otherwise has maximal possible grade. An important step of the proof is the calculation of the degree of the variety parametrized by the forms generating the grade three Gorenstein ideal.This is joint work with Claudia Polini and Bernd Ulrich. (Received August 26, 2016)

1124-13-84 **Evan Houston*** (eghousto@uncc.edu), **Eun Kyung Lee** (eklee@cau.ac.kr) and **Mi Hee Park** (mhpark@cau.ac.kr). *Locally pseudo-valuation domains with only finitely many star operations.*

Recall that a pseudo-valuation domain (PVD) is a local domain (R, M) such that $(M : M)$ is a valuation domain with maximal ideal M. Park (2012) characterized PVDs having only finitely many star operations. The notion of PVD was globalized in two ways by Dobbs and Fontana (1983). In the simpler of these, a domain R is an LPVD (locally PVD) if each localization at a maximal ideal is a PVD. In this talk we characterize LPVDs admitting only finitely many star operations, and we give examples to illustrate some of the subtleties involved. (We also characterize globalized PVDs, the other Dobbs-Fontana extension of "PVD," with only finitely many star operations.) Many of the techniques come from the characterization of integrally closed domains having only finitely many star operations by Houston, Mimouni, and Park (2014). (Received August 30, 2016)

1124-13-89 **Alessandro De Stefani**, **Thomas Polstra** and **Yongwei Yao***, Department of Mathematics and Statistics, Georgia State University, Atlanta, GA 30303. *Globalizing F-invariants.*

We define and study the global Hilbert-Kunz multiplicity and the global F-signature of prime characteristic rings which are not necessarily local. Our techniques are made meaningful by extending many known theorems about Hilbert-Kunz multiplicity and F-signature to the non-local case. This is joint work with Alessandro De Stefani and Thomas Polstra. (Received August 30, 2016)

1124-13-120 **Hans Schoutens*** (hschoutens@citytech.cuny.edu). *Extended dimensions and the spectrum of ultraproducts of Noetherian local rings.*

I will discuss a few extended dimensions, meaning that on the class of Noetherian local rings, they all give Krull dimension, but without the Noetherian assumption they may differ. I will apply this in particular to ultraproducts of Noetherian local rings, in which case these dimensions can often be calculated. (Received September 03, 2016)

1124-13-130 **Sean Sather-Wagstaff*** (ssather@clemson.edu). *Associated Primes of Derived Local Cohomology.* Preliminary report.

Let I be a proper ideal of a (commutative noetherian) ring R. A well-known question of Huneke asks whether the set of associated primes of each local cohomology module $\mathrm{H}^i_I(R)$ is finite. Counterexamples to this question were constructed by Singh, then improved by Katzman and Singh-Swanson. In this talk, we will discuss a variation on this question which *is* true: the derived local cohomology complex $\mathbf{R}\Gamma_I(R)$, the complex with cohomology defining the local cohomology modules $\mathrm{H}^i_I(R)$, has only finitely many associated primes in the sense of L. W. Christensen. (Received September 05, 2016)

1124-13-146 **Warren Wm. McGovern*** (warren.mcgovern@fau.edu), Jupiter, FL 33458, **Lee Klingler** (klingler@fau.edu), Boca Raton, FL 33431, and **Drake Harmon**, Boca Raton, FL 33431. *LOCAL TYPES OF CLASSICAL RINGS.* Preliminary report.

Motivated by recent results showing that the Prufer condition on rings with zero-divisors is not a local condition, we investigate the difference between the three notions of locally classical, maximally classical, and classical rings. We explore the notions of locally classical and maximally classical rings when restricted to the semi-regular prime and maximal ideals of the ring. In the context of completely regular Hausdorff spaces, maximally classical and classical rings of real-valued continuous functions have already been considered; we examine the case of locally classical rings of continuous functions. (Received September 06, 2016)

1124-13-148 **Lokendra Paudel** (lpaudel1@uakron.edu) and **Simplice Tchamna*** (simplice.tchamna@gcsu.edu), 231 W. Hancock St, Campus Box 17, Milledgeville, GA 31061. *Star operations induced by saturations.*

Let $R \subseteq S$ be a ring extension, and let A be an R-submodule of S. The saturation of A (in S) by τ is the set $A_{[\tau]} = \{x \in S : tx \in A \text{ for some } t \in \tau\}$, where τ is a multiplicative subset of R. We use the notion of saturation to define and study properties of star operations on ring extensions. In particular, we characterize star operations $\star$ on ring extensions $R \subseteq S$ satisfying the relation $(A \cap B)^\star = A^\star \cap B^\star$ whenever A and B are two R-submodules of S such that $AS = BS = S$. (Received September 06, 2016)

1124-13-158 **Scott T Chapman*** (scott.chapman@shsu.edu), Sam Houston State University, Department of Mathematics and Statistics, Box 2206, Huntsville, TX 77341. *Factorizaton properties of submonoids of $\mathbb{Z}$ defined by congruences.* Preliminary report.

Let $\mathbb{N}$ represent the natural numbers and $\mathbb{Z}$ the integers. If $n > 1$ is in $\mathbb{N}$ and Γ a multiplicatively closed subset of $\mathbb{Z}/n\mathbb{Z}$, then the set

$$M_\Gamma = \{n \in \mathbb{N} \mid \overline{n} \in \Gamma\} \cup \{1\}$$

is a multiplicative submonoid of $\mathbb{Z}$ known as the *Congruence Monoid* determined by Γ. If $\mid \Gamma \mid = 1$, then M_Γ is called *arithmetic*. This talk will review the extensive work done on factorization properties of these monoids, with an emphasis on the M_Γ which are arithmetic. We will focus on some recent results concerning the catenary degree of arithmetic congruence monoids. (Received September 06, 2016)

1124-13-170 **Marco Fontana*** (fontana@mat.uniroma3.it), Università degli Studi "Roma Tre", Dipartimento di Matematica e Fisica, 1, Largo San Leonardo Murialdo, 00146 Rome, Italy. *Amalgamated algebras along ideals: recent developments.*

After a short introduction on the motivations for studying an amalgamated algebra along a given ideal, in this talk I will present a brief survey on some of the recent results obtained by several authors in this research area.

The talk is based on recent papers written jointly with Marco D'Anna (Università di Catania, Italy) and Carmelo A. Finocchiaro (TU, Graz, Austria). (Received September 07, 2016)

1124-13-176 **Jim Coykendall*** (jcoyken@clemson.edu), Department of Mathematical Sciences, Clemson Univerity, Martin Hall O-103, Clemson, SC 29634, **Tridib Dutta**, Charles H. Dyson School of Management, Cornell University, Ithaca, NY 14853, and **Todd Fenstermacher**, Department of Mathematical Sciences, Clemson University, Martin Hall O-103, Clemson, SC 29634. *Generalizing Integrality.*

In this talk will will examine some older and newer generalizations of integrality. The theme here will be to look at some types of "near integrality" that are between the concepts of integral and almost integral. Examples to compare and contrast these notions will be given and some new directions will be highlighted, especially in the context of valuation overrings. (Received September 07, 2016)

1124-13-198 **David E. Dobbs***, Department of Mathematics, University of Tennessee, Knoxville, Tennessee 37996-1320, Knoxville, TN 37996-1320. *When the juxtaposition of two minimal ring extensions produces no new intermediate rings.*

Let $R \subset S$ and $S \subset T$ be minimal ring extensions of (commutative) rings. Jay Shapiro and the author recently gave 13 mutually exclusive conditions on these minimal ring extensions and their crucial maximal ideals to characterize when $R \subset T$ satisfies FIP, that is, when $R \subset T$ has only finitely many intermediate rings. Here it is shown that exactly two of these 13 conditions imply that S is the only ring properly contained (via unital ring extensions) between R and T. Moreover, if one assumes, in addition, that R is quasi-local, it is shown that exactly two of the other 11 conditions imply that S is the only ring properly contained between R and T. In all, there are seven (of the 13) conditions which each implies that S is not the only ring properly contained between R and T. Also, for four of the 13 conditions, some examples satisfying the condition are such that S is the only ring properly contained between R and T while other examples satisfying the condition do not have this feature. (Received September 08, 2016)

1124-13-223 **Kyle S. Trainor*** (kyle_trainor@knights.ucf.edu), Department of Mathematics, University of Central Florida, 4393 Andromeda Loop N, Orando, FL 32816. *The Italian identities for Hilbert series of hypergraphs.* Preliminary report.

We provide an algebraic proof of an identity for Hilbert series of hypergraphs derived from identities of Borzacchini and Pulito for subgraph enumerating polynomials. (Received September 09, 2016)

1124-13-232 **Martine Picavet*** (picavet.gm@wanadoo.fr) and **Gabriel Picavet**. *FCP or FIP extensions and the Chinese Remainder Theorem.*

Let $R \subseteq S$ be an extension of commutative rings and $[R, S]$ the set of R-subalgebras of S. Then $R \subseteq S$ is said to have FCP (resp. FIP) if each chain of the poset $([R, S], \subseteq)$ is finite (resp. $[R, S]$ is finite). The aim of this talk is to get an extension of the Chinese Remainder Theorem in the following sense. Let R be a ring, $n > 1$ an integer and $I_1, \ldots, I_n$ ideals of R distinct from R, but not necessarily distinct, such that $\cap_{j=1}^{n} I_j = 0$. Consider the ring extension $R \subseteq \prod_{j=1}^{n}(R/I_j) =: S$ with conductor C. This extension is an isomorphism if $C = R$ (Chinese Remainder Theorem). We address the following questions: When is $R \subseteq S$ a minimal extension, or more generally an FCP or FIP extension? We generalize a Ferrand-Olivier's result when $n > 2$. If $R \subseteq S$ a minimal extension, then $\{I_1, \ldots, I_n\}$ satisfies a weak Chinese Remainder Theorem. We prove that $R \subseteq S$ has FCP if and only if R/C is Artinian. If $n = 2$, we get that $R \subseteq S$ has FIP if and only if $R/(I_1 + I_2)$ has finitely many ideals. The characterization of the FIP property when $n > 2$ is much more complicated. (Received September 10, 2016)

1124-13-233 **Gabriel Picavet*** (picavet.gm@wanadoo.fr) and **Martine Picavet** (picavet.gm@wanadoo.fr). *Quasi-Prüfer extensions.* Preliminary report.

We introduce quasi-Prüfer extensions of commutative rings, in order to relativize the notion of quasi-Prüfer domains. These extensions allow us to take into account contexts, recently considered by some authors, like FCP extensions followed by a normal pair. The class of quasi-Prüfer extensions is stable under composition and has a very good behavior with respect to classical algebra operations. Quasi-Prüfer extensions coincide with INC-pairs. Prüfer extensions of Knebush and Zhang are well known to coincide with normal pairs. As Knebusch and Zhang did, we use flat epimorphisms instead of integrally closed extensions, providing quick proofs. We define the quasi-Prüfer hull of any ring extension. We also introduce almost-Prüfer extensions. They are quasi-Prüfer and their Prüfer hulls commute with the formation of localizations. As an application, we study extensions whose subextensions have finite fibers, a work initiated by Dobbs and Ayache. (Received September 10, 2016)

1124-13-236 **Teresa Cortadellas Benitez**, **Carlos D'Andrea** and **Florian Enescu*** (fenescu@gsu.edu), Department of Mathematics and Statistics, Georgia State University, 30 Pryor Street, Atlanta, GA 30303. *The Free Resolution of Fan Algebras of Principal Ideals in the Plane.* Preliminary report.

Let $\mathcal{F}$ be a fan in $\mathbb{R}^m$, $f_1, \ldots, f_n$ a family of fan-linear maps on $\mathcal{F}$, and $I_1, \ldots, I_n$ ideals in a commutative ring R. Fan algebras are R-algebras associated to this collection of data. They provide an interplay between the geometry and combinatorics of the fan and the algebraic properties of the ideals and fan linear maps. In our talk, we will describe their presentation ideal and free resolution when $m = 2$ and the ideals I_i, $i = 1, \ldots, n$, are principal, an important case with applications to the intersection algebra of principal monomial ideals. (Received September 10, 2016)

1124-13-247 **John Myers*** (jmyers4@math.unl.edu). *Ext-algebras and minimal multiplicity.* Preliminary report.

If R is a commutative noetherian local ring with residue field k, then the graded vector space $\mathrm{Ext}^*_R(k,k)$ has a product giving it the structure of a graded k-algebra, called the Ext-algebra or Yoneda algebra of R. In this talk we will explain how rings with minimal Hilbert-Samuel multiplicity can be detected by examining the structure of this algebra. (Received September 10, 2016)

1124-13-248 **Bruce Olberding*** (olberdin@nmsu.edu), New Mexico State University, Las Cruces, NM 88003-8001. *Local rings that behave like Noetherian rings in dimension zero.* Preliminary report.

Let R be a (not necessarily Noetherian) local ring with finitely generated maximal ideal M. By a result of Cohen, the M-adic completion of R is a Noetherian ring. We examine from several perspectives the situation in which the completion of R is a one-dimensional Cohen-Macaulay ring. In such a case, classical properties of reductions, integral closure and multiplicity are reflected at the "top" of the ring R. One motivation for this topic comes from joint work with Jay Shapiro in 2005 on ultrapowers of Noetherian rings. Another comes from the class of stable rings, those rings for which every regular ideal is projective over its ring of endomorphisms. A theme throughout the talk is the use of pullbacks as a classification tool. Even in the case in which the completion is a one-dimensional Cohen-Macaulay ring, the structure of these pullbacks has a number of subtleties. As an example, we use pullbacks to classify the local rings for which the square of the maximal ideal can be generated by two elements. (Received September 11, 2016)

1124-13-275 **Timothy S Long*** (tlong314@gmail.com). *Epimorphisms and the Amalgamated Duplication of a Ring Along an Ideal.* Preliminary report.

We consider homomorphisms involving the ring construction $R \bowtie I$, the amalgamated duplication of a ring along an ideal. Given two such rings $R \bowtie I$, $T \bowtie J$, and a ring map $f : R \to T$, we find necessary and sufficient conditions for the map $\hat{f} : R \bowtie I \to T \bowtie J$ defined by $\hat{f}(r, r+i) := (f(r), f(r)+f(i))$ to be a (flat) epimorphism. Consequently, we are able to describe certain localizations of $R \bowtie I$. We use these results to examine the structure of the total quotient ring of $R \bowtie I$, determine when $R \bowtie I$ is complemented, and attain partial results describing the epimorphic hull of $R \bowtie I$. (Received September 11, 2016)

1124-13-291 **Amy Dannielle Schmidt*** (amy.schmidt@hamptonu.edu), 100 E Queen St, Department of Mathematics, S&T Room 318, Hampton University, Hampton, VA 23668. *Fixed Rings: Minimal Ring Extensions and FIP and FCP Extensions.*

Let $R \subset T$ be a unital extension of commutative rings. Let G be a subgroup of the automorphism group of a ring T such that R is G-invariant. We say a property of the extension $R \subset T$ is *invariant (under G)* if the extension of fixed rings $R^G \subset T^G$ has the property. We continue the investigation of determining such invariant properties. One such property is minimality. We also consider the finite chain property (FCP) and finite intermediate algebra property (FIP) and related properties of ring extensions. (Received September 12, 2016)

1124-13-304 **Brittney Falahola*** (brittney.falahola@huskers.unl.edu), 203 Avery Hall, Department of Mathematics, Lincoln, NE 68588. *Characterizing Gorenstein Rings Using Frobenius.*

We will give two characterizations of Gorenstein rings of prime characteristic using the Frobenius functor in various ways. The first characterization, which only applies for rings which possess a canonical module, states that a ring is Gorenstein if and only if the Frobenius functor preserves the injective dimension of the canonical module. As a result of this characterization, we'll see that in rings possessing a canonical module, the canonical module serves as a test module for when the Frobenius functor preserves injective dimension. The second

characterization depends on the existence of a certain finitely generated module M of finite injective dimension for which the Frobenius functor "plays well" with an injective resolution of M. (Received September 12, 2016)

1124-13-310 **Andrew R Kustin**, **Liana M Sega** and **Adela N Vraciu*** (vraciu@math.sc.edu).
Poincare series of compressed level local Artinian rings with odd socle degree.

A recent result of Rossi and Şega shows that if R is a compressed Artinian Gorenstein local ring with socle degree not equal to three, then the Poincaré series of all finitely generated modules over R are rational, sharing a common denominator.

We generalize this result by replacing the Gorenstein assumption by the requirement that the ring $(R, \mathfrak{m})$ is level, i.e. the socle of R is $\mathfrak{m}^s$ for some s (called the socle degree of R). We need to add the assumption that the socle degree is odd. Our method relies on the same technique used by Rossi and Şega, which is exhibiting a Golod surjective homomorphism from a complete intersection onto R. In order to ensure that this technique works in the generalized setting, we undertake a detailed study of properties of compressed level Artinian local rings. In the process we show that the concept of compressed ring, which was previously studied under the assumption that the ring contains a field, also behaves well in the absence of a field. (Received September 12, 2016)

1124-13-343 **Janet Striuli*** (jstriuli@fairfield.edu), North Benson, Fairfield, CT 06825, and **HAydee Lindo**. *A different proof of a theorem of Braun.* Preliminary report.

In this talk we will present an alternative proof of a theorem of Braun, extending a result of Auslander. (Received September 12, 2016)

1124-13-359 **Lars Winther Christensen*** (lars.w.christensen@ttu.edu), **Srikanth B. Iyengar** and **Thomas Marley**. *Rigidity of Ext and Tor with coefficients in residue fields of a commutative noetherian ring.* Preliminary report.

For a finitely generated module M over a commutative noetherian local ring $(R, \mathfrak{m}, k)$, vanishing of $\operatorname{Tor}^R_{n+1}(k, M)$ for some $n \geq 0$ implies vanishing of $\operatorname{Tor}^R_i(k, M)$ for all $i \geq n+1$; this phenomenon is known as *rigidity*, and here it is a consequence of the existence of minimal free resolutions.

We prove that for any module M over a commutative noetherian ring R, and for any prime ideal $\mathfrak{p}$ in R, vanishing of $\operatorname{Tor}^R_{n+1}(R_\mathfrak{p}/\mathfrak{p}R_\mathfrak{p}, M)$ for some $n \geq \dim R_\mathfrak{p}$ implies vanishing of $\operatorname{Tor}^R_i(R_\mathfrak{p}/\mathfrak{p}R_\mathfrak{p}, M)$ for all $i \geq n+1$. A similar result holds for vanishing of Ext, and these results allow us to improve existing characterizations of modules of finite homological dimensions. (Received September 13, 2016)

1124-13-380 **Robert Krone*** (rk71@queensu.ca), Department of Math & Stats, Jeffery Hall, University Ave., Kingston, Ontario K7L 3N6, Canada, and **Anton Leykin** and **Andrew Snowden**.
Hilbert series of infinite symmetric ideals.

An infinite symmetric ideal I encodes a sequence of ideals indexed by a natural number n, each closed under an action of the nth symmetric group, with compatible maps between them. Nagel and Römer recently defined a Hilbert series of such a family and proved that it is rational. Using tools from the theory of formal languages we offer an easier proof and a simple algorithm that computes the series. (Received September 13, 2016)

1124-13-381 **David A. Jorgensen*** (djorgens@uta.edu) and **Yousuf Alkhezi**. *Stable tensor products.* Preliminary report.

Stable Hom for pairs of maximal Cohen-Macaulay modules over a Gorenstein ring is well-understood: it is the quotient of ordinary Hom by the submodule of maps factoring through a projective module. Stable Hom's counterpart, stable tensor, for pairs of maximal Cohen-Macaulay modules over a Gorenstein is less well-understood. In this talk we provide a preliminary investigation of stable tensor. In particular, we show that for ideals I and J in an artinian Gorenstein ring, the stable tensor product of R/I and R/J is $\operatorname{ann}\left(\operatorname{ann}(I) \cdot \operatorname{ann}(J)\right)/(I+J)$. (Received September 13, 2016)

1124-13-383 **Denise Rangel Tracy*** (drangeltracy01@manhattan.edu). *Examples of non-trivial totally reflexive modules over local non-Gorenstein rings.* Preliminary report.

Totally reflexive modules over a non-Gorenstein ring are an analog to maximal Cohen-Macaulay modules over a Gorenstein ring. It is known that the category of totally reflexive modules over a non-Gorenstein ring is either trivial (consisting only of projective modules) or is infinite, when it is infinite it is of wild representation type. For this talk we are interesting in finding explicit examples of such modules. A large portion of examples of nontrivial totally reflexive modules are due to Yoshino's results concerning local rings where the cubic of the maximal ideal is zero or are tied to the existence of exact zero pairs. We will discuss using these two method to

construct other nontrivial totally reflexive modules over local rings not fitting Yoshino's description. (Received September 13, 2016)

1124-13-396 **Jonathan Totushek*** (jtotushe@uwsuper.edu) and **Sean Sather-Wagstaff** (ssather@clemson.edu). *A variation on the complete intersection injective dimension.* Preliminary report.

The injective dimension (id) is a classical invariant used, e.g., by Auslander, Buchsbaum, and Serre to characterize regular local rings. Recently, other incarnations of this have been introduced that characterize other classes of rings. For instance, Sather-Wagstaff's complete intersection injective dimension (CI-id) characterizes formal complete intersections like its progenitor, the complete intersection dimension (CI-dim) of Avramov, Gasharov, and Peeva. Unfortunately, the CI-id is not as amenable to study as other such constructions.

In this talk, we will introduce a new version of the CI-id, which is more natural in some ways. We will describe several of its properties. In particular, we will show how it satisfies several natural properties that we have been unable to verify for Sather-Wagstaff's original notion. (Received September 13, 2016)

1124-13-401 **Joseph P Brennan*** (joseph.brennan@ucf.edu), Department of Mathematics, University of Central Florida, 4393 Andromeda Loop N, Orlando, FL 32816, and **Alex York**. *Fossum Modules and Grothendieck-Witt Groups.* Preliminary report.

This talk will address extending a result of Frobenius and Stickelberger to relate Fossum modules over a commutative ring to the Grothendieck-Witt group of the derived category (Received September 13, 2016)

1124-13-402 **Neil Epstein*** (nepstei2@gmu.edu), Fairfax, VA , and **Yongwei Yao**, Atlanta, GA. *Unmixed Hilbert-Kunz multiplicity.*

After providing foundations for Hilbert-Kunz theory of a non-embedded pair of modules (originally introduced without a name by Seibert), we introduce the Hilbert-Kunz multiplicity of a non-embedded *triple* of modules with finite length tensor product. The latter specializes to what we call the *unmixed Hilbert-Kunz multiplicity* of an arbitrary ideal, which coincides with ordinary Hilbert-Kunz multiplicity if the ideal has finite colength. We derive some key properties, including a criterion for a nested pair of ideals to have the same 'unmixed tight closure'. The definition for the triple leads to a double limit that we show is interchangeable because it exists in a uniform way.

Note that these generalizations of Hilbert-Kunz multiplicity do *not* coincide with any of those from the authors' recent article "Some generalizations of Hilbert-Kunz multiplicity", including the one that led to Brenner's counterexample to rationality of Hilbert-Kunz multiplicity. (Received September 13, 2016)

1124-13-407 **Claudia Miller** and **Hamid Rahmati*** (rahmath@miamioh.edu). *Free Resolutions of Artinian Gorenstein Algebras.* Preliminary report.

Let k be a field of characteristic zero and let $R = k[x_1, \ldots, x_n]$. In 2014, S. El Khoury and A. Kustin gave a construction of the minimal free resolution of R/I, as an R-module, where R/I is a generic graded Artinian Gorenstein k-algebra of even socle degree. We construct free resolutions of generic graded Artinian Gorenstein k-algebras of odd socle degree. In fact, our proof, which is different from that of El Khoury and Kustin, covers both odd and even cases. This is joint work with Claudia Miller. (Received September 13, 2016)

1124-13-409 **Peter Malcolmson*** (petem@wayne.edu) and **Frank Okoh** (okoh@math.wayne.edu). *Which power series are associated to polynomials?* Preliminary report.

When R is a commutative ring with an element which is neither a unit nor a zero-divisor, then $R[[T]]$ has uncountably many associate classes. If such an R is countable, then uncountably many power series are not associated to polynomials. If R is the ring with 4 elements (generated by 1), then all power series are associated to polynomials. It is only when R has infinitely many indeterminates that we have a concrete example of a power series that is not associated to a polynomial. (Received September 13, 2016)

14 ► Algebraic geometry

1124-14-6 **Tolga Karayayla*** (tkarayay@metu.edu.tr). *Finite groups which act freely on smooth Schoen threefolds.*

A Schoen 3-fold is a fiber product $X = B_1 \times_{\mathbb{P}^1} B_2$ over $\mathbb{P}^1$ of two rational elliptic surfaces B_1 and B_2 with section. If X is smooth, it is a simply connected Calabi-Yau 3-fold. If a finite group G acts freely on X, then the quotient space X/G is a non-simply connected Calabi-Yau 3-fold. In order to list all non-simply connected Calabi-Yau 3-folds which are obtained as quotients of smooth Schoen 3-folds, the finite groups which act freely

on Schoen 3-folds must be classified. We consider group actions on X where any element of the group is a product $\tau_1 \times \tau_2$ of automorphisms of the elliptic surfaces B_1 and B_2 so that the automorphisms $\phi(\tau_1)$ and $\phi(\tau_2)$ on the base curve $\mathbb{P}^1$ induced by τ_1 and τ_2 are the same. Each group G acting on X induces a group action on the base curve $\mathbb{P}^1$.The group actions on X which induce cyclic group actions on $\mathbb{P}^1$ were classified by Bouchard and Donagi. In this talk, I will present my recent result that any finite group which acts freely on a smooth Schoen 3-fold induces a cyclic group action on the base curve $\mathbb{P}^1$. This result completes the classification of finite groups which act freely on smooth Schoen 3folds. (Received March 17, 2016)

1124-14-17 **Lubjana Beshaj*** (beshaj@math.utexas.edu), UT Austin, Dept. of Math., RLM 8.100, Austin, TX 78712. *Minimal models for superelliptic curves with extra automorphisms.* Preliminary report.

Let K be an algebraic number field and $\mathcal{O}_K$ its ring of integers. A superelliptic curve $\mathcal{X}$ defined over $\mathcal{O}_K$ is a planar curve with equation of the form $y^n = f(x)$, for $n \geq 2$ and some $f \in \mathcal{O}_K[x]$. Finding a nice polynomial $f(x)$ such that it has " small" coefficients correspond to the case when the zero map $\epsilon(f^\star)$ of the homogenized form $f^\star \in K[x, z]$ is in the fundamental domain of the modular group $\Gamma_K := SL_2(\mathcal{O}_K)/\{\pm I\}$ action on the upper-half plane. In this talk we discuss how to choose f in the case when the curve $\mathcal{X}$ has extra automorphisms and $K = \mathbb{Q}$. (Received September 08, 2016)

1124-14-22 **Emilio Bujalance**, **Antonio F. Costa** and **Milagros Izquierdo***, Department of Mathematics, Linköping University, 58183 Linköping, Sweden. *Riemann Surfaces with 4g Automorphisms.*

We see that with a finite (quite small) number of exceptions, given a genus g, there is just a uniparametric family of Riemann surfaces having full automorphism group of order 4g. In this talk we study the this family and their real forms. The results are joint work with Antonio F. Costa, and Emilio Bujalance (Received July 14, 2016)

1124-14-63 **Alexander Varchenko*** (anv@email.unc.edu), Department of Math, UNC at Chapel Hill, Chapel Hill, NC 27599. *Elliptic dynamical quantum group $E_{\tau,h}(gl_2)$ and elliptic equivariant cohomology of the cotangent bundles of Grassmannians.* Preliminary report.

The torus T equivariant elliptic cohomology defines a functor $Ell_T : \{T - \text{spaces } X\} \to \{\text{schemes}\}$. For example, for the cotangent bundle of a Grassmannian the scheme $Ell_T(T^*Gr(k, n))$ is some explicitly given sub-scheme of $S^k E \times S^{n-k} E \times E^n \times E^2$ with coordinates $t_1, \dots, t_k, s_1, \dots, s_{n-k}, z_1, \dots, z_n, h, \lambda$, where t_i, s_j correspond to the Chern roots of the two standard vector bundles over the Grassmannian, z, y correspond to the torus parameters, λ is the dynamical parameter also called the Kähler parameter, and E is an elliptic curve.

I will define a class of line bundles on the scheme $\cup_{k=0}^n Ell_T(T^*Gr(k, n))$ such that the operator algebra of the elliptic dynamical quantum group $E_{\tau,h}(gl_2)$ will act on sections of those line bundles (a generator of the operator algebra will send a section of such a line bundle to a section of possibly another line bundle). That construction is an analog of the Yangian $Y(gl_2)$ action on the direct sum $\oplus_{k=0}^n H_T^*(T^*Gr(k, n))$ of equivariant cohomology.

This is a joint work with G.Felder and R.Rimanyi. (Received August 26, 2016)

1124-14-70 **Grigoriy Blekherman**, **Torin Greenwood** and **Rainer Sinn*** (sinn@math.gatech.edu). *More on the Geometry of Positive Semidefinite Matrix Completion.* Preliminary report.

We will study two geometric invariants of the positive semidefinite matrix completion problem, the Gaussian rank and the maximum likelihood threshold of a graph. We will give interpretations of these invariants from the point of view of algebraic geometry and sums of squares and give the first example of a graph where these two invariants are different. (Received August 27, 2016)

1124-14-86 **Ada Boralevi**, **Jan Draisma**, **Emil Horobet** and **Elina Robeva*** (erobeva@gmail.com). *Orthogonal tensor decomposition from an algebraic perspective.*

While every matrix admits a singular value decomposition, in which the terms are pairwise orthogonal in a strong sense, higher-order tensors typically do not admit such an orthogonal decomposition. We give an algebro-geometric analysis of the set of orthogonally decomposable tensors. More specifically, we prove that they form a real-algebraic variety defined by polynomials of degree two. A key feature of our approach is a surprising connection between orthogonally decomposable tensors and associative semisimple algebras. (Received August 30, 2016)

1124-14-92 **Justin Sawon*** (sawon@email.unc.edu), Department of Mathematics, University of North Carolina, Chapel Hill, NC 27599-3250. *Lagrangian fibrations on holomorphic symplectic manifolds.*

A holomorphic symplectic manifold is a Kahler manifold with a closed non-degenerate holomorphic two-form. In this talk we consider fibrations on these manifolds whose fibres are complex tori that are Lagrangian with respect to the holomorphic two-form. We describe the standard examples and survey some recent results. (Received August 30, 2016)

1124-14-98 **Luke Oeding*** (oeding@auburn.edu), Department of Mathematics and Statistics, 221 Parker Hall, Auburn, AL 36849. *Border Ranks of Monomials.*

Young flattenings, introduced by Landsberg and Ottaviani, give determinantal equations for secant varieties and provide lower bounds for border ranks of tensors. We find special monomial-optimal Young flattenings that provide the best possible lower bound for all monomials up to degree 6. For degree 7 and higher these flattenings no longer suffice for all monomials. To overcome this problem we introduce partial Young flattenings and use them to give a lower bound on the border rank of monomials which agrees with Landsberg and Teitler's upper bound. (Received August 31, 2016)

1124-14-106 **Hirotachi Abo*** (abo@uidaho.edu), 875 Perimeter Drive, MS 1103, Moscow, ID 83844-1103. *On the discriminant of a section of a vector bundle.* Preliminary report.

The main purpose of the talks is to discuss the variety formed by global sections of a vector bundle on projective space whose zero scheme is singular. We call such a variety the discriminant locus of a global section of the vector bundle (or just the discriminant of the vector bundle).

The discriminant locus of a vector bundle can be very naturally considered as a generalization of the classical discriminant of a polynomial in one variable, i.e., a polynomial in the coefficients which vanishes at the polynomial whenever it has a multiple root. It is very natural to ask "What is the dimension of the discriminant of a vector bundle? What about the degree?" The discriminant locus of a line bundle is also naturally identified with the dual variety of the Veronese variety, and hence its dimension and degree are already known. The focus of this talk is therefore on the discriminant locus for a vector bundle of higher rank. In this talk, I plan to show that the discriminant locus of a so-called the Schwarzenberger type bundle (STB) is an irreducible hypersurface. I also plan to discuss how the geometry of a non-singular curve associated with STB helps us find the degree of such a hypersurface. (Received September 01, 2016)

1124-14-112 **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 September 01, 2016)

1124-14-125 **Timo de Wolff*** (dewolff@math.tamu.edu), Texas A&M University, Department of Mathematics, College Station, TX 77843-3368, and **Sadik Iliman** and **Mareike Dressler**. *New Certificates for Nonnegativity via Nonnegative Circuit Polynomials.*

Deciding nonnegativity of real polynomials is a fundamental problem in real algebraic geometry. Since this problem is NP-hard, one is interested in finding certificates for nonnegativity, which are easier to check. Since the 19th century the standard certificates for nonnegativity are sums of squares (SOS). In practice, one uses semidefinite programming (SDP), which is based on SOS certificates, as the standard method to solve polynomial optimization problems.

We introduce an *entirely new class* of nonnegativity certificate based on *sums of nonnegative circuit polynomials* (SONC), which are *independent* of sums of squares. We establish a Positivstellensatz which guarantees that every polynomial which is positive on a given compact, semi-algebraic set can be represented by the constraints of the set and SONC polynomials.

Similar as SOS correspond to SDP, our certificates correspond to geometric programming and relative entropy programming. We show that our certificates allow to compute lower bounds both for unconstrained and constrained polynomial optimization problems efficiently. Particularly, our approach outperforms semidefinite programming dramatically in various examples. (Received September 04, 2016)

1124-14-155 **Marco Aldi*** (maldi2@vcu.edu) and **Andrija Perunicic**. *Invertible Hypersurfaces over a Finite Field and Mirror Symmetry.*

Berglund-Huebsch duality is an explicit construction of mirror pairs of Calabi-Yau manifolds. In this talk we present some applications of Berglund-Huebsch duality to the study of the Frobenius operator acting on the Monsky-Washnitzer cohomology of invertible hypersurfaces. (Received September 06, 2016)

1124-14-171 **Grigoriy Blekherman*** (greg@math.gatech.edu), **Daniel Plaumann**, **Rainer Sinn** and **Mauricio Velasco**. *Matrix Completion and Sum-of-Squares Length.* Preliminary report.

For a projective variety X with coordinate ring R let p(X) denote the least number such that any sum of squares of linear forms in R can be written as p(X) many squares. When X is defined by a square-free quadratic monomial ideal determining p(X) corresponds to low-rank positive semidefinite matrix completion. I will present some new bounds on p(X) and explain the connection to matrix completion and distance realization problems. (Received September 07, 2016)

1124-14-192 **Jonathan Mboyo Esole*** (j.esole@northeastern.edu). *Flop transitions of elliptic fibrations with Mordell-Weil group with $\mathbb{Z}/(2)$ Torsion.*

I will discuss the resolved geometry of elliptic fibrations corresponding to gauge theories with gauge group SO(3), SO(5), and SO(6). I will present a generating function for the Euler characteristic of these elliptic fibrations with a base of arbitrary dimension. I will also discuss the network of flops of the SO(6) case. (Received September 08, 2016)

1124-14-201 **Hoon Hong**, **Zachary Hough*** (zchough@ncsu.edu) and **Irina Kogan**. *Algorithm for computing μ-bases of univariate polynomials.*

We present a new algorithm for computing a μ-basis of the syzygy module of n polynomials in one variable over an arbitrary field $\mathbb{K}$. The algorithm is conceptually different from the previously-developed algorithms by Cox, Sederberg, Chen, Zheng, and Wang for $n = 3$, and by Song and Goldman for an arbitrary n. The algorithm involves computing a "partial" reduced row-echelon form of a $(2d + 1) \times n(d + 1)$ matrix over $\mathbb{K}$, where d is the maximum degree of the input polynomials. The proof of the algorithm is based on standard linear algebra and is completely self-contained. The proof includes a proof of the existence of the μ-basis and as a consequence provides an alternative proof of the freeness of the syzygy module. The theoretical (worst case asymptotic) computational complexity of the algorithm is $O(d^2n + d^3 + n^2)$. We have implemented this algorithm (HHK) and the one developed by Song and Goldman (SG). Experiments on random inputs indicate that SG is faster than HHK when d is sufficiently large for a fixed n, and that HHK is faster than SG when n is sufficiently large for a fixed d. (Received September 08, 2016)

1124-14-213 **Ke Ye*** (kye@galton.uchicago.edu) and **Lek Heng Lim**. *Tensor network states and G-ranks.* Preliminary report.

Tensor network states (TNS) are tensors associated to graphs.TNS are used to study quantum systems in condensed matter physics. In this talk, we will first define tensor network states and give some examples, including tensor trains (TT) and matrix product states (MPS). Then we will discuss the dimension of the set of tensor network states associated to a graph. Finally, for any graph G, we will define the notion of G-rank which generalizes the rank of matrices and we will show that the G-rank is unique if and only if G is a tree. If time permits, we will also discuss some properties of G-ranks. This talk is based on a joint work with Lek-Heng Lim. (Received September 09, 2016)

1124-14-230 **Savdeep S Sethi*** (sethi@uchicago.edu), Enrico Fermi Institute, 5640 S. Ellis Ave., Chicago, IL 60637. *Quantum Rings from Duality.* Preliminary report.

This talk will re-examine how quantum field theory, together with duality, can be used to compute quantum sheaf cohomology rings. Most work, both in physics and in mathematics, has focused on the quantum rings that arise for deformations of the tangent bundle. My aim will be to explore aspects of the quantum rings that characterize more general models, which involve a choice of sheaf that is not necessarily a deformed tangent bundle. (Received September 10, 2016)

1124-14-272 **Joe Kileel*** (jkileel@math.berkeley.edu), **Zuzana Kukelova**, **Tomas Pajdla** and **Bernd Sturmfels**. *Distortion Varieties.*

We discuss a project at the interface of computer vision and algebraic geometry. Work with Zuzana Kukelova, Tomas Pajdla and Bernd Sturmfels introduces the distortion varieties of a given projective variety. These are parametrized by duplicating coordinates and multiplying them with monomials. We study their degrees and

defining equations. Exact formulas are obtained for the case of one-parameter distortions, the case of most interest for modeling cameras with image distortion. (Received September 11, 2016)

1124-14-277 **Jimmy Dillies***, Jimmy Dillies, Georgia Southern University, Statesboro, GA 30458. *Models of automorphisms and fibrations.*

Constructing examples of varieties with prescribed automorphisms can often be daunting when no extrinsic geometric information is given. When the variety is an elliptic K3 surface, we show how the action induced on the Gram graph helps us create geometric models and visualize factorization of automorphisms. (Received September 11, 2016)

1124-14-281 **J. Maurice Rojas*** (rojas@math.tamu.edu), TAMU 3368, College Station, TX 77843-3368. *Fast Approximation of Certain A-Discriminant Contours.* Preliminary report.

Determining the topology of real algebraic hypersurfaces is important in many applications, but current methods still lead to average-case complexity polynomial in the degree. We show that, when f is an n-variate (n+3)-nomial, we can compute the topology of the real zero set of f in time polynomial in the log of the degree, for most inputs. The key trick is a fast method to determine discriminant chamber membership for an explicitly large set of inputs. Some of the results presented are joint work with Erin Lipman and Korben Rusek. (Received September 11, 2016)

1124-14-325 **Andrew Obus*** (andrewobus@gmail.com), Department of Mathematics, 141 Cabell Drive, Kerchof Hall, Charlottesville, VA 22904. *Good reduction of three-point Galois covers.*

We study Galois covers of the projective line branched at three points with Galois group G. When such a cover is defined over a p-adic field, it is known to have potentially good reduction to characteristic p if p does not divide the order of G. We give a sufficient criterion for good reduction, even when p does divide the order of G, so long as the p-Sylow subgroup of G is cyclic and the absolute ramification index of a field of definition of the cover is small enough. This extends work of (and answers a question of) Raynaud. Our proof (which will only be briefly sketched) depends on working very explicitly with Kummer extensions of complete discrete valuation rings with imperfect residue fields. (Received September 12, 2016)

1124-14-358 **Hoon Hong*** (hong@ncsu.edu), Department of Mathematics, Campus Box 8205, North Carolina State University, Raleigh, NC 27695. *Test-Data Generation using Computational Real Algebraic Geometry.* Preliminary report.

One of the fundamental challenges in software testing is automatic test-data generation. Due to its importance, intensive research have been carried out among computer scientists, resulting in various methods such as structural testing, model-based testing, combinatorial testing, random testing, search -based testing, etc.

In this talk, we will present another method intended for numerical software. The method is based on various ideas and theories from computational real algebraic geometry and topology such as critical points, gradient tracking, Morse-Smale complex, etc. It can in principle generate one and only one test-input for each and every possible execution path. Various heuristics are being developed in order to increase the practical efficiency.

We hope that the method will grow mature through collaboration between the program verification community and the computational real algebraic geometry community. (Received September 13, 2016)

1124-14-371 **Jim Wolper*** (wolpjame@isu.edu), Idaho State University, Department of Mathematics and Statistics, 921 S. 8th Ave., Mail Stop 8085, Pocatello, ID 83209. *Distribution of Periods of Macbeath's Curve.* Preliminary report.

The automorphism group of Macbeath's Curve of genus 7 has the maximum size, making it an ongoing example of intense study. This talk applies a new tool, the distribution of the periods, to studying Macbeath's curve. While period distributions have been studied numerically, the periods of this curve are known exactly. Furthermore, the Jacobian is isogenous to a seven-fold product of an elliptic curve, leading to a different period distribution. How are these related? (Received September 13, 2016)

1124-14-400 **Brent R. Davis*** (davisb@math.colostate.edu), **E. Gross**, **K. Ho**, **D. Bates** and **H. Harrington**. *Numerical algebraic geometry for model selection.*

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 nonlinearity, 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 September 13, 2016)

15 ► Linear and multilinear algebra; matrix theory

1124-15-240 **Lek-Heng Lim*** (lekheng@galton.uchicago.edu) and **Shmuel Friedland**. *From secant varieties to nuclear norm balls.*

It is well-known that for $d > 2$, the set of d-tensors of rank $\leq r$ is not a closed set. The usual approach to remedy this is to take Zariski closure (in this case equivalent to Euclidean closure) to obtain the rth secant variety. While the secant variety is attractive for various reasons (e.g., cut out by polynomials; defined over arbitrary fields), it is not so from an applications perspective (e.g., border rank-r tensors may have ranks much larger than r; there is no general expression for a border rank-r tensor). We propose an alternative way of 'closing up' the set of rank-r tensors over $\mathbb{C}$ or $\mathbb{R}$, namely, using tensor nuclear norm as a continuous proxy for tensor rank. Tensor nuclear norm has properties much like tensor rank (e.g., base field dependence, NP-hard to compute) but is somewhat easier to study (e.g., one can prove Comon conjecture for tensor nuclear norm) because of properties (e.g., convexity, dual norm) peculiar to a norm. In addition, we will show that it gives rise to a notion of tensor *nuclear rank*, a nuclear norm attaining decompositions with a minimum number of rank-1 terms. Among other properties, the set of d-tensors of nuclear rank $\leq r$ will always be a closed set. (Received September 10, 2016)

1124-15-418 **J Ding***, Department of Mathematics, University of Southern Mississippi, Hattiesburg, MS 39406. *Commuting Solutions of the Yang-Baxter-Like Matrix Equation.*

Let A be a complex square matrix. We solve the Yang-Baxter-like matrix equation $AXA = XAX$ to find all of its commuting solutions. The structure of the solution set is also given. (Received September 14, 2016)

16 ► Associative rings and algebras

1124-16-27 **Xin Tang*** (xtang@uncfsu.edu), 1200 Murchison Road, Fayetteville, NC 28301. *The Automorphism Groups for a Family of Generalized Weyl Algebras.*

We present some results on the algebra automorphisms for a family of generalized Weyl algebras $\mathcal{A}_p(\lambda, \mu, K_q[s,t])$ and some related algebras. First of all, we show that these generalized Weyl algebras possess simple localizations in the case where none of p and q is a root of unity. As an application, we are able to determine height-one prime ideals and the automorphism groups for these generalized Weyl algebras, and solve the isomorphism problem in the generic case. Second of all, we establish a quantum analogue of the Dixmier conjecture and determine their automorphism groups for the simple localizations of these generalized Weyl algebras. Using the method of discriminant, we are also able to determine the automorphism group for the generalized Weyl algebras $A_p(1, 1, K_q[s,t])$ in the case where neither p nor q is equal to one. Some relevant problems will be addressed as well. (Received August 01, 2016)

1124-16-28 **Hiroyuki Yamane*** (hiroyuki@sci.u-toyama.ac.jp), Department of Mathematics, Fac. of Sci., University of Toyama, Gofuku, Toyama 930-8555, JAPAN, Toyama, Toyama 930-8555, Japan. *Representations of generalized quantum groups.*

Let K be an algebraically closed field. Let $K^\times := K \setminus \{0\}$. Let X be a finite rank free abelian group. Let $\chi : X \times X \to K^\times$ be a map such that $\chi(a+b,c) = \chi(a,c)\chi(b,c)$ and $\chi(a,b+c) = \chi(a,b)\chi(a,c)$. Let n be a rank of X. Let $I := 1, \ldots, n\}$. Let $\Pi = \{\alpha_i | i \in I\}$ be a base of X. To the pair (χ, Π), one can associate a Hopf K-algebra $U = U(\chi, \Pi)$ in a standard way. Let G be a simple Lie algebra of rank n. For some (χ, Π), U is virtually isomorphic to the quantum group U_qG (resp. the small quantum group u_qG), or the (small) quantum superalgebra of a simple (contragredient, or basic classical) Lie superalgebra. The following results have been achieved. (1) Matsumoto type theorem of Weyl groupoids (joint with Heckenberger (2008)). (2) Shapovalov determinants of U (joint with Heckenberger (2010)). (3) Universal R-matrix of U (joint with Angiono (2015)). (4) Classification of the finite dimensional simple modules of U (joint with Azam and Yousofzadeh (2015)). (5) Harish-Chandra type theorem of U (joint with Batra (2013)). In the talk, mainly (4) and (5) will be presented. (Received August 01, 2016)

1124-16-398 **Kiyoshi Igusa**, **Gordana Todorov*** (g.todorov@northeastern.edu) and **Jerzy Weyman**. *Cohomology of picture groups for Dynkin quivers of type A.* Preliminary report.
For every Dynkin quiver of finite representation type we define a finitely presented group called a picture group. This group is very closely related to the cluster theory of the quiver. For example, positive expressions for the Coxeter element in the group are in bijection with maximal green sequences. The picture group is derived from the semi-invariant picture for the quiver. We use this picture to construct a finite CW complex which has this group as its fundamental group i.e. is a K(π,1) for this group. The cells are in bijection with cluster tilting objects. For example, in type An there are a Catalan number of cells.
The main result is the computation of the cohomology ring of all picture groups of type A_n with any orientation and any coefficient ring. (Received September 13, 2016)

1124-16-408 **Jason Gaddis** (gaddisjd@wfu.edu), PO Box 7388, 127 Manchester Hall, Winston-Salem, NC 27109, **Ellen Kirkman** (kirkman@wfu.edu), PO Box 7388, 127 Manchester Hall, Winston-Salem, NC 27109, **W. Frank Moore*** (moorewf@wfu.edu), PO Box 7388, 127 Manchester Hall, Winston-Salem, NC 27109, and **Rob Won** (wonrj@wfu.edu), PO Box 7388, 127 Manchester Hall, Winston-Salem, NC 27109. *On the pertinency of symmetric group actions on (-1)-skew polynomial rings.* Preliminary report.
Let k be a field, A an $\mathbb{N}$-graded k-algebra, and G be a group of graded automorphisms of A. Auslander proved that in case A is the commutative polynomial ring, the skew group ring $A\#G$ is isomorphic to the ring of A^G-linear endomorphisms of A if and only if G does not contain a nontrivial pseudo-reflection.

Recent work of Bao, He and Zhang have couched the existence of such an isomorphism for a general graded algebra in terms of the pertinency of the group action, which is the difference in Gelfand-Kirillov dimensions of $A\#G$ and $(A\#G)/\langle f\rangle$ where f is the Reynolds idempotent. In this preliminary report, we provide some new computations of this invariant when A is the (-1)-skew polynomial ring in n variables, and S_n acts as permutations of A, the details of which use commutative algebra in an interesting way. (Received September 13, 2016)

17 ► Nonassociative rings and algebras

1124-17-34 **J. T. Hird*** (john.hird@mail.wvu.edu), **Lindsey Bosko-Dunbar**, **Jonathan Dunbar** and **Kristen Stagg-Rovira**. *Second-maximal subalgebras of Leibniz algebras.*
We study Leibniz algebras whose second-maximal subalgebras are ideals. We classify these algebras based on solvability, nilpotency, and the size of the derived algebra. (Received August 08, 2016)

1124-17-79 **Ismail Demir*** (idemir@ncsu.edu). *Classification of Complex Nilpotent Leibniz Algebras.*
Leibniz algebras are non-antisymmetric generalization of Lie algebras. Classification of all nilpotent Lie algebras is still unsolved and is very difficult problem. Due to lack of antisymmetry in Leibniz algebras, the problem of classifying all nilpotent Leibniz algebras is more complicated. We give classification of 5−dimensional complex nilpotent Leibniz algebras. We use the canonical forms for the congruence classes of matrices of bilinear forms and some algebraic invariants to obtain our result. This is a joint work with my advisors Kailash C. Misra and Ernie Stitzinger. (Received August 29, 2016)

1124-17-104 **Naihuan Jing** and **Chad R. Mangum*** (cmangum@niagara.edu), Dunleavy 333, 5795 Lewiston Rd, Niagara University, NY 14109, and **Kailash C. Misra**. *A New Realization of Twisted Toroidal Lie Algebras.*
Lie algebra representation theory is a vibrant field of research and has been significant in various areas of mathematics and physics for several decades. In this talk, we will discuss a recent advance in the specific theory of twisted (2-)toroidal (Lie) algebras, which we view as universal central extensions of twisted multi-loop algebras. The usual loop algebra realization generalizes the familiar realization of affine Kac-Moody algebras. We will discuss a new realization of these algebras given by generators and relations, based on a similar realization for untwisted toroidal algebras by Moody, Rao, and Yokonuma. This has the advantage of being more amenable than the loop algebra realization to studying the representation theory. This is joint work with Dr. Kailash Misra and Dr. Naihuan Jing. (Received August 31, 2016)

1124-17-118 **Ben Lewis Cox*** (coxbl@cofc.edu), 66 George St., Charleston, SC 29401. *Module structure of the center of the universal central extension of a genus zero Krichever-Novikov algebra.*

We describe how the center of the universal central extension of the genus zero Krichever-Novikov current algebra decomposes as a direct sum of irreducible modules for automorphism group of the coordinate ring of this algebra. (Received September 03, 2016)

1124-17-127 **Garrett Johnson***, gjohns62@nccu.edu. *Frobenius functionals and Boundary Solutions of the Classical Yang-Baxter Equation.* Preliminary report.

Quasitriangular solutions to the classical Yang-Baxter equation (CYBE) were classified by Belavin and Drinfeld in the early 1980's. We study a conjecture of Gerstenhaber and Giaquinto concerning boundary solutions to the CYBE. Their conjecture leads one to consider maximal parabolic subalgebras of $\mathfrak{sl}_n$ that are also Frobenius (which occur only for the i-th parabolic subalgebra when i is coprime to n). In this talk, we present our results on this conjecture in the case when n is congruent to -1 or 1 modulo i. We conclude with some ideas on proving the conjecture outside of this special case. (Received September 05, 2016)

1124-17-137 **Weiqiang Wang*** (ww9c@virginia.edu). *Multiparameter quantum Schur duality of type B.*

We establish a Schur type duality between a coideal subalgebra of the quantum group of type A and the Hecke algebra of type B with 2 parameters. We identify the i-canonical basis (developed by Bao and Wang) on the tensor product of the natural representation with Lusztig's canonical basis of the type B Hecke algebra with unequal parameters associated to a weight function. This is joint work with Huanchen Bao (IAS) and Hideya Watanabe (Tokyo Institute of Technology). (Received September 05, 2016)

1124-17-164 **Kyu-Hwan Lee***, Department of Mathematics, University of Connecticut, Storrs, CT 06268, and **Jang Soo Kim** and **Se-jin Oh**. *Multiplicities of maximal dominant weights of affine Lie algebras.* Preliminary report.

In this talk, we consider multiplicities of maximal dominant weights of level 2 highest weight representations of affine Lie algebras. We will describe the multiplicities using triangular arrays of numbers and combinatorics of tableaux. This is a joint work with Jang Soo Kim and Se-jin Oh. (Received September 06, 2016)

1124-17-165 **Ashley Walls White*** (anwalls@ncsu.edu), North Carolina State University, Department of Mathematics, Raleigh, NC 27695. *Conjugacy Results in Solvable Leibniz Algebras.*

Part of an ongoing project to extend results from Lie algebras to Leibniz algebras we present results dealing with conjugacy in Leibniz algebras, including results on Cartan Subalgebras. The proofs of these results differ from the Lie algebra cases that often depend on the anti-symmetry of the Lie bracket. Consequences of the main result, conjugacy of Cartan subalgebras in solvable Leibniz algebras, will be presented. (Received September 06, 2016)

1124-17-183 **Drazen Adamovic*** (adamovic@math.hr), Department of Mathematics, University of Zagreb, Bijenicka 30, 10 000 Zagreb, Croatia. *On Wakimoto and Whittaker modules for affine vertex algebras.*

We shall present recent results on classification and explicit realizations of Wakimoto and Whittaker modules for affine Lie algebras by using vertex-algebraic techniques. First we shall present a result on classification of irreducible Wakimoto modules in principal graduation for the affine Lie algebra $A_1^{(1)}$ (obtain in a joint work with N. Jing and K. Misra) and discuss some combinatorial applications. Next we will consider Whittaker modules for affine Lie algebras as modules for universal affine vertex algebras. We present a result on classification of Whittaker modules for $A_1^{(1)}$ (joint work with K. Zhao and R. Lu). Some possible generalizations will be also discussed. (Received September 08, 2016)

1124-17-190 **Kristen Boyle*** (kjboyle@ncsu.edu) and **Elyse Rogers** (esrogers@ncsu.edu). *Characteristic Ideals and Leibniz Algebras.*

George Seligman wrote an article on characteristic ideals and the structure of Lie Algebras. In this talk we will discuss the corresponding results in Leibniz Algebras. (Received September 08, 2016)

1124-17-194 **Rebecca L. Jayne*** (rjayne@hsc.edu), Box 187, Hampden-Sydney, VA 23901. *Multiplicities of maximal dominant weights of integrable $\widehat{sl}(n)$-modules.*

For $n, k \geq 2$, we study the multiplicities of certain maximal dominant weights of the irreducible highest weight $\widehat{sl}(n)$-module $V(k\Lambda_0)$. We give the multiplicity of the weight $k\Lambda_0 - \sum_{i=0}^{\ell}(\ell - i)(\alpha_i + \alpha_{n-i})$ by the number of certain admissible sequences of $k-1$ lattice paths in a colored $\ell \times \ell$ square. In turn, we find that the number

of such admissible sequences of lattice paths is given by the sum of squares of the number of standard Young tableaux of shape $\lambda \vdash \ell$ with $l(\lambda) \leq k$, a value that can be calculated using the well known Frame-Robinson-Thrall hook length formula. This is a joint work with Kailash C. Misra. (Received September 08, 2016)

1124-17-288 **Shashank Kanade*** (kanade@ualberta.ca), **Matthew C Russell** (russell2@math.rutgers.edu) and **Debajyoti Nandi** (djn@cmi.ac.in). *A new search for partition identities motivated by Lepowsky-Wilson Z-algebras.* Preliminary report.

J. Lepowsky and R. L. Wilson, in their highly influential work, built a framework for interpreting, proving and finding partition identities using the representation theory of affine Lie algebras. They achieved this via the invention Z-algebras and what came to be known as vertex-operator-algebraic relations among Z-operators. In this talk, I'll report on a recent search (purely at the level of q-series) for new integer partition identities that is motivated by one aspect of Lepowsky and Wilson's mechanism. This new search is a variant of an earlier joint work with Matthew C. Russell and is a joint work with Debajyoti Nandi and Russell. (Received September 12, 2016)

1124-17-289 **Dijana Jakelić*** (jakelicd@uncw.edu) and **Adriano Moura** (aamoura@ime.unicamp.br). *Demazure flags and tensor products of integrable modules for affine algebras.* Preliminary report.

Let $\hat{\mathfrak{g}}$ be an affine Kac-Moody algebra. The problem of computing outer multiplicities of irreducible modules in tensor products of two integrable irreducible modules of $\hat{\mathfrak{g}}$ has gathered a lot of attention because of its connections to mathematical physics and number theory. In particular, tensor products of integrable irreducible modules with the basic representation of $\hat{\mathfrak{g}}$ are of special interest. We discuss the relation of this problem with the one of computing multiplicities in Demazure flags of a given Demazure module. (Received September 12, 2016)

1124-17-301 **Vyacheslav Futorny**, **Dimitar Grantcharov*** (grandim@uta.edu) and **Luis Enrique Ramirez**. *New irreducible singular Gelfand-Tsetlin modules of* $\mathfrak{gl}(n)$. Preliminary report.

Every irreducible finite-dimensional module of $\mathfrak{gl}(n)$ can be described with the aid of the classical Gelfand-Tsetlin formulas. The same formulas can be used to define a $\mathfrak{gl}(n)$-module structure on some infinite-dimensional modules - the so-called generic (nonsingular) Gelfand-Tsetlin modules. To study singular Gelfand-Tsetlin modules we introduce new type of tableaux, derivative Gelfand-Tsetlin tableaux. In this talk we will discuss a special type of singular Gelfand-Tsetlin $\mathfrak{gl}(n)$-modules - those of index 2. In particular, we obtain new tableaux basis for some irreducible Verma modules. The talk is based on a joint work with V. Futorny and L. E. Ramirez. (Received September 12, 2016)

1124-17-315 **Bethany Turner***, turnerbn2@appstate.edu. *Some Criteria for Solvable and Supersolvable Leibniz Algebras.* Preliminary report.

Leibniz algebras are generalizations of Lie algebras which are not antisymmetric. Since the introduction of Leibniz algebras in 1993 by Jean-Louis Loday, many results for Lie algebras have been generalized to the Leibniz case, such as Lie's Theorem and Engel's Theorem. Since 2008, motivated by group theory, David Towers has used several types of subalgebras to characterize solvable and supersolvable Lie algebras. Among these subalgebras are c-ideals, CAP-subalgebras and Cartan subalgebras. In this talk we introduce definitions for c-ideals and CAP-subalgebras of Leibniz algebras. We then give some characterizations of solvable and supersolvable Leibniz algebras based on the behavior of these subalgebras. (Received September 12, 2016)

1124-17-357 **Elizabeth Jurisich*** (jurisiche@cofc.edu), Mathematics Department, The College of Charleston, 66 George Street, Charleston, SC 29424, and **Ben L. Cox** (coxbl@cofc.edu). *Actions of a three-point algebra and semi-direct product on a Fock space.* Preliminary report.

We present a natural free field realization in terms of a beta- gamma system and the oscillator algebra of the three-point affine Lie algebra when $\mathfrak{g} = \mathfrak{sl}(2, C)$. We present a preliminary result of a semi-direct product "gauge algebra" acting on the Fock space of the three-point algebra. (Received September 13, 2016)

1124-17-393 **Darlayne Addabbo*** (addabbo2@illinois.edu), Champaign, IL 61820. *Q-systems and Generalizations in Representation Theory.*

We will define tau-functions given as matrix elements for the action of $\widehat{GL_2}$ on two-component fermionic Fock space and explain how to show that they satisfy an $A_{\infty/2}$ Q-system. Since Q-systems are of interest in many areas of mathematics, for example in representation theory and in combinatorics, it is interesting to ask what sort of discrete relations are satisfied by analogous tau-functions given as matrix elements for the action of

$\widehat{GL_3}$ on three-component fermionic Fock space. We will define these new tau-functions and describe the system of equations that they satisfy. We will also discuss progress we have made in finding applications for this new system of equations. If time permits, generalizations will be discussed. (Joint with Maarten Bergvelt.) (Received September 13, 2016)

18 ► Category theory; homological algebra

1124-18-56 **Georgios Dalezios** (georgios.dalezios@um.es), Departamento de Matemáticas, Campus de Espinardo, 30100 Murcia, Murcia, Spain, **Sergio Estrada*** (sestrada@um.es), Departamento de Matemáticas, Campus de Espinardo, 30100 Murcia, Murcia, Spain, and **Henrik Holm**, Department of Mathematical Sciences, Universitetsparken 5, 2100 Copenhagen, Denmark. *Derived equivalences between stable categories of Gorenstein projective and injectives.*

Our work is motivated by a recent interesting result by Zheng and Huang which asserts that for "many" rings R (more precisely, R should be left and right noetherian with a dualizing complex) the categories $\underline{\mathrm{GProj}}(R)$ and $\underline{\mathrm{GInj}}(R)$ are triangulated equivalent. The stable categories $\underline{\mathrm{GProj}}(R)$ and $\underline{\mathrm{GInj}}(R)$ can be realized as the homotopy category of certain model categories (for instance the Frobenius model categories $\mathrm{GProj}(R)$ and $\mathrm{GInj}(R)$). So it is natural to ask when the triangulated equivalence between $\underline{\mathrm{GProj}}(R)$ and $\underline{\mathrm{GInj}}(R)$ is, in addition, a derived equivalence (i.e. induced from a Quillen equivalence of model categories). In the talk we will consider the following more general question:

For which abelian categories $\mathcal{A}$ (assumed to be bicomplete with enough projectives and enough injectives) are the categories $\underline{\mathrm{GProj}}(\mathcal{A})$ and $\underline{\mathrm{GInj}}(\mathcal{A})$ derived equivalent?. We will give sufficient conditions to ensure this and for such cases we will construct new examples for some abelian categories $\mathcal{B}$ naturally constructed from $\mathcal{A}$. (Received August 23, 2016)

1124-18-121 **Hans Schoutens*** (hschoutens@citytech.cuny.edu). *Balanced depth and pseudo-canonical modules.*

In a local CM ring, any part of a system of parameters is regular and generates an unmixed ideal. A generalization of this notion would be a regular sequence (on a module) such that each subsequence generates an unmixed ideal (submodule). Call the maximal length of such a sequence the balanced depth (of the module). I will show how this can be calculated by means of the vanishing of the Maltis duals of the local cohomology groups, the so-called pseudo-canonical modules. (Received September 03, 2016)

1124-18-298 **Hannah Altmann*** (haltmann@morris.umn.edu), **Eloisa Grifo**, **Jonathan Montano**, **William Sanders** and **Thanh Vu**. *Lower Bounds on Levels of Perfect Complexes.* Preliminary report.

Let R be an associative ring. An R-complex F is *perfect* if it is quasiisomorphic to a bounded complex of finitely generated projective modules. A useful invariant associated to every perfect complex is its level. We can think of the level of F as the number of steps it takes to build F out of R. We will discuss finding bounds on the level of a perfect complex. In particular, we will show that the length of the largest gap in the homology of a complex F gives a lower bound for the level of F. (Received September 12, 2016)

19 ► K-theory

1124-19-116 **Seth Baldwin*** (seth.e.baldwin@gmail.com) and **Shrawan Kumar**. *Positivity in T-equivariant K-theory of flag varieties associated to Kac-Moody groups.*

The cohomology ring of flag varieties has long been known to exhibit positivity properties. One such property is that the structure constants of the Schubert basis with respect to the cup product are non-negative. Brion (2002) and Anderson-Griffeth-Miller (2011) have shown that positivity extends to K-theory and T-equivariant K-theory, respectively. In this talk I will discuss recent work (joint with Shrawan Kumar) which generalizes these results to the case of Kac-Moody groups. (Received September 02, 2016)

20 ► Group theory and generalizations

1124-20-10 **David Terna Achaku*** (achakudt@yahoo.co.uk), Federal University Lafia, P.M.B. 146, Lafia, Nigeria. *On Character of index 2 Subgroups.*

In this work we use constructed character tables of symmetric groups, tensor product and orthogonality relations as our working tools. For (ρ, V) as a representation of the group G, and $\rho : G \longrightarrow GL(V)$ as a group homomorphism and placing a restriction on the map ρ to H a subgroup of G denoted as $\rho|H$ we obtained a representation for H. We then define an inner product on $[G]$ as $\langle , \rangle_H$ thinking of H as a group in itself. We were then ready and proved that characters of S_n always take values in integers however, this is not true for A_n and may not be even real valued.

Keywords: Character, group representation, G-invariant, orthogonality relation and dimension. (Received April 12, 2016)

1124-20-138 **Peter J Olver*** (olver@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *Symmetry groupoids and weighted signatures of geometric objects.*

In this talk, I will refine the concept of the symmetry group of a geometric object through its symmetry groupoid, which incorporates both global and local symmetries in a common framework. The symmetry groupoid is related to the weighted differential invariant signature of a submanifold, that is introduced to capture its fine grain equivalence and symmetry properties. The groupoid/signature approach will be connected recent developments in signature-based recognition and symmetry detection of objects in digital images. (Received September 05, 2016)

1124-20-160 **Amrita Acharyya**, **Jon M Corson** and **Bikash C Das*** (bikash.das@ung.edu), University of North Georgia, 3820 Mundy Mill Rd., OAKWOOD, GA. *Cofinite Connectedness and Cofinite Group Actions.*

We have defined and established a theory of cofinite connectedness of a cofinite graph. Many of the properties of connectedness of topological spaces have analogs for cofinite connectedness. We have seen that if G is a cofinite group and Gamma = Gamma(G,X) is the Cayley graph. Then Gamma can be given a suitable cofinite uniform topological structure so that X generates G, topologically iff Gamma is cofinitely connected.

Our immediate next concern is developing group actions on cofinite graphs. Defining the action of an abstract group over a cofinite graph in the most natural way we are able to characterize a unique way of uniformizing an abstract group with a cofinite structure, obtained from the cofinite structure of the graph in the underlying action, so that the afore said action becomes uniformly continuous. (Received September 06, 2016)

1124-20-189 **Skip Garibaldi**, **Robert M. Guralnick** and **Daniel K. Nakano*** (nakano@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30602. *Globally Irreducible Weyl Modules.*

In the representation theory of split reductive algebraic groups, the following is a well known fact: for every minuscule weight, the Weyl module with that highest weight is irreducible over every field. The adjoint representation of E_8 is also irreducible over every field. Recently, Benedict Gross conjectured that these two examples should be the only cases where the Weyl modules are irreducible over arbitrary fields. In this talk I will present our results which prove Gross' suggested converse to these statements, i.e., that if a Weyl module is irreducible over every field, it must be either one of these, or trivially constructed from one of these. If time permits, I will also explain analogues for quantum groups at roots of unity. (Received September 08, 2016)

1124-20-354 **Jie Du**, **Brian Parshall*** (bjp8w@virginia.edu) and **Leonard Scott**. *Stratifying Hecke endomorphism algebras.*

The Hecke algebra in the title is a q-deformation $\mathcal{H}$ of the group algebra of a finite Weyl group. It has a natural enlargement to an endomorphism algebra $\mathcal{A} := \mathrm{End}_{\mathcal{H}}(\mathcal{T})$, where $\mathcal{T}$ is a certain q-permutation module. In type A, $\mathcal{A}$ is a (quasi-hereditary) q-Schur algebra which plays an important role in cross-characteristic representation theory of the finite general linear groups. In other types, $\mathcal{A}$ is not always quasi-hereditary, but the authors conjectured in 1996 that $\mathcal{T}$ can be enlarged to a module $\mathcal{T}^+$ such that $\mathcal{A}^+ := \mathrm{End}_{\mathcal{A}}(\mathcal{T}^+)$ is "standardly" stratified (with strata associated to Kazhdan-Lusztig cells). In 2015, the authors proved a local version of the conjecture, using rational Cherednik algebras. More recently, much progress has made on the "global" conjecture (at the moment in the equal parameter case, but over $\mathbb{Z}[t, t^{-1}]$), using constructions in the setting of exact categories in order to make certain Ext^1-groups better behaved. The talk will concentrate on this recent progress. (Received September 13, 2016)

22 ► Topological groups, Lie groups

1124-22-82 **Jiuzu Hong*** (jiuzu@email.unc.edu), Department of Mathematics,UNC Chapel HIll, Phillips Hall CB#3250, Chapel Hill, NC 27599-3250. *Conformal blocks, Verlinde formula and diagram automorphism.*

A diagram automorphism of a simply-laced simple Lie algebra induces operators on conformal blocks associated to a pointed projective curve. I will explain my recent result on the Verlinde formula for the trace of the diagram automorphism on conformal blocks. A non simply-laced simple algebraic group associated to this diagram automorphism appears mysteriously in the formula. This formula and twining formula for Kac-Moody algebras suggests a conjecture on the Verlinde formula for the dimension of conformal blocks for twisted affine Lie algebras on a pointed orbi-curve. (Received August 29, 2016)

1124-22-174 **Xiao Chang*** (xic58@pitt.edu) and **Paul M Gartside** (gartside@math.pitt.edu). *When is $H(X)$ compact?* Preliminary report.

Hofmann and Morris recently showed in "Compact Homeomorphism Groups are Profinite" that if X is a compact space and $H(X)$ the autohomeomorphism group of X, with the compact-open topology, is also compact, then $H(X)$ is profinite. They asked whether the converse is true: if G is a profinite group then is there is a compact (preferably, connected) space X such that $H(X) = G$?

We survey what is known about this problem, and give some partial positive answers. (Received September 07, 2016)

1124-22-177 **Evgeny Feigin**, **Ievgen Makedonskyi** and **Daniel Orr*** (dorr@vt.edu). *Generalized Weyl modules and nonsymmetric q-Whittaker functions.*

For the current algebra of a finite-dimensional simple Lie algebra, there are universal finite-dimensional highest weight modules known as Weyl modules. These modules have been studied extensively by Chari-Pressley, Chari-Loktev, Fourier-Littelmann, and others. Their graded characters are known to coincide with well-known objects from algebraic combinatorics, namely the Macdonald polynomials specialized at $t = 0$.

This talk will focus on joint work with E. Feigin and I. Makedonskyi in which we study "generalized" Weyl modules. These are graded modules for the Borel subalgebra of the associated affine Lie algebra. We will explain the connections between the graded characters of these modules, nonsymmetric Macdonald polynomials, and nonsymmetric q-Whittaker functions.

Generally, q-Whittaker functions are defined as eigenfunctions of the q-Toda difference operators. We prove that a generating function for the graded characters of generalized global Weyl modules is an eigenfunction of Dunkl-type operators associated with the q-Toda difference operators, i.e., this generating function is a nonsymmetric q-Whittaker function. This implies certain linear relations among the characters of generalized Weyl modules. (Received September 07, 2016)

1124-22-179 **Kristin Renee Bugg*** (kbugg@ncsu.edu). *Invariance of the Radical and Nilradical of an Ideal in a Leibniz Algebra.*

In Lie algebra it is known that the radical is invariant under derivations, which is useful in a variety of results. For Leibniz algebras, the corresponding result is not known. We will show a useful substitute as well as some consequences. (Received September 07, 2016)

34 ► Ordinary differential equations

1124-34-12 **Alexandra Smirnova** (asmirnova@gsu.edu), **Hui Liu*** (hliu34@uncc.edu) and **Linda deCamp** (ldecamp1@student.gsu.edu). *Inverse Problems and Ebola Virus Disease.*

Parameter estimation problems in ordinary and partial differential equations constitute a large class of models described by ill-posed operator equations.A considerable number of such problems come from epidemiology and infectious disease modeling, with Ebola Virus Disease (EVD) being an important example. While it is not difficult to find a solution of an SEIJCR ODE constrained least squares problem, this problem is extremely unstable and a number of different parameter combinations produce essentially the same case curve. This is a serious obstacle in the study of the Ebola virus epidemics. We attempt a stable estimation of system parameters with the use of iterative regularization along with a special algorithm for computing initial values. The numerical study is illustrated for the most recent EVD outbreak in Sierra Leone and Liberia. (Received September 13, 2016)

1124-34-196 **Anthony M Bloch*** (abloch@umich.edu), **Francois Gay-Balmaz** and **Tudor S Ratiu**. *Low rank integrable systems, moment maps and optimal control.*

In this talk we consider certain integrable systems and their relationship to optimal control problems. In particular we consider the rigid body problem and its symmetric representation and low rank formulation, a class of flows on symmetric matrices, the geodesic flows on Stiefel manifolds and the Toda flow. We also discuss the role that the geometry of the moment map plays in this problem. (Received September 08, 2016)

1124-34-306 **Hai Dang** and **Ratnasingham Shivaji*** (r_shivaj@uncg.edu), Dept of Mathematics & Statistics, University of North Carolina at Greeensboro, 116 Petty, 317 College Ave, Greensboro, NC 27412. *On radial solutions for singular combined superlinear elliptic systems on annular domains.*

We prove the existence of a large positive solution to the system

$$\begin{cases} -(r^{N-1}\phi_1(u'))' = \lambda r^{N-1} f_1(v), & a < r < b, \\ -(r^{N-1}\phi_2(v'))' = \lambda r^{N-1} f_2(u), & a < r < b, \\ u(a) = 0 = u(b), v(a) = 0 = v(b), \end{cases}$$

where $a > 0$, λ is a small positive parameter, $f_i : (0, \infty) \to \mathbb{R}$ are continuous and $\lim_{z\to\infty} \frac{\phi_1^{-1}(f_1(c(\phi_2^{-1}(f_2(z)))}{z} = \infty$ for all $c > 0$. (Received September 12, 2016)

1124-34-347 **M N Nkashama***, Mathematics Department, Birmingham, AL 35294-1170, and **N Mavinga**, Department of Mathematics and Statistics, Swarthmore, PA 19081. *Bifurcation from infinity and multiplicity of solutions for nonlinear second order periodic boundary value problems.* Preliminary report.

We shall present bifurcation and multiplicity results at higher eigenvalues for periodic solutions of nonlinear perturbations of second order linear differential equations with periodic boundary conditions. Since higher eigenvalues have even multiplicity (specifically, multiplicity two) and associated eigenfunctions are oscillatory, some care is taken to study the problem when the bifurcation parameter varies in a nontrivial continuum about the eigenvalues and the nonlinearity is not necessarily smooth. The proofs are based on *a priori* estimates, degree theory, variational arguments, continuation methods and bifurcation from infinity techniques. (Received September 13, 2016)

35 ► Partial differential equations

1124-35-14 **W. Feng*** (wfeng1@vols.utk.edu), Department of Mathematics, The University of Tennessee, Knoxville, TN 37996, **A.J. Salgado** (asalgad1@utk.edu), Department of Mathematics, The University of Tennessee, Knoxville, TN 37996, **S.M. Wise** (swise@math.utk.edu), Department of Mathematics, The University of Tennessee, Knoxville, TN 37996, and **C. Wang** (cwang1@umassd.edu), Department of Mathematics, The University of Massachusetts, North Dartmo, MA 02747. *Preconditioned Steepest Descent Methods for some Regularized p-Laplacian Problems.*

We present preconditioned steepest descent solvers for some fourth- and sixth-order nonlinear elliptic equations that include p-Laplacian terms. The highest and lowest order terms are constant-coefficient, positive linear operators. Instead of solving the nonlinear systems directly, we minimize the convex energies associated with the equations. By using the energy dissipation property, we derive a discrete ℓ^p bound for the solution, as well as the upper-bound for the second derivative of the energy. These bounds allow us to investigate the convergence properties of our method. In particular, the geometric convergence rate is shown for the nonlinear preconditioned steepest descent (PSD) iteration applied to the regularized equation, which provides a much sharper theoretical result over the existing works. Numerical simulations for thin film epitaxy with slope selection are carried out to verify well-known physical scaling laws for the long time coarsening process. Moreover, we present, for the first time, numerical simulations for the 6-Laplacian thin film epitaxy and the H^{-1} gradient flows of squared phase field crystal model, using the proposed method. (Received June 11, 2016)

1124-35-64 **Marian Bocea*** (mbocea@luc.edu), Loyola University Chicago, Department of Mathematics and Statistics, 1032 W. Sheridan Road, Chicago, IL 60660. *On a family of inhomogeneous torsional creep problems.*

The asymptotic behavior of solutions to a family of inhomogeneous PDEs in divergence form is studied in an Orlicz-Sobolev setting. Solutions are shown to converge uniformly to the distance function to the boundary of the domain. One consequence is that a well-known result in the analysis of problems modeling torsional

creep continues to hold under much more general constitutive assumptions on the stress. Joint work with M. Mihailescu. (Received August 26, 2016)

1124-35-81 **John Gemmer*** (gemmerj@wfu.edu), Department of Mathematics and Statistics, Wake Forest University, 127 Manchester Hall, Winston Salem, NC 27109, and **Shankar Venkataramani**, **Toby Shearman** and **Eran Sharon**. *Isometric Immersions, Energy Minimization and Branch Points in Non-Euclidean Elastic Sheets.*

The edges of torn elastic sheets and growing leaves often display hierarchical self-similar like buckling patterns. On the one hand, such complex, self similar patterns are usually associated with a competition between two distinct energy scales, e.g. elastic sheets with boundary conditions that preclude the possibility of relieving in plane strains, or at alloy-alloy interfaces between distinct crystal structures. On the other hand, within the non-Euclidean plate theory this complex morphology can be understood as low bending energy isometric immersions of hyperbolic Riemannian metrics. In this talk we will show that this complex morphology (i) arises from isometric immersions (ii) is driven by a competition between the two principal curvatures, rather than between bending and stretching. We identify the key role of branch-point (or monkey-saddle) singularities, in complex wrinkling patterns within the class of finite bending energy isometric immersions. Using these defects we will give an explicit construction of strain-free embeddings of hyperbolic surfaces that are fractal like and have lower elastic energy than their smooth counterparts. (Received August 29, 2016)

1124-35-97 **Leo G Rebholz** (rebholz@clemson.edu) and **Camille Zerfas*** (czerfas@clemson.edu). *The reduced NS-α model of turbulent flow.*

We introduce a new, reduced order NS-α (rNS-α) model for the purpose of efficient, stable and accurate simulations of incompressible flow problems at high Reynolds numbers on coarse meshes. We motivate the new model as an adaptation of the well-known NS-α model that is more efficiently computable, then analyze its well-posedness, treatment of energy, and discuss numerical discretizations. Several numerical tests are given which reveal remarkable coarse-mesh accuracy for turbulent flow simulations. Finally, we examine sensitivity of the models solutions to the filtering radius. (Received September 12, 2016)

1124-35-109 **Yang Yang*** (yang926@purdue.edu), 150 N. University Street, West Lafayette, IN 47906, and **Plamen Stefanov** (stefanop@purdue.edu), 150 N. University Street, West Lafayette, IN 47906. *Thermo-Acoustic Tomography with reflectors.*

Thermo-Acoustic tomography (TAT) is a recently developed coupled physics imaging modality. In this talk we will discuss the mathematical model of TAT in heterogeneous medium with the presence of sound-hard reflectors. We will demonstrate an averaged time reversal algorithm which leads to an exponentially convergent Neumann series reconstruction. Numerical implementation of the algorithm will be presented. This is joint work with Plamen Stefanov. (Received September 01, 2016)

1124-35-117 **Michael Victor Klibanov***, Michael V. Klibanov, University of North Carolina at Charlotte, Charlotte, NC 28223. *Phaseless inverse scattering problems and Carleman weight functions for global convergence.*

Phaseless inverse scattering problems are common in: 1. Quantum inverse scattering theory, where only the differential cross-section can be measured outside the scatterer. 2. Lensless imaging of nanostructures. This imaging is vital for quality control of manufactured nanostructures.

The question about the investigation of #1 was posed by K. Chadan and P.C. Sabatier in their book of 1977 and was also posed implicitly by R.G. Newton in his book of 1989. However, no progress was achieved until a work of the author in 2014.

1. Uniqueness theorems. 2. Reconstructions methods.

This is closely linked with another topic: global convergence for Coefficient Inverse Problems (CIPs). We call a numerical method for a CIP "globally convergent" if there is a theorem which guarantees that this method delivers at least one point in a sufficiently small neighborhood of the correct solution without a priori knowledge of this neighborhood. This theorem must be confirmed numerically.

The only alternative to global convergence is the least squares minimization. However, there is no guarantee of convergence of this technique, unless a very good first guess about solution is known in advance.

We will present:

A globally convergent method based on Carleman Weight Functions. (Received September 02, 2016)

1124-35-133 **Pavel Drabek*** (pdrabek@kma.zcu.cz), NTIS and Department of Mathematics, University of West Bohemia in Pilsen, 306 14 Pilsen, Czech Rep. *Convergence to travelling waves in the Fisher's population genetics model with a non-Lipschitzian reaction term.*

We consider the semilinear Fisher equation for the advance of an advantageous gene in biology:

$$\begin{cases} \dfrac{\partial u}{\partial t} - \dfrac{\partial^2 u}{\partial x^2} = f(u) \quad \text{for } (x,t) \in \mathbb{R} \times \mathbb{R}_+ ; \\ u(x,0) = u_0(x) \quad \text{for } x \in \mathbb{R} . \end{cases}$$

In contrast with previous works, we relax the differentiability hypothesis on f to being only Hölder-continuous and "one-sided" Lipschitz-continuous (i.e., $s \mapsto f(s) - Ls \colon \mathbb{R} \to \mathbb{R}$ is monotone decreasing, for some constant $L \in \mathbb{R}_+$). In particular, our hypotheses allow for the singular derivatives

$$f'(0) = \lim_{s \to 0} \frac{f(s)}{s} = -\infty \quad \text{and} \quad f'(1) = \lim_{s \to 1} \frac{f(s)}{s-1} = -\infty .$$

The fact that reaction function f is not smooth allows for the introduction of travelling waves with a new profile. We study existence and uniqueness of this new profile, as well as a long-time asymptotic behavior of the solutions of the Cauchy problem to a travelling wave. Presented results are based on joint research with P. Takáč from the University of Rostock, Germany. (Received September 05, 2016)

1124-35-134 **Yuhua Li**, **Fuyi Li** and **Junping Shi*** (jxshix@wm.edu), Department of Mathematics, College of William and Mary, Williamsburg, VA 23187. *Ground States of Nonlinear Schödinger Equation on Star Metric Graphs.*

The existence and nonexistence of the ground state to Nonlinear Schödinger equation on several types of metric graphs are considered. In particular, for some star graphs with only one central vertex, the existence of ground state solution or positive solutions are shown. It is shown that the structure of the set of positive solution is quite different from the one for corresponding bounded n-dimensional domain. The proofs are based on variational methods, rearrangement arguments, energy estimates and phase plane analysis. (Received September 05, 2016)

1124-35-136 **G. Moon** and **S. Raynor*** (raynorsg@wfu.edu). *A Two-Phase Free Boundary Problem in Two Dimensions.* Preliminary report.

In this work, we review a classical free boundary problem with several applications in jets, fluids, and heat flow. We prove a new result about the regularity of such a solution in two dimensions and discuss simulations of the problem on simple domains. (Received September 05, 2016)

1124-35-144 **Sun-Sig Byun** (byun@snu.ac.kr) and **Eunkyung Ko*** (ekko1115@unist.ac.kr). *Global $C^{1,\alpha}$ regularity and existence of multiple positive solutions for a singular $p(x)-$Laplacian equation.*

In this talk, we discuss positive solutions of the singular $p(x)-$Laplacian problem:

$$\begin{cases} -\mathrm{div}(|\nabla u|^{p(x)-2}\nabla u) = \frac{\lambda}{u^{\beta(x)}} + u^{q(x)}, & \text{in } \Omega, \\ u > 0, & \text{in } \Omega, \\ u = 0, & \text{on } \partial\Omega, \end{cases}$$

where Ω is bounded domain in $\mathbb{R}^N, N \geq 2$, with smooth boundary $\partial\Omega$, $\lambda > 0$ is a parameter, $\beta \in C^1(\bar{\Omega})$ with $0 < \beta(x) < 1$, $p \in C^1(\bar{\Omega}), q \in C(\bar{\Omega})$ with $p(x) > 1$ and $p(x) - 1 \leq q(x) < p^*(x) - 1$ for $x \in \bar{\Omega}$ where $p^*(x) = \frac{Np(x)}{N-p(x)}$ for $p(x) < N$ and $p^*(x) = \infty$ for $p(x) \geq N$. We prove the existence of multiple positive solutions by establishing the global $C^{1,\alpha}$ regularity of weak solutions and the strong comparison principle for the singular $p(x)$-Laplacian problem. (Received September 06, 2016)

1124-35-169 **Justin T Webster*** (websterj@cofc.edu), 66 GEORGE ST, Charleston, SC 29424, and **Irena Lasiecka**. *Stabilization of a fluttering beam or plate via internal damping.*

When a thin elastic structure is immersed in a fluid flow, certain conditions may bring about excitations in the structure. That is, the "dynamic loading" of the fluid couples to the "natural oscillatory modes" of the structure. In this talk we consider panel and cantilevered configurations for pertinent nonlinear plate or beam models, and investigate the effect of damping on long-time behavior. We discuss recent results on stabilization of the structural dynamics to a smooth set (a global attractor) in the presence of any internal damping (for instance, viscous dissipation due to the fluid flow). Moreover, we describe how imposing large damping in the interior of the structure results in the strong stabilization of fluid-plate trajectories to the equilibria set for subsonic flows; for arbitrary flow velocities, large damping may improve the global attractor to a fractal exponential attractor. Recent numerical simulations will be discussed, including so called modal analyses, which allow for the prediction of instability (flutter) from the given system parameters. (Received September 06, 2016)

1124-35-175 **Jing Zhang*** (jizhang@vsu.edu), Petersburg, VA 23806. *The Analyticity and Exponential Decay of a Stokes-Wave Coupling System with Viscoelastic Damping in the Variational Framework.*

In this paper, we study a fluid-structure interaction model of Stokes-wave equation coupling system with Kelvin-Voigt type of damping. We show that this damped coupling system generates an analyticity semigroup and thus the semigroup solution, which also satisfies variational framework of weak solution, decays to zero at exponential rate. (Received September 07, 2016)

1124-35-191 **Jason L. Metcalfe*** (metcalfe@email.unc.edu). *Local energy decay for the wave equation.*

We will discuss local energy decay estimates for the wave equation, which are measures of the extent to which energy from an initial disturbance leaves a given compact set. These have been especially important for the study of wave equations on nontrivial asymptotically flat space-times as other common measures of dispersion, such as Strichartz estimates or pointwise decay estimates, have been shown to follow once local energy decay is available. We will examine obstacles to such decay estimates, namely trapping and eigenfunctions / resonances, and some partial results that can be recovered when these obstacles are present. We will also discuss the stability of such estimates when the background geometry is time-dependent. (Received September 08, 2016)

1124-35-195 **John M. Neuberger*** (john.neuberger@nau.edu), Department of Mathematics and Statistics, Box 5717, NAU, Flagstaff, AZ 86011. *A reduction minimax algorithm for the nonlinear deflation of sublinear and superlinear elliptic BVP.* Preliminary report.

We present a reduction minimax algorithm for approximating a sequence of solutions of increasing Morse index to sublinear and superlinear elliptic boundary value problems. The algorithm is phrased as a pair of conjectures, whereby the solutions are produced as the minimums of the action functional on a nested sequence of maximizing subsets. (Received September 08, 2016)

1124-35-203 **Matthew Rudd*** (mbrudd@sewanee.edu), 735 University Avenue, Sewanee, TN 37383. *Dirichlet puzzles and nonlinear averaging.* Preliminary report.

This will be a progress report on joint work with David Hartenstine (Western Washington University) on functional equations and nonlinear averaging operators related to the normalized p-Laplacian. I will discuss some generalizations of our previous results and some possible extensions to vector-valued Dirichlet problems. (Received September 08, 2016)

1124-35-206 **Junshan Lin*** (jzl0097@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849. *Scattering and Field Enhancement of Narrow Slits.*

Subwavelength apertures and holes on surfaces of noble metals (e.g., gold or silver) induce strong electromagnetic field enhancement and extraordinary optical transmission. This remarkable phenomenon can lead to potentially significant applications in biological and chemical sensing, spectroscopy, and other novel optical devices. In this talk, I will present a quantitative analysis for the field enhancement of narrow slits perforated in a slab of perfect conductor. Both the single slit and periodic slits will be discussed. We demonstrate that the enhancement of the electromagnetic field can be induced by either scattering resonances or certain non-resonant effect in the quasi-static regime. We derive the asymptotic expansions of the resonances and quantitatively analyze the field enhancement at the resonant frequencies. The field enhancement at non-resonant frequencies in the quasi-static regime is also investigated. It is shown that the fast transition of the magnetic field in the slit induces strong electric field enhancement. (Received September 08, 2016)

1124-35-221 **Jacob S Perry***, Office 362, Phillips Hall CB#3250, Chapel HIll, NC 27514. *Localized energy for wave equations with degenerate trapping.* Preliminary report.

Local smoothing estimates for the Schrödinger equation are well established and show that locally in space and averaged in time, solutions gain one half of a derivative in regularity compared to the initial data. Analogous estimates for solutions to the wave equation, so-called localized energy estimates, have also been studied, and provide a global integrability estimate (in both time and space). When considering such estimates for equations on differentiable manifolds, in either case it is known that geodesic trapping necessitates a loss. For non-degenerate hyperbolic trapping, the loss is logarithmic. For elliptic trapping, everything is lost except a logarithm. Recently, Christianson and Wunsch demonstrated an algebraic loss for solutions to the Schrödinger equation on a surface of revolution with degenerate hyperbolic trapping. In this talk, we will review these prior results and consider the analogue for the wave equation on a warped product manifold with degenerate hyperbolic trapping, attaining an algebraic loss of derivative. We will then use a quasimode construction to show that our estimate is sharp. This is a joint work with Robert Booth, Hans Christianson, and Jason Metcalfe (Received September 09, 2016)

1124-35-229 **J. Goddard II** and **Quinn Morris*** (qamorris@uncg.edu), 116 Petty Building, PO Box 26170, Greensboro, NC 27402, and **C. Payne**, **J. Price** and **R. Shivaji**. *Analysis of steady states for classes of reaction-diffusion equations with U-shaped density dependent dispersal on the boundary.*

We consider positive solutions to equations of the form:

$$\begin{cases} -\Delta u = \lambda u(1-u); & \Omega \\ \frac{\partial u}{\partial \eta} + \gamma\sqrt{\lambda}(u-A)^2 u = 0; & \partial\Omega \end{cases}.$$

where $\lambda > 0, \gamma > 0, A \in (0,1)$ are parameters, Ω is a bounded domain in $\mathbb{R}^n$; $n \geq 1$ with smooth boundary $\partial\Omega$ and $\frac{\partial u}{\partial \eta}$ is the outward normal derivative. Such models arise in the study of population dynamics in a habitat Ω when the population exhibits U-shaped density dependent dispersal on the boundary. We analyze the persistence of the population (existence, non-existence, uniqueness and multiplicity of positive solutions) as the patch size (λ) and the hostility of the outside matrix (γ) vary. Building upon the results obtained when $\Omega = (0,1)$ via a quadrature method, we obtain solutions for any bounded domain Ω in $\mathbb{R}^n$; $n > 1$ by the method of sub-super solutions. (Received September 10, 2016)

1124-35-231 **Loc Hoang Nguyen***, Department of Mathematics and Statistics, University of North Carolina Charlotte, 9201 University City Blvd, Charlotte, NC 28262. *A globally convergent numerical method for a 1-d inverse medium problem with experimental data.*

In the talk, we will introduce a globally convergent algorithm to reconstruct the spatially distributed dielectric constant of a medium from the back scattered wave field in the frequency domain. It is worth mentioning that no knowledge of an initial guess for the true solution is required. The Quasi-Reversibility Method is used in the algorithm. The convergence of the algorithm is proved using Carleman estimates. The method is tested on both computationally simulated and experimental data. (Received September 10, 2016)

1124-35-235 **Linh V Nguyen*** (lnguyen@uidaho.edu), Department of Mathematics, University of Idah, 875 Perimeter Dr, MS 1103, Moscow, ID 83844, and **Leonid Kunyansky**. *Photoacoustic tomography in a cavity.*

Photoacoustic tomography (PAT) is a hybrid method of imaging. It combines the high contrast of optical tomography and high resolution ultrasound tomography. In this talk, we will discuss the problem of PAT in a cavity. Our solution employs the so-called dissipative time reversal technique. (Received September 10, 2016)

1124-35-237 **Jonas Luehrmann*** (luehrmann@math.jhu.edu). *Concentration Compactness for Energy Critical Geometric Wave Equations.*

In this talk we consider the Maxwell-Klein-Gordon equation and radially symmetric wave maps into compact target manifolds in the energy critical case. We discuss proofs of global regularity, scattering and a priori bounds of solutions for essentially arbitrary smooth data of finite energy along the concentration compactness/rigidity scheme. The key idea here is to introduce novel "twisted" profile decompositions to take into account the strong interactions in the nonlinearities. This is joint work with Joachim Krieger. (Received September 10, 2016)

1124-35-249 **Irena Lasiecka*** (lasiecka@memphis.edu), Dunn Hall, Department of Mathematical Sciences, Memphis, TN 38152-3370, and **Mihaela Ignatova**, **Igor Kukavica** and **Amjad Tuffaha**. *Global existence and partial stability of a 3 D fluid structure interaction with moving frame.*

We address the system of partial differential equations modeling motion of an elastic body inside an incompressible fluid. The fluid is modeled by the incompressible Navier-Stokes equations while the structure is represented by the wave equation with a feedback control interior damping. The additional boundary stabilization of the pressure , considered in our previous paper cited below , is no longer necessary. We prove the global existence of solutions for small initial data in a suitable Sobolev space. Decay rates of solutions with respect to lower topology are also established. Construction of the solutions is based on maximal regularity of Stokes dynamics along with sharp trace regularity obtained for Dirichlet-Neumann map corresponding to the hyperbolic dynamics.

This work is joint with M. Ignatova (Stanford University), I. Kukavica (University of Southern California) and A. Tuffaha (The Petroleum Institute, Abu Dhabi).

REF: On wellposedness and small data global existence for an interface damped free boundary fluid-structure interaction model (M. Ignatova, I. Kukavica. I. Lasiecka and A. Tuffaha) - Nonlinearity ,vol 27, issue 3, 467-499,2014 (Received September 11, 2016)

1124-35-251 **Shirshendu Chaudhury**, **Debanjana Mitra** and **Mythily Ramaswamy*** (mythily@math.tifrbng.res.in), TIFR CAM, Bangalore, 560065, India, and **Michael Renardy**. *Ingham type inequalities and applications to PDE.* Preliminary report.

After Ingham proved some trigonometric type inequalities in 1936, they have been applied in Series expansion, Function theory and also PDE's. Depending on the PDE and the spectrum of the operator, new extensions of these inequalities have been found. I show one such application to a coupled system of PDE of hyperbolic and parabolic types. (Received September 11, 2016)

1124-35-264 **Ben Harrop Griffiths**, **Mihaela Ifrim*** (ifrim@math.berkeley.edu) and **Daniel Ioan Tataru**. *Title: Finite depth gravity water waves in holomorphic coordinates.*

Abstract: In this article we consider irrotational gravity water waves with finite bottom. Our goal is two-fold. First, we represent the equations in holomorphic coordinates and discuss the local well-posedness of the problem in this context. Second, we consider the small data problem and establish cubic lifespan bounds for the solutions. Our results are uniform in the infinite depth limit, and match the earlier infinite depth result of Hunter-Ifrim-Tataru. (Received September 11, 2016)

1124-35-266 **Mauricio A Rivas*** (rivasma@wfu.edu), Wake Forest University, Department of Mathematics and Statistics, Wake Forest Rd., PO Box 7388, Winston Salem, NC 27109, and **Stephen B Robinson**. *Eigencurves for elliptic equations.*

This talk will outline the analysis of eigencurves associated with a triple (a, b, m) of continuous symmetric bilinear forms on a real Hilbert space V that arise in the study of self-adjoint linear elliptic equations. Variational characterizations of associated eigencurves, as well as various orthogonality results for corresponding eigenspaces, are described. Regularity and asymptotic properties for these eigencurves are discussed. These results lead to a geometrical description of the eigencurves, and the results are exemplified for two-parameter Robin-Steklov eigenproblems for the Laplacian. (Received September 11, 2016)

1124-35-280 **Elisabeth MM Brown*** (embrown5@ncsu.edu) and **Michael Shearer**. *A Nonlinear PDE Modeling Plume Migration in Carbon Sequestration.*

A quasi-linear hyperbolic partial differential equation with a discontinuous flux models geologic carbon dioxide (CO_2) migration and storage. Dual flux curves emerge in this model, giving rise to flux discontinuities. One flux describes the invasion of the plume into pore space, and the other captures the flow as the plume leaves CO_2 bubbles behind, which are then trapped in the pore space. Flux functions with discontinuities in space have been previously studied; the flux in this model depends on how the unknown is changing at any position and time. We prove the existence of an entropy solution of the Cauchy problem for any initial CO_2 plume using wave-front tracking. During our analysis, we introduce a new construction with *cross-hatch characteristics* in regions of the characteristic plane where the solution is constant, and the characteristic speed depends on which flux is invoked. We present a computer simulation that tracks CO_2 plume migration in the characteristic plane. Some wave interactions yield novel phenomena due to the dual flux, such as shock-rarefaction interactions that would persist for all time with a single flux, here are completed in finite time. (Received September 11, 2016)

1124-35-290 **Hans Lindblad** and **Mihai Tohaneanu*** (mihai.tohaneanu@uky.edu). *Global existence for quasilinear wave equations close to Schwarzschild.*

We study the quasilinear wave equation $\Box_g u = 0$, where the metric g depends on u and equals the Schwarzschild metric when u is identically 0. Under a couple of extra assumptions on the metric g near the trapped set and the light cone, we prove global existence of solutions. (Received September 12, 2016)

1124-35-302 **Casey Jao*** (cjao@math.berkeley.edu). *Microlocal dispersive estimates and the energy-critical NLS on perturbations of* $\mathbf{R}^3$.

It is well known that solutions to the linear Schrödinger equation in $\mathbf{R}^d$ decay in time at a rate of $t^{-d/2}$. This is in general false on a curved background due to refocusing of geodesics. However, as shown by Burq, Gérard, and Tzvetkov, it holds microlocally provided one restricts to times less than a sufficiently small multiple of the semiclassical parameter, essentially stopping the geodesic flow before refocusing can occur. I will discuss long-time refinements of this estimate which exhibit weaker but still nontrivial decay. Such weak dispersive estimates play an essential role in the study of energy-critical NLS on manifolds. Time permitting, I will specifically consider the quintic NLS on small perturbations of $\mathbf{R}^3$. (Received September 12, 2016)

1124-35-305 **Kristina Martin*** (kmmarti6@ncsu.edu) and **Lorena Bociu**. *Optimal Control in Free or Moving Boundary Coupling of Navier-Stokes and Nonlinear Elasticity.*

We consider optimal control problems involving free or moving boundary fluid-elasticity interaction described by a coupling of Navier-Stokes with the equations of nonlinear elastodynamics in the context of isotropic elasticity. We prove in the free boundary, steady case that a distributed control can minimize the difference between the fluid velocity and a desired velocity. In the dynamic, moving boundary case we prove that a distributed control can minimize turbulence in the fluid flow. We additionally discuss sensitivity analysis, including derivation of the linearized adjoint equations. (Received September 12, 2016)

1124-35-308 **Dean Baskin***, Department of Mathematics, Texas A&M University, Mailstop 3368, College Station, TX 77843. *Asymptotics of the radiation field.*

In this talk I will describe work (with Andras Vasy and Jared Wunsch) characterizing the asymptotic behavior of the radiation field on asymptotically Minkowski spaces. The result captures the long-time behavior of the wave equation in terms of the resonances on an associated asymptotically hyperbolic space (which can be thought of as a limit of the foliation of the interior of the light cone by CMC spacelike hypersurfaces). If time permits, I will describe how one can use the work of Cheeger–Taylor to obtain a similar result on cones (joint with Jeremy Marzuola). (Received September 12, 2016)

1124-35-318 **M. Paul Laiu*** (laiump@ornl.gov) and **Cory D. Hauck** (hauckc@ornl.gov). *Positivity Limiters on the Filtered P_N Method for Linear Transport Equations.*

We analyze the properties and compare the performance of several positivity limiters on the recently proposed filtered P_N (FP_N) method for linear transport equations. The original FP_N method is known to suffer from the occurrence of (unphysical) negative particle concentrations, which origins from the fact that FP_N spherical harmonic approximations are not always positive at the kinetic level. These limiters enforce positivity of the FP_N approximations on a finite set of pre-selected points. With a proper PDE solver, this ensures positivity of the particle concentration at each step in the time integration. We give error estimates for the positive approximations produced by these limiters, and verify the estimates with numerical consistency tests. We simulate problems of various regularities using the FP_N method with several limiters, and report the efficiency of these limiters. The numerical results give a guideline on selecting positivity limiters for problems with solving different regularities. (Received September 12, 2016)

1124-35-320 **Inbo Sim**, **Ratnasingham Shivaji** and **Byungjae Son*** (b_son@uncg.edu), Department of Mathematics and Statistics, University of North Carolina at Greensboro, 116 Petty Building, Greensboro, NC 26402. *Uniqueness results for classes of semipositone p-Laplacian problems.*

We consider steady state reaction diffusion equations on the exterior of a ball, namely, boundary value problems of the form :

$$\begin{cases} -\Delta_p u = \lambda K(|x|) f(u) & \text{in } \Omega_E, \\ Bu = 0 & \text{on } |x| = r_0, \\ u \to 0 & \text{when } |x| \to \infty, \end{cases}$$

where $\Delta_p z := \mathrm{div}(|\nabla z|^{p-2}\nabla z)$, $1 < p < n$, $\lambda > 0$, $\Omega_E := \{x \in \mathbb{R}^n \mid |x| > r_0 > 0\}$ and B is either $Bu \equiv u$ or $Bu \equiv \frac{\partial u}{\partial y} + c(u)u$ where $c \in C((0,\infty),(0,\infty))$ and $\frac{\partial u}{\partial \eta}$ is the outward normal derivative of u on $|x| = r_0$. Here the weight function $K \in C^1([r_0,\infty),(0,\infty))$ satisfies $\lim_{r\to\infty} K(r) = 0$, and the reaction term $f \in C^1[0,\infty)$ is strictly increasing and satisfies $f(0) < 0$, $\lim_{s\to\infty} f(s) = \infty$, $\lim_{s\to\infty} \frac{f(s)}{s^{p-1}} = 0$ and $\frac{f(s)}{s^q}$ is nonincreasing on $[a,\infty)$ for some $a > 0$ and $q \in (0, p-1)$. We establish uniqueness results for positive radial solutions for $\lambda \gg 1$. (Received September 12, 2016)

1124-35-323 **Thanh Trung Nguyen*** (thanh@iastate.edu), 452 Carver Hall, 411 Morrill Road, Ames, IA 50011. *Recursive optimization algorithms for inverse scattering problems using multi-frequency data.*

In this talk we discuss a recursive optimization algorithm for solving inverse scattering problems in frequency domain. The method consist of two steps: in the first step, a rough estimate of the parameter of interest is obtained using data at a low frequency. In the second step, the estimate is refined recursively using data at higher frequencies. We will discuss the convergence of this method and show some numerical examples to demonstrate its performance. (Received September 12, 2016)

1124-35-335 **Benjamin Harrop-Griffiths*** (benjamin.harrop-griffiths@cims.nyu.edu), **Mihaela Ifrim** and **Daniel Tataru**. *The lifespan of small data solutions to the KP-I.*

We show that for small, localized initial data in a Galilean-invariant space, there exists a global solution to the Kadomtsev–Petviashvili I equation, using the method of testing by wave packets. This is joint work with Mihaela Ifrim and Daniel Tataru. (Received September 12, 2016)

1124-35-339 **Rowan Killip** and **Jason Murphy***, Evans 857, UC Berkeley, Berkeley, CA 94720, and **Monica Visan** and **Jiqiang Zheng**. *The focusing nonlinear Schrödinger equation with inverse square potential.*

For the focusing cubic nonlinear Schrödinger equation (NLS) in three space dimensions, Duyckaerts, Holmer, and Roudenko have established a sharp criterion for blowup versus scattering for solutions 'below the ground state'. In this talk, we will adapt their approach to prove an analogous result for the case of NLS with an inverse square potential. To prove our result, we need to understand the sense in which the original equation embeds into the equation with potential in certain limiting regimes. This is joint work with R. Killip, M. Visan, and J. Zheng. (Received September 12, 2016)

1124-35-346 **Nsoki Mavinga*** (nmaving1@swarthmore.edu) and **Rosa Pardo**. *A priori bounds and existence of positive solutions for semilinear elliptic systems.*

We provide a-priori L^∞-bounds for positive solutions of semilinear elliptic systems in bounded convex domains when the nonlinearities are below the power functions v^p and u^q for any (p, q) lying on the critical Sobolev hyperbola. The proof combines moving planes method and Rellich-Pohozaev type identities for systems. Using these a-priori bounds, and local and global bifurcation techniques, we prove the existence of positive solutions for a semilinear elliptic system depending on two parameters. (Received September 12, 2016)

1124-35-348 **Peter Hintz*** (phintz@berkeley.edu), 805 Evans Hall, Berkeley, CA 94720. *Non-linear stability of Kerr–de Sitter black holes.*

I will discuss the stability of the Kerr–de Sitter family of slowly rotating black holes as solutions of the initial value problem for the Einstein vacuum equations with positive cosmological constant. I will explain the general framework which enables us to deal systematically with the diffeomorphism invariance of Einstein's equations, and thus how our solution scheme picks a suitable gauge within a carefully chosen finite-dimensional family of gauges. Joint work with András Vasy. (Received September 13, 2016)

1124-35-356 **Daniel Toundykov*** (dtoundykov@unl.edu) and **Jean-Paul Zolésio**. *Control by moving boundary.*

We consider a wave equation on a domain whose shape evolves according to a prescribed space- and time-dependent velocity field. On the moving boundary the solution is subject to zero Dirichlet conditions. First, we show that if the domain keeps expanding at a small "subsonic" speed bounded away from zero, then the associated finite energy decays uniformly at a rate arbitrarily close to exponential. The scenario when the domain remains bounded and undergoes phases of expansion and contraction is investigated numerically with an "adaptive" boundary movement control. The simulations indicate potential for strong stability of regular solutions by means of very small fluctuations in the domain shape only. (Received September 13, 2016)

1124-35-364 **Jerome Goddard II*** (jgoddard@aum.edu), Department of Mathematics & Computer Science, Auburn University Montgomery, P.O. Box 244023, Montgomery, AL 36124, and **R. Shivaji**. *Modeling the effects of U-shaped density dependent dispersal via reaction diffusion equations.*

Dispersal is broadly defined as movement from one habitat patch to another and typically is considered to encompass three stages: 1) emigration, 2) inter-patch movement, & 3) immigration. Dispersal can have both beneficial and detrimental effects on the persistence of spatially structured systems. Recent empirical results indicate that certain organisms' emigration from a patch is dependent on their own density—known as density dependent emigration. In fact, a U-shaped relationship between density and emigration has been observed in several organisms in field studies. To date, little is known about the patch-level consequences of such a dispersal strategy. In this talk, we will discuss a population model built upon the reaction diffusion framework that is designed to model the patch-level effects of U-shaped density dependent emigration. In particular, we will discuss the existence and stability properties of positive steady state solutions to this model for one-dimensional habitat patches. A brief discussion regarding ecological conclusions of the model's predictions will also be included. Several methods from nonlinear analysis will be employed such as time map analysis (quadrature method) and linearized stability analysis. (Received September 13, 2016)

1124-35-365 **Kiril Datchev***, Department of Mathematics, Purdue University, 150 N. University Avenue, West Lafayette, IN 47907. *Resolvent estimates away from trapping.*

We consider resolvent estimates of the form

$$\|\chi(H-\lambda\pm i0)^{-1}\chi\|_{L^2(\mathbb{R}^n)\to L^2(\mathbb{R}^n)}\leq C(\lambda),$$

where H is a long range perturbation of the (nonnegative) Laplacian $-\Delta$, $\chi\in C_c^\infty(\mathbb{R}^n)$, and $\lambda\gg 1$. It is well-known that $C(\lambda)$ depends on the relationship between the set trapped trajectories of H (if any) and the support of χ. In this talk we will discuss the case when these are disjoint, and mention applications to scattering theory and Schrödinger evolution. (Received September 13, 2016)

1124-35-370 **Gregory J Herschlag*** (gjh@math.duke.edu), 120 Science Drive, 117 Physics Building, Campus Box 90320, Durham, NC 27708, and **Jian-Guo Liu** and **Anita T Layton**. *Fast solutions for material transport across pumping and permeable channels.*

Abstract: We examine a class of fluid flow eqautions through a channel that (i) are considered at low Reynolds number, (ii) contain permeable walls, (iii) have moving walls, and (iv) consider a dynamic model for the behavior of fluid exterior to the channel. Due to its biological relevance, there is interest to run parameter studies that determine the average flux across the permeable walls. Such a system is prohibitively expensive to study with traditional numerical methods, such as finite difference or finite volume, due to the problem class existing in a high dimensional parameter space. To alliviate this, we employ a spectral method to first solve the original partial differential equation, and then analyze this solution at the channel boundary. The result is that the partial differential equation reduces to a first order, linear, ordinary differential equation. By numerical analyzing the reduced problem, we find that there exist optimal parameter regimes that generate an average flux moving out of the channel; this result is surprising due to fact that the the fluid dynamics within the channel are time reversible. (Received September 13, 2016)

1124-35-379 **Ana Vivas-Barber*** (alvivasbarber@nsu.edu), 4145 Rundel Ln, Virginia Beach, VA 23452. *Age-Structured SAIQR Model for Influenza Transmission Dynamics.*

An integral-partial differential system for Influenza transmission dynamics is presented. Since a significant proportion of individuals is asymptomatic or experience mild infections, the model includes A (asymptomatic)-class. It is well known that when quarantine individuals are considered in the model, recurrent outbreaks of influenza happened. A complete analysis of the SAIQR model will be shown, including a specific expression for Ro (The basic reproduction number).Existence of an endemic steady state as well as the local and global stability of the disease-free equilibrium were established. Numerical simulations were performed using age-dependent influenza parameter values. (Received September 13, 2016)

1124-35-386 **H.T. Banks** and **Kidist Bekele-Maxwell*** (ktzeleke@ncsu.edu), Center for Research in Scientific Computation, NC state university, Raleigh, NC 27695, and **Lorena Bociu**, **Giovanna Guidoboni** and **Marcella Noorman**. *Sensitivity analysis for poro-visco-elastic equations.* Preliminary report.

Poro-elastic and poro-visco-elastic models find many applications in bioengineering and medicine. Inspired from applications in geophysics and petroleum engineering, they are more and more frequently being applied to biological tissues, such as for modeling a thin membrane found at the base of the optic nerve head called lamina-cribrosa. For many of these biological applications, the boundary data plays a crucial role.

In a recent theoretical and numerical analysis of poro-elastic and poro-visco-elastic models, the time regularity of the imposed boundary traction was identified as a crucial factor in guaranteeing boundedness of the solutions. Here, in an effort to further extend the analysis, we study the sensitivity of the model solutions to imposed boundary data. Since, nonlinear coupling causes difficulty when implementing traditional methods, we will be using the less known complex-step method for sensitivity analysis. (Received September 13, 2016)

1124-35-389 **Lorena Bociu***, 2311 Stinson Drive, Raleigh, NC 27695. *Optimization and Control in Free Boundary Fluid-Structure Interactions.*

We consider optimization and optimal control problems subject to free and moving boundary fluid-structure interactions. As the coupled fluid-structure state is the solution of a system of PDEs that are coupled through continuity relations defined on the free/moving interface, the investigation (existence of optimal controls, sensitivity equations, optimality conditions, etc.) is heavily dependent on the geometry of the problem, and falls into moving shape analysis framework. (Received September 13, 2016)

1124-35-414 **George Avalos*** (gavalos@math.unl.edu), PO Box 22560, Lincoln, NE 68588. *A Frequency Domain Approach for Uniform Stability of Solutions to a Structural Acoustics Interactive PDE.*

A rate of rational decay is obtained for smooth solutions of a PDE model which has been used in the literature to describe structural acoustic flows. This structural acoustics model is composed of two distinct PDE systems: (i) a wave equation, to model the interior acoustic flow within the given cavity Ω; (ii) a structurally damped elastic equation, to describe time-evolving displacements along the flexible boundary portion Γ_0 of the cavity walls. Our main result is the derivation of uniform decay rates for classical solutions of this particular structural acoustic PDE, decay rates which are obtained without incorporating any additional boundary dissipative feedback mechanisms. In particular, in the case that full Kelvin-Voight damping is present in fourth order elastic dynamics, solutions which correspond to smooth initial data decay at a rate of $\mathcal{O}(t^{-1/6})$. By way of deriving these stability results, necessary a priori inequalities for a certain static structural acoustics PDE model are generated here; these inequalities ultimately allow for an application of a recently derived resolvent criterion for rational decay. This is joint work with Pelin Güven Geredeli of Hacettepe University (Ankara, Turkey). (Received September 14, 2016)

37 ► Dynamical systems and ergodic theory

1124-37-271 **Yogesh Joshi*** (yogesh.joshi@kbcc.cuny.edu), Kingsborough Community College, Brooklyn, NY 11235, and **Denis Blackmore**. *New Chaotic Strange Attractors and Their Applications.*

Novel strange chaotic attractor theory and constructions for discrete dynamical systems generated by C^1 maps $f : U \to \mathbb{R}^n$, where U is an open subset of $\mathbb{R}^n$ are presented. They are for the most part generalizations and variations of recent results obtained in collaboration with D. Blackmore (Strange attractors for asymptotically zero map, *Chaos, Solitons & Fractals* **68** (2014)). In particular, we describe and analyze generalized attracting horseshoes and generalized attracting multi-horseshoes, which give rise to strange chaotic attractors in any finite-dimensional euclidean space, and are such that their fractal dimensions can be approximated with considerable accuracy. We shall show, for example, that the theory of these types of attractors can be applied to obtain a much shorter proof of the existence of Hénon attractors than that of Benedicks & Carleson. Finally, we shall indicate how the new constructions may lead to methods for extending the rank-one theory of Wang & Young to attractors of rank greater than one. (Received September 11, 2016)

39 ► Difference and functional equations

1124-39-16 **Chris D. Lynd*** (clynd@bloomu.edu). *The Global Dynamics of Several Systems of Non-Linear Difference Equations.*

We will present the global character of the solutions of a class of systems of rational difference equations. We will demonstrate that this class of systems can be divided into three distinct groups based upon the global character of their solutions. (Received June 19, 2016)

1124-39-31 **Michael Alexander Radin*** (michael.radin@rit.edu), Rochester Institute of Technology, School of Mathematical Sciences, Rochester, NY 14623, **Inese Bula** (inese.bula@lu.lv), University of Latvia, Department of Mathematics & Computer Science, Riga, Latvia, and **Nicholas Wilkins** (npw3202@rit.edu), Rochester Institute of Technology, School of Mathematical Sciences, Rochester, NY 14623. *Neuron model with a period three internal decay rate.* Preliminary report.

In this paper we will study a non-autonomous piece-wise linear difference equation which describes a discrete version of a single neuron model. We will investigate the periodic behavior of solutions relative to the periodic sequence with period three internal decay rate. We will show that only periodic cycles with period $3k$, $k = 1, 2, 3, ...$ can exist and also show their stability character. (Received August 05, 2016)

1124-39-74 **Murat Adivar*** (madivar@uncfsu.edu), Fayetteville State University, 1200 Murchison Rd. SBE 345, Fayetteville, NC 28301, and **Youssef N Raffoul** and **Halis Can Koyuncuoglu**, 35330 Izmir, Turkey. *Almost automorphic solutions of delayed neutral dynamic systems on hybrid domains.*

We study the existence of almost automorphic solutions of the delayed neutral dynamic system on hybrid domains that are additively periodic. We use exponential dichotomy and prove uniqueness of projector of exponential

dichotomy to obtain some limit results leading to sufficient conditions for existence of almost automorphic solutions to neutral system. Unlike the existing literature we prove our existence results without assuming boundedness of the coefficient matrices in the system. Hence, we significantly improve the results in the existing literature. Finally, we also provide an existence result for an almost periodic solutions of the system. (Received August 28, 2016)

1124-39-95 **Nika Lazaryan*** (lazaryans@vcu.edu), Richmond, VA , and **Hassan Sedaghat**, Richmond, VA. *Periodic and Chaotic Solutions in the Survival Region of a Second Order Exponential Difference Equation with Allee Effect.*

We study the second-order difference equation

$$x_{n+1} = x_{n-1}^{\lambda} e^{a - b x_n - x_{n-1}}$$

with $a > 0, \lambda > 1, 0 < b < 1$. For a range of positive parameter values a, b, λ we show that the above equation exhibits Allee type bistability: solutions from certain set of initial values converge to zero, while others do not. We focus on identifying the *survival region* - the subset in the space of initial values that lead to solutions that do not converge to zero. Moreover, we provide sufficient conditions on parameter values that lead to periodic and chaotic solutions in the survival region. (Received August 31, 2016)

1124-39-99 **Hassan Sedaghat*** (hsedagha@vcu.edu), Department of Mathematics, Virginia Commonwealth University, Richmond, VA 23284-2014. *Extinction and the Allee Effect in an Age Structured Ricker Population Model.*

We determine conditions for the convergence of orbits to the origin (extinction) in the presence of the Allee effect and time-dependent vital rates. We show that when stages interact, extinction need not occur in the absence of positive fixed points, a situation that is impossible without inter-stage interactions. We also examine the shift in the Allee equilibrium caused by the occurrence of interactions between stages. This shift away from the origin leads to an expected enlargement of the extinction region when interactions occur between stages but surprisingly, we find that the enlargement is not the maximum possible allowed by the shift. (Received August 31, 2016)

1124-39-110 **Daniel M. Maroncelli*** (maroncdm@wfu.edu), PO Box 7388, 127 Manchester Hall, Winston-Salem, NC 27109, and **Jesus Rodriguez**. *On the solvability on nonlinear discrete Sturm-Liouville problems at resonance.*

In this work we provide conditions for the existence of solutions to nonlinear, discrete Sturm–Liouville problems of the form

$$\Delta(p(t-1)\Delta x(t-1)) + q(t)x(t) + \lambda x(t) = f(x(t)); \qquad t \in \{a+1, \cdots, b+1\}$$

subject to

$$a_{11}x(a) + a_{12}\Delta x(a) = 0 \text{ and } a_{21}x(b+1) + a_{22}\Delta x(b+1) = 0.$$

The parameter λ will be assumed to be an eigenvalue of the associated linear Sturm–Liouville boundary value problem. Our results generalize those found in the existing literature. (Received September 01, 2016)

1124-39-119 **Candace M. Kent*** (cmkent@vcu.edu), 3510 Hanover Avenue, Richmond, VA 23221. *A Proposal for an Application for a Max-Type Difference Equation.* Preliminary report.

Difference equations with the maximum function, unlike differential equations with the maximum function, have no known applications. We propose, for the sake of dialogue, that the particular nonautonomous max-type difference equation

$$x_{n+1} = \max\left\{\frac{A_n}{x_n}, \frac{B_n}{x_{n-1}}\right\}, \quad n = 0, 1, \ldots,$$

where A_n and B_n are positive periodic sequences and $x_{-1}, x_0 \in (0, \infty)$, may serve as a model of the onset and offset of a seizure as is seen, for example, in mesial temporal lobe epilepsy. (Received September 03, 2016)

1124-39-187 **Youssef N Raffoul*** (yraffoul1@udayton.edu), 300 Coollege Park, Dayton, OH 45469-2316. *Stability and Boundedness in Nonlinear Infinite Delay Volterra Discrete Systems Using Lyapunov Functionals.*

We utilize Lyapunov functionals and obtain sufficient conditions for the stability of the zero solution and boundedness of solutions for the discrete Volterra system with infinite delay of the form

$$x(t+1) = Px(t) + \sum_{s=-\infty}^{t-1} C(t,s)g(x(s)).$$

Due to the nature of the Lyapunov functional, we will be able to show that all solutions are $l\big([t_0, \infty) \cap \mathbb{Z}\big)$. (Received September 08, 2016)

1124-39-246 **Michael A. Radin** (michael.radin@rit.edu), Rochester Institute of Technology, College of Science, School of Mathematical Sciences, Rochester, NY 14623, **Harold M. Hastings*** (hhastings@simons-rock.edu), Bart College at Simon's Rock, 84 Alford Rd, Great Barrington, MA 01230, and **Tamas I. Wiandt** (tiwsma@rit.edu), Rochester Institute of Technology, College of Science, School of Mathematical Sciences, Rochester, NY 14623. *Fishing Quotas, Induced Allee Effect and Fluctuation-Driven Extinction.*

The problem: planning for sustainable harvesting of a fishery in a fluctuating environment, in the face of global climate change

Challenges: data poor fisheries [1], global climate change

Deterministic dynamics: harvesting policies can induce Allee effect in logistic and similar fishery growth models [2-4]

Stochastic dynamics: Fluctuations, generalized Ornstein-Uhlenbeck dynamics, expected survival time (first-passage time to extinction) depends sensitively upon model parameters [5], especially harvest rates. C.f. also [6].

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(Received September 10, 2016)

1124-39-388 **Andrew Arnold*** (a.arnold256@gmail.com) and **Erich Kaltofen**. *Applications of the Berlekamp–Massey–Sakata algorithm to multivariate sparse polynomial interpolation.*

The Berlekamp–Massey–Sakata (BMS) algorithm produces a Groebner basis for an ideal of linear generators for an infinite array of field elements. It is the multidimensional generalization of the Berlekamp–Massey algorithm for sequences. We give termination conditions for the BMS algorithm in the case of positive-dimensional ideals. Moreover, we apply the BMS algorithm to Las Vegas and deterministic sparse multivariate polynomial interpolation. (Received September 13, 2016)

1124-39-415 **Aykut Arslan*** (aykut.arslan858@topper.wku.edu), 1906 College Height Blvd #11078, Dept. of Mathematics, Western Kentucky University, Bowling Green, KY 42101, and **Ferhan M. Atici** (ferhan.atici@wku.edu), 1906 College Height Blvd #11078, Dept. of Mathematics, Western Kentucky University, Bowling Green, KY 42101. *Discrete Convexity and Fractional Hermite-Hadamard Inequality.*

In this talk, we introduce the definition of a convex function defined on an isolated time domain. As an application of this new concept, we state and prove the discrete Hermite-Hadamard inequality using time scale calculus. We also give a new characterization of convexity of a function defined on an isolated time domain by the discrete fractional Hermite-Hadamard inequality. (Received September 14, 2016)

40 ► Sequences, series, summability

1124-40-209 **Mehmet Unver*** (munver@ankara.edu.tr), Ankara University, Faculty of Science, Department of Mathematics, Tandogan, 06100 Ankara, Turkey. *Some Summability Properties of Sequences of Random Elements in Banach Spaces.*

In this talk, using Bochner integral and considering the compact subsets of a Banach space we introduce a new type of uniform integrability for sequences of random elements in a Banach space. Thus we generalize the concept of A-compactly uniform integrability. Moreover, we study the concepts of A-strong convergence and A-statistical convergence, which are some of the main concepts of the summability theory, for sequences of random elements and we investigate the relationship between these concepts by using this new type of uniform integrability. (Received September 09, 2016)

1124-40-210 **Seyhmus Yardimci*** (smyardimci@ankara.edu.tr), Ankara University, Faculty of Science, Department of Mathematics, Tandogan, 06100 Ankara, Turkey, and **Mehmet Unver** (munver@ankara.edu.tr), Ankara University, Faculty of Science, Department of Mathematics, Tandogan, 06100 Ankara, Turkey. *A Generalization of A-Strong Convergence in Hausdorff Spaces.*

In the present talk we introduce a version of A-strong convergence in Hausdorff topological spaces which extends the notion of strong convergence to topological spaces. This new definition leads to study a new type of convergence in Hausdorff topological spaces. We also investigate the relationship between this concept and statistical convergence in topological spaces. (Received September 09, 2016)

42 ► Fourier analysis

1124-42-256 **Ioan Bejenaru***, 9500 Gilman Dr., Dept of Mathematics, La Jolla, CA. *Multilinear Restriction Theory.*

This talk will introduce the linear and multilinear restriction theory and their relations with various fields in Mathematics: Harmonic Analysis, PDE, Number Theory, Incidence Geometry and Geometric Analysis. I will talk in more detail about the effect of the underlying geometry in the context of multilinear theory. (Received September 11, 2016)

46 ► Functional analysis

1124-46-5 **Mujahid Abbas*** (abbas.mujahid@gmail.com), Department of Mathematics, University of Pretoria, Pretoria, Gauteng 0002, South Africa. *Soft Fixed Point in Soft Metric Spaces.*

The aim of this talk is to introduce the concept of soft contraction mapping on soft metric spaces and then present among other results, a theorem of Banach contraction principle type called soft contraction theorem in the setup of soft complete metric spaces . We also present a fixed point results when a soft mapping satisfies soft contraction condition on the soft closed balls in complete soft metric spaces. We provide some examples to illustrate the validity of our presented results. We believe that this will open some new avenues of research in soft metric fixed point theory. (Received February 15, 2016)

1124-46-7 **Sartaj Ali*** (sartajali2004@yahoo.com), Women University, Azad Jammu and Kashmir, Bagh, and **Mujahid Abbas** and **Clement Boateng Ampadu**. *Best Proximity Point Theorems inspired by Chatterjee-Wardowski Type Contractions in Modular Function Spaces.*

Inspired by the works in [S. K. Chatterjee, "Fixed point theorem," C. R. Acad. Bulgare Sci., vol. 25, pp. 727–730, 1972; Wardowski Fixed Point Theory and Applications 2012, 2012:94], we introduce a new contraction called Chatterjee-Wardowski contraction, and use it to obtain some best proximity results in the setting of this paper. We define Chatterjee-Wardowski proximal contraction of the first and second kind and obtain some best proximity theorems insipired by the notion of Chatterjee-Wardowski contraction. Examples are given to motivate the preliminaries and main results.
(Received August 04, 2016)

1124-46-58 **Abba Auwalu*** (abba.auwalu@neu.edu.tr), Mathematics Department, Near East University, 99138 Nicosia, TRNC, Turkey, and **Evren Hıncal** (evren.hincal@neu.edu.tr), Mathematics Department, Near East University, 99138 Nicosia, TRNC, Turkey. *Some Fixed Point Theorems for Expansive Mappings in Cone Pentagonal Metric Spaces.* Preliminary report.

In the present paper, we prove some fixed point theorems for mappings satisfying expansive conditions in non-normal cone pentagonal metric spaces. Our results extend and improve the recent results announced by Patil and Salunke [Fixed point theorems for Expansion mappings in Cone rectangular metric spaces, Gen. Math. Notes, 29(1), (2015), 30-39], Shatanawi and Awawdeh, [Some fixed and coincidence point theorems for Expansive maps in Cone metric spaces, Fixed Point Theory and Applications, 1(2012), 1-10], Huang, Zhu and Wen, [Fixed point theorems for Expanding mappings in Cone metric spaces, Math. Reports 14(64), 2(2012), 141-148], Kadelburg, Murthy and Radenovic, [Common xed points for Expansive mappings in Cone metric spaces, Int. J. Math. Anal, 5(27), (2011), 1309-1319], Aage and Salunke, [Some fixed point theorems for Expansion onto mappings on Cone metric spaces, Acta Mathematica Sinica, 27(6), (2011), 1101-1106], Kumar and Garg, [Common fixed points for

Expansion mappings Theorems in metric spaces, Int. J. Contemp. Math. Sciences, 4(36), (2009), 1749-1758], and many others in the literature. (Received August 24, 2016)

1124-46-208 **Murat Olgun*** (olgun@ankara.edu.tr), Ankara Uni. Science Fac. Dept. of Mathematics, 06100 Ankara, Turkey. *New fixed point theorems for multivalued contractive maps.*

In this talk, using the Wardowski's technique we give new fixed point theorems for multivalued maps on complete metric space without using the Hausdorff metric. Our results are real generalization of some related fixed point theorems including the famous Feng and Liu's result in the literature. We also give some examples to both illustrate and show that our results are proper generalizations of the mentioned theorems. (Received September 09, 2016)

1124-46-243 **Buthinah A. Bin Dehaish*** (bbindehaish@yahoo.com), department of mathematics KAU, jeddah, Saudi Arabia. *Fixed Point Theorem of Monotone Nonlinear Mappings.*

Abstract Let T: C→ C be a monotone nonlinear mapping on a nonempty, bounded, closed, and convex subset of a metric space X . We will prove the fixed point theorem of this kind of mappings under some geometrical condition on X. (Received September 10, 2016)

1124-46-390 **Zachary J Abernathy*** (abernathyz@winthrop.edu). *Existence of Solutions to a Nonlinear Sturm-Liouville Problem on Time Scales.*

In this talk, we shall establish sufficient conditions for the existence of solutions to the nonlinear equation

$$-(p(t)u^{\Delta}(t))^{\Delta} + q(t)u^{\sigma}(t) = \psi(u^{\sigma}(t)) + h(t)$$

subject to nonlinear boundary conditions of the form

$$\begin{cases} \alpha u(a) + \beta u^{\Delta}(a) = \eta_1(u) + v_1 \\ \\ \gamma u(\rho(b)) + \delta u^{\Delta}(\rho(b)) = \eta_2(u) + v_2. \end{cases}$$

We will emphasize the relationship between the eigenvalues of a related linear Sturm-Liouville problem and the rate of growth of nonlinearities present in both the differential equation and boundary conditions. The use of an arbitrary time scale allows us to unify and generalize previous existence results for Sturm-Liouville problems in continuous and discrete settings. (Received September 13, 2016)

1124-46-404 **Yunyun Yang*** (yunyun.yang@mail.wvu.edu), West Virginia University, Institute of techno, Department of mathematics, 405 Fayette Pike, Charleston, WV 25136, and **Ricardo Estrada**. *Distributions in space with thick points.*

The theory of thick distributions in dimension one was initially introduced to deal with the occurrence of a distributional singularity on the bounday of a domain of integration. We introduced a similar theory in higher dimensions [**?**], yet the approach was quite different: we considered asymptotic expansions of test functions. I will explain the motivations of our work. I will present the construction of the new spaces, I will present several important examples of thick distributions, including the "thick delta functions". In the end I will briefly discuss the relation to asymptotic analysis. This is a joint work with my thesis advisor Ricardo Estrada. (Received September 13, 2016)

47 ► Operator theory

1124-47-38 **Bo Zhang*** (bzhang@uncfsu.edu), Fayetteville State University, Department of Mathematics and Computer Scienc, 1200 Murchison Road, Fayetteville, NC 28301. *Stability by Fixed Point Theory for Infinite Delay Systems.* Preliminary report.

In this paper we study a system of nonlinear differential equations with variable delays and give conditions to ensure that the zero solution is asymptotically stable by applying Schauder's fixed point theorem. These conditions do not require the boundedness of delays, nor do they ask a fixed sign condition on the coefficient functions. An asymptotic stability theorem with necessary and sufficient conditions is proved. The reader will also see how very complete, simple, and rigorous analysis on a highly challenging stability problem can be achieved using fixed point theory on the space of continuous functions with the supremum norm. (Received August 12, 2016)

1124-47-67 **Safeer Hussain Khan*** (safeer@qu.edu.qa), Dept Math, Stat and Physics, Doha, 2713, Qatar. *On some iterative processes in fixed point theory.*

Several functional equations do not have exact solutions; therefore the need arises to consider their approximate solutions. One way of doing so is to use iterative processes. Several iterative processes have been and are being considered for approximating fixed points. Despite its power and simplicity, the Picard iteration proces fails to work for a very important class of mappings: nonexpansive mappings. Therefore need arises to consider other processes. Mann iteration process introduced in 1954, provides the remedy to the above problem and works for nonexpansive mappings. However, this method fails to work for the so-called pseudo-contractive mappings. Ishikawa process already in use since 1974, works well for Lipschitz and Psuedocontractive mappings. Rate of convergence tells us which process is better than the other. Our talk aims at discussing various types of iterative processes starting from apparently simple but very powerful one-step-one-mapping Picard process. We compare some of the iterative processes for the rate of convergence. (Received August 27, 2016)

1124-47-262 **Claudio H. Morales*** (morales@math.uah.edu), Department of Mathematics, 301 Sparkman Dr., Huntsville, AL 35899. *EXPLORING THE POSITIVE DEFINITE PROPERTY FOR MONOTONE OPERATORS IN INFINITE DIMENSIONAL SPACES.* Preliminary report.

begindocument For the past few years, we have been exploring this notion, that for finite dimensional vectors spaces, is known as positive definite. In fact, we begin our presentation, with some basic results for finite dimensional vector spaces, which are related to this very well-known *Theorem of Bolzano (1817).* Certainly, our main objective is discussed this particular condition on linear and/or monotone operators defined for Hilbert spaces and beyond, to derive surjectivity results. The well-known *Lax-Milgram Theorem* may be derived as a consequence of these findings. (Received September 11, 2016)

1124-47-303 **Dhruba R. Adhikari*** (dadhikar@kennesaw.edu), Kennesaw State University, Department of Mathematics, 1100 S. Marietta Pkwy,Math Building - Bldg. D, Marietta, GA 30060. *Solvability of Inclusions Involving Perturbed Maximal Monotone Operators.*

The existence of nontrivial solutions of the operator inclusion of the form $Lx + Tx + Cx \ni 0,\ x \in X$, will be discussed. Here, X is a real reflexive Banach space with X^* its dual, $L : X \supset D(L) \to X^*$ a densely defined linear maximal monotone operator, and $T : X \supset D(T) \to 2^{X^*}$, $0 \in T(0)$, a strongly quasibounded maximal monotone and positively homogeneous of degree 1. Also, $C : X \supset D(C) \to X^*$ is bounded, demicontinuous and of type (S_+) w.r.t. to $D(L)$. In the special case when $L = 0$, a mapping $G : D(G) \to X^*$ of class (P) introduced by Hu and Papageorgiou will be considered and the existence of nonzero solutions of $Tx+Cx+Gx \ni 0$, where T is only maximal monotone and positively homogeneous of degree $\alpha \in (0, 1]$, will also be discussed. Applications to elliptic partial differential equations involving $p-$Laplacian with $p \in (1, 2]$ and time-dependent parabolic partial differential equations on cylindrical domains will be presented. (Received September 12, 2016)

1124-47-313 **Xavier Alexius Udo-utun*** (xvior@yahoo.com), Department of Mathematics and Statistics, University of Uyo, No. 1 Ikpa Road, Uyo, 520001, Nigeria. *On Unification of fixed point techniques - Applications of (δ, k)-weak contractions.*

Author (Udo-utun Fixed Point Theory and Applications 2014, 2014:65) derived a novel property in his study of F-contractions (Wardowski Fixed Point Theory and Applications 2012:94,2012). Applications yield asymptotic fixed point theorems for contractive, nonexpansive and all Lipschitzian operators sharing the property. Attempt is made to extend applicability to include certain discontinuous operators in Banach and metric spaces as a unifying significance of the property and the notion of (δ, k)-weak contractions introduced earlier by Berinde (Carpath. J. Math. 19(1), 7-22 2003; Nonlinear Forum 9(1), 43-53, 2004). Interesting examples are illustrated (Received September 12, 2016)

49 ► Calculus of variations and optimal control; optimization

1124-49-113 **Cristopher Hermosillo** and **Peter R Wolenski*** (wolenski@math.lsu.edu), Department of Mathematics, Louisiana State University, Baton Rouge, LA 70806. *Fully convex control problems with state constraints and impulses.* Preliminary report.

A Fully Convex Control (FCC) problem has the appearance of the classical calculus of variations Bolza problem

$$\min \int_0^T L(x(t), \dot{x}(t))dt + \ell(x(0), x(T)),$$

where the minimization is over $x(\cdot)$ belonging to some class of arcs. The distinguishing features of FCC are that the data L and ℓ (i) may take on the value $+\infty$ and (ii) are convex functions. Allowance of (i) provides great flexibility incorporating constraints so that most standard control problems come under its purlieu. However, broad generality is restrained by (ii), but includes the classical linear quadratic regulator and many of its generalizations. The speciality of (ii) opens up the possibility of using convex dual formulations.

We review the Hamilton-Jacobi (HJ) theory for FCC problems when the data is finite and coercive, in which case the minimizing class of arcs are absolutely continuous. A natural extension is to allow for state constraints and impulsive arcs. We shall describe how to approximate these utilizing Goebel's self-dual envelope. The approximate problems maintain duality and the existing theory can be applied to them. It is proposed that an HJ theory can be developed as an appropriate limit of the approximating problems. An explicit example will illustrate this. (Received September 02, 2016)

1124-49-140 **Peter J Olver*** (olver@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *Invariant variational problems and invariant flows.*

I will discuss the moving frame approach to the analysis of invariant variational problems and the evolution of differential invariants under invariant submanifold flows. Applications will include variational principles and flows arising in geometry, mechanics, image processing, and integrable systems. (Received September 05, 2016)

1124-49-185 **Alberto Bressan*** (bressan@math.psu.edu), Department of Mathematics, McAllister Building, University Park, PA 16802. *Game-theoretical models of debt management with bankruptcy risk.* Preliminary report.

A problem of optimal debt management is modeled as a non-cooperative game between a borrower and a pool of risk-neutral lenders. Since the debtor may go bankrupt, lenders charge a higher interest rate to offset the possible loss of part of their investment. Existence and properties of optimal strategies are studied, both in a deterministic and in a stochastic framework. (Received September 08, 2016)

1124-49-214 **Norma Ortiz-Robinson*** (nlortiz@vcu.edu), Richmond, VA 23229. *Optimal control problems with input time delay.* Preliminary report.

In this talk we will discuss aspects of optimal control problems with delay in the input. We present our results on the characterization and analysis of the reachable set in this setting. (Received September 09, 2016)

1124-49-218 **Vakhtang Putkaradze*** (putkarad@ualberta.ca), Department of Mathematis, University of Alberta, Edmonton, AB T6G 2J1, Canada. *Variation integrator methods for fluid-structure interactions.*

Abstract: Variational integrators for numerical simulations of Lagrangian systems have the advantage of conserving the momenta up to machine precision, independent of the time step. While the theory of variational integrators for mechanical systems is well developed, there are obstacles in direct applications of these integrators to systems involving fluid-structure interactions. In this talk, we derive a variational integrator for a particular type of fluid-structure interactions, namely, simulating the dynamics of a bendable tube conveying ideal fluid that can change its cross-section. The key to the method lies in the appropriate discretization of the fluid's back-to-labels map, coupled with a variational discretization with elastic part of the Lagrangian.

Joint work with F. Gay-Balmaz (ENS and LMD, Paris). The work was partially supported by NSERC and the University of Alberta Centennial Fund. (Received September 09, 2016)

1124-49-238 **Nicolas Charon*** (charon@cis.jhu.edu), Clark Hall, office 317 B, 3400 N. Charles Street, Baltimore, MD 21218. *Applications of geometric measure theory to shape registration: past, present and future.*

This talk intends to make a synthesis of the interest in various concepts borrowed from geometric measure theory within the framework of shape analysis and large deformation models. More specifically, I will explain how such representations like measures, currents, varifolds or normal cycles among others have proved crucial over the past ten years in providing adequate and robust data fidelity terms between curves, surfaces and submanifolds both continuous and discrete and thereby extending the scope of shape analysis to these classes of objects. The talk shall focus on the basic mathematical exposition of these different notions of generalized measures with emphasis on how they apply and compare in problems like diffeomorphic registration. (Received September 10, 2016)

1124-49-241 **Michele Palladino*** (mup26@psu.edu), Penn State University, Mathematics Department, State College, PA 16802. *Minimum Time Problem for the Controlled Sweeping Process.*

In this talk, we address some recent advances in Dynamic Optimization for the Controlled Sweeping Process (also known in the literature as Moreau's process)

$$(\star) \qquad \dot{x} \in -N_{C(t)}(x) + f(t,x,u), \qquad u \in U$$

where $C(.)$ is a Lipschitz continuous set-valued mapping. Such a framework is a general way to model optimal control problems with state constraints depending on time, but it also arises in many other applications like crowd motion, electric circuit and mechanical system modelling. Here we present a minimum time problem related $(\star)$ and we characterize the minimum time function $T(t,x)$ as the continuous solution of a set of Hamilton-Jacobi inequalities. The main difficulty is due to the presence of the normal cone $N_{C(t)}(x)$ in the right hand side of $(\star)$, which is a not Lipschitz continuous mapping with respect to x and contains implicitly the state constraint $x(t) \in C(t)$. (Received September 10, 2016)

1124-49-242 **Harbir Antil*** (hantil@gmu.edu), Department of Mathematical Sciences, 4400 University Drive, MS: 3F2, Exploratory Hall, room 4201, Fairfax, VA 22030. *Optimal control of fractional order PDEs.*

Diffusion is the tendency of a substance to evenly spread into an available space, and is one of the most common physical processes. The classical models of diffusion lead to well-known equations. However, in recent times, it has become evident that many of the assumptions involved in these models are not always satisfactory or not even realistic at all. Consequently, different models of diffusion have been proposed, fractional diffusion being one of them. The latter has received a great deal of attention recently, mostly fueled by applications in diverse areas such as finance, turbulence and quasi-geostrophic flow models, image processing, peridynamics, biophysics, and many others.

This talk will serve as an introduction to fractional diffusion equation - fractional derivative in both space and time. A novel PDE result by Caffarelli and Silvestre '07 has led to innovative schemes to realize the fractional order operators. We will discuss these numerical methods and their application to PDE constrained optimization problems. (Received September 10, 2016)

1124-49-286 **Stuart Marcus Rogers*** (smr1@ualberta.ca), CAB 632, University of Alberta, Edmonton, AB T6G 2G1, Canada, and **Vakhtang Putkaradze** (putkarad@ualberta.ca), CAB 632, University of Alberta, Edmonton, AB T6G 2G1, Canada. *Optimal Control of a Nonholonomic Mechanical System.*

This talk investigates the optimal control of a mechanical system with nonholonomic constraints. Suslov's problem is an algebraically simple and classical example of a nonholonomic mechanical system. This mechanical system considers the motion of a rigid body rotating about a fixed point subject to the constraint $\Omega(t) \cdot \xi(t) = 0$, where $\Omega(t)$ denotes the rigid body's angular velocity and $\xi(t)$ is a prescribed time-varying vector, both expressed in the rigid body's body frame. First, the pure equations of motion of this nonholonomic mechanical system are derived. Next, letting $\xi(t)$ serve as the control, the optimally controlled equations of motion are derived that obey the pure equations of motion, satisfy prescribed initial and terminal boundary conditions, and minimize the time integral of a prescribed cost function $C(t, \Omega(t), \dot{\Omega}(t), \xi(t), \dot{\xi}(t))$. Finally, numerical solutions of the optimally controlled equations of motion are presented. (Received September 12, 2016)

1124-49-350 **Marco Mazzola*** (marco.mazzola@imj-prg.fr). *Neighboring feasible trajectories in infinite dimension.*

In optimal control theory under state constraints, approximations of solutions of the control system by trajectories lying in the given constraint set are very useful for applications. For instance they can be used in the study of the regularity of the value function and the non degeneracy of first order necessary conditions for optimality. In this talk we are interested in this kind of results when dealing with differential inclusions of the form

$$\dot{x}(t) \in Ax(t) + F(t, x(t)),$$

with $x(\cdot)$ staying in a given closed subset of an infinite dimensional separable Banach space. The presence of the operator A, the infinitesimal generator of a strongly continuous semigroup, makes the differential inclusion be a convenient tool for the study of control problems involving PDEs. This is a joint work with Hélène Frankowska and Elsa Maria Marchini. (Received September 13, 2016)

1124-49-395 **Kazufumi Ito*** (kito@math.ncsu.edu), Dept. of Mathematics, Box 8205, North Carilina State University, Raleigh, NC 27695. *Boundary control of Cahn-Hilliard-Navier- Stokes systems.*

The optimal boundary control of a Cahn-Hilliard-Navier- Stokes system is discussed. A general class of free energy potentials is considered, especially the double-obstacle potential. The well-posedness and existence of the boundary optimal control problems are established. The necessary optimality is derived and analyzed. (Received September 13, 2016)

1124-49-397 **Alan Newell**, **Toby Shearman** and **Shankar C Venkataramani*** (shankar@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N. Santa Rita Ave, Tucson, AZ 85721. *Structures and universality: Rough solutions in geometric analysis and calculus of variations.* Preliminary report.

Energy driven pattern formation is ubiquitous, and manifests itself in a variety of systems including convection patterns, crumpled paper, the complex morphology of leaves and, as we will argue, in the large scale structure of the Universe. A key idea in understanding these phenomena is through "rough solutions" in geometry, i.e. through the study of geometric objects that are "piecewise smooth" but that also contain lower dimensional defects.

We will present some recent work, aiming to show that the nature of such defects in piecewise smooth surfaces (2 dimensional objects) is constrained, and thus there are only a few possible types of defects in a wide variety of systems. Further, and analysis of one system then gives insights into the analysis of other systems in the same "universality" class, i.e that have the same types of defects. We will illustrate this approach with concrete examples. (Received September 13, 2016)

51 ► Geometry

1124-51-297 **Patrick Clarke*** (pclarke@math.drexel.edu). *Deformed T-duality.* Preliminary report.

We will present an approach to homological mirror symmetry for toric Landau-Ginzburg models using a combination of T-duality between dual torus fibrations and deformation theory. (Received September 12, 2016)

52 ► Convex and discrete geometry

1124-52-224 **Gabor Pataki*** (gabor@unc.edu), Department of Statistics, and Operations Research, Chapel Hill, NC 27599, and **Minghui Liu**. *An elementary certificate of infeasibility in semidefinite programming.*

Proving infeasibility is a central problem in optimization and it is a straightforward task in linear programming, using the well known Farkas' lemma. In contrast, in semidefinite programming (SDP) the known infeasibility certificates are either not exact (they do not certify infeasibility of all infeasible SDPs), or are fairly complex.

In this work we obtain a short certificate of infeasibility in SDP by simply reformulating equality constrained semidefinite systems using elementary row operations, and rotations. When a system is infeasible, the reformulated system is trivially infeasible.

Our reformulation is an analogue of the row echelon form of a linear system of equations.

As a corollary, we obtain algorithms to generate the data of all infeasible SDPs; and the data of all feasible SDPs whose maximum rank feasible solution has a prescribed rank.

In somewhat different language, our reformulations provide a standard form of spectrahedra, to easily verify either their emptiness, or a tight upper bound on the rank of feasible solutions. (Received September 09, 2016)

53 ► Differential geometry

1124-53-13 **Nima Anvari*** (anvarin@math.miami.edu), Coral Gables, FL 33146. *Equivariant rho-invariants and instanton homology of torus knots.* Preliminary report.

The equivariant rho-invariants are a version of the classical rho-invariants of Atiyah, Patodi, and Singer in the presence of an isometric involution. In this talk, we discuss these rho-invariants for all involutions on 3-dimensional lens spaces with 1-dimensional fixed point sets, as well as for some involutions on Brieskorn homology spheres. As an application, we compute the generators and Floer gradings in the singular instanton chain complex of (p, q)-torus knots with odd p and q. (Received June 06, 2016)

1124-53-72 **Jo Nelson***, nelson@math.columbia.edu, and **Michael Hutchings**. *An integral lift of cylindrical contact homology.*

I will discuss joint work with Hutchings which gives a rigorous construction of cylindrical contact homology via geometric methods. This talk will highlight our use of non-equivariant constructions, automatic transversality, and obstruction bundle gluing. Together these yield a nonequivariant homological contact invariant which is expected to be isomorphic to SH^+ under suitable assumptions. By making use of family Floer theory we obtain an S^1-equivariant theory defined over $\mathbb{Z}$ coefficients, which when tensored with $\mathbb{Q}$ recovers the classical cylindrical contact homology, now with the guarantee of well-definedness and invariance. This integral lift of contact homology also contains interesting torsion information. (Received August 28, 2016)

1124-53-154 **Marco Aldi*** (maldi2@vcu.edu). *Generalized CRF structures and T-duality.*

The notion of Generalized CRF structure extends the definition of generalized complex structure. When applied to odd-dimensional it yields classical constructions such as cosymplectic structures, normal almost complex structures etc. In this talk we present some recent work on generalized CRF structure including their behavior under T-duality and their double sigma-model interpretation. (Received September 06, 2016)

1124-53-184 **Hamid Krim*** (ahk@ncsu.edu), 890 OVAL DRIVE, NCSU, Raleigh, NC 27695. *A Geometric View of Learning Shape Models.*

We propose an efficient novel lower dimensional representation of shape dynamics. In contrast to related works, the proposed dimension reduction is invertible, efficient and adaptive to the geometry of shape manifolds. The essence of the proposed technique is that every sample path of shape dynamics is representable by a moving frame on the shape manifold. The choice of the moving frame is optimized to result in a well approximated sample path representation in a lower dimensional subspace. Specifically, we avoid a global projection of a high dimensional path onto a single flat subspace, in favor of a local projection of a path onto a sequence of flat subspaces spanned by an optimal moving frame. The moving frame method as an optimization of a basis sequence, however does not induce too many additional degrees of freedom the optimization. The parallelism defined by Levi-Civita connection are imposed on the moving frame, which for a given sample path uniquely determines the form of the corresponding moving frame up to the selection of the initial frame. In experiments, the consistency with the original geometry of the shape manifold is demonstrated by the dimension reduction results in R3 in case of geodesic paths, geodesic triangles and real activity data. (Received September 08, 2016)

1124-53-226 **Michael R Benfield**, **Helge Kristian Jenssen** and **Irina A Kogan*** (iakogan@ncsu.edu). *Hyperbolic conservation laws with prescribed eigenfields.*

We consider systems of conservation laws $u_t + f(u)_x = 0$ in one spatial dimension, i. e. $x, t \in \mathbb{R}$, $u(x,t)$ belongs to an open subset of $\Omega \subset \mathbb{R}^n$, called the state space, and $f\colon \Omega \to \mathbb{R}^n$ is a smooth map, called flux. It is well known that eigenvectors of the Jacobian matrix of the flux play an important role in determining wave curves of a hyperbolic system of conservation laws, and hence in constructing solutions of the system. Since eigenvectors depend on a point in the state space, they are called eigenfields. We will discuss the inverse problem: finding hyperbolic conservative systems with fully or partially prescribed set of eigenfields. This problem is part of a larger project of determining the effects of geometric properties of the wave curves on the behavior of the solutions of the conservative systems. It also has an interesting geometric interpretation and can be studied via classical integrability theorems and their appropriate generalizations. (Received September 09, 2016)

1124-53-244 **Bojko Bakalov*** (bojko_bakalov@ncsu.edu), Department of Mathematics, North Carolina State University, Raleigh, NC 27695, and **William Wheeless**. *Additional symmetries of the extended bigraded Toda hierarchy.*

The extended bigraded Toda hierarchy is an integrable system satisfied by the total descendant potential of $\mathbb{CP}^1$ with two orbifold points. We construct its additional symmetries and describe explicitly their action on the Lax operator, wave operators, and tau-function of the hierarchy. In particular, we obtain infinitesimal symmetries that act on the tau-function as a subalgebra of the Virasoro Lie algebra. (Received September 10, 2016)

1124-53-295 **Kristen Hendricks*** (hendricks@math.msu.edu), **Robert Lipshitz** (lipshitz@uoregon.edu) and **Sucharit Sarkar** (sucharit@math.ucla.edu). *A simplicial construction of G-equivariant Floer homology.* Preliminary report.

For G a Lie group acting on a symplectic manifold and preserving a pair of Lagrangians, we use techniques from simplicial sets to construct the G-equivariant Floer homology of L_0 and L_1 without equivariant transversality. We give a sample application to symplectic Khovanov homology, and discuss other places in low dimensional topology where it would be interesting to apply this construction. (Received September 12, 2016)

1124-53-328 **Ziva Myer*** (zmyer@brynmawr.edu). *Product Structures for Generating Family Cohomology of Legendrian Submanifolds.* Preliminary report.

In contact geometry, invariants of Legendrian submanifolds in 1-jet spaces have been obtained through a variety of techniques. I will discuss how I am enriching one invariant, Generating Family Cohomology, by constructing a product structure on the cohomology groups. The construction uses moduli spaces of Morse flow trees – spaces of intersecting gradient trajectories of functions whose critical points encode Reeb chords of the Legendrian. This product structure lays the foundation for an A-infinity algebra structure for the Legendrian that shows, in particular, that this product gives Generating Family Cohomology a ring structure. (Received September 12, 2016)

1124-53-337 **Yu Pan*** (yp37@math.duke.edu). *Exact Lagrangian Fillings of Legendrian* $(2, n)$ *torus links.*

For a Legendrian $(2, n)$ torus knot or link with maximal Thurston-Bennequin number, Ekholm, Honda, and Kálmán constructed C_n exact Lagrangian fillings, where C_n is the n-th Catalan number. We show that these exact Lagrangian fillings are pairwise non-isotopic through exact Lagrangian isotopy. To do that, we compute the augmentations induced by the exact Lagrangian fillings L to $\mathbb{Z}_2[H_1(L)]$ and distinguish the resulting augmentations. (Received September 12, 2016)

1124-53-374 **T. H. Wears*** (wearsth@longwood.edu). *Lorentzian Ricci Solitons on Solvable Lie Groups.* Preliminary report.

We present the classification of algebraic Ricci solitons of Lorentzian signature on a five-dimensional solvable Lie group, the geometry of which has previously been extensively investigated by M. Aghasi and M. Naheshi, and G. Calvaruso, O. Kowalski, R. Marinosci. Using the symmetries of the Lie algebra, we find canonical forms of the left invariant Lorentzian metrics on the group in question and then use the canonical forms to classify the algebraic Ricci solitons. In particular, we establish the existence of inequivalent algebraic Ricci solitons exhibiting a wide variety of qualitative behaviors. In comparison with the work of Aghasi and Nasehi, where the authors establish that a particular family of left invariant metrics are not homogeneous Ricci solitons, this shows that the geometry of Ricci soliton structures on the indicated group is in fact quite rich. (Received September 13, 2016)

54 ► General topology

1124-54-8 **Parvateesam Murthy Penumarthy*** (ppmurthy@gmail.com), Department of Pure & Applied Mathematics, Guru Ghasidas Vishwavidyalaya, Bilaspur, Chhattisga 495009, India. *Problems in Metric Fixed Point Theory and Applications.* Preliminary report.

Metric Fixed Point Theory and Applications coined when Banach(S. Banach, Surles operations dans les ensembles abstraits et Leur application aux equations integrales, Fund. Math.3(1922); 133 .. 181:(French)) proved a unique fixed point theorem in a complete metric space. Let T be a self mapping dened on a complete metric space satisfying: d(Tx, Ty)$\leq$ α d(x, y) for all x, y $\in$ X and α $\in$ (0, 1). Then T has a unique fixed point. The above inequality is very essential for proving convergence as well as for obtaining unique fixed point. I have been mainly inspired by the condition of Banach and wish to discuss some variety of results which are mainly generalizing and extending the above condition for the past NINE DECADES. I wish to discuss some of very interesting TOOLS (Ref : P. P. Murthy, Important Tools and Possible Applications of Metric Fixed Point Theory, Nonlinear Analysis, 44(5)(2001); 3479..3490.) for obtaining fixed points and common fixed points in some abstract spaces along with some possible applications. (Received March 09, 2016)

1124-54-20 **Balwant Singh Thakur*** (balwantst@gmail.com), School of Studies in Mathematics, Pt. Ravishankar Shukla University, Raipur, Raipur, Chhattisga 492010, India. *On the convergence of some iterative algorithm to approximate fixed points of nonexpansive mappings.*

In recent year's iterative algorithms, involving perturbed mapping has been studied by various authors to study weak and strong convergence of nonexpansive mappings. In this paper, we will continue this direction of research and propose a new three-step iteration scheme for approximation of fixed point of a nonexpansive self-mapping in the framework of Banach space. We establish some strong convergence theorems. Further, we show that the new iteration process is faster than a number of existing iteration processes. To support the claim, we consider a numerical example and approximated the fixed point numerically by computer using Matlab.

There is a huge body of literature related to iterative approximation of fixed points of nonexpansive mapppings, but there are very few with concrete examples. In this paper, we set an example and apply the proposed algorithm; the behaviour of proposed iteration is explained by graph and tables.

We compare the behaviour of the proposed algorithm with the existing iteration process. It shows that the new algorithm converges faster than the existing iteration also it is very stable and effective. (Received July 11, 2016)

1124-54-23 **Clement Boateng Ampadu*** (drampadu@hotmail.com), West Roxbury, MA 02132-6303.
On a Question of C. Ampadu: Higher Order Reich Mapping Theorem for Self-Maps.

Reich Mapping Theorem was given in [Simeon Reich, Some Remarks Concerning Contraction Mappings, Canad. Math. Bull. Vol. 14 (1), 1971]. In the book [Clement Ampadu, Characterization Theorems Inspired by the Hardy-Rogers Map I: Some Results in Metric Spaces, lulu.com, ISBN: 1365101185, 9781365101182] the author proposed obtaining a higher-order version of this theorem. Motivated by ideas contained in [Ampadu,Clement (2015): Generalization of Higher Order Contraction Mapping Theorem, Unpublished] we introduce a higher-order version of the Reich mapping Theorem. Examples are given to motivate the main result (Received July 15, 2016)

1124-54-40 **Chuan Liu*** (liuc1@ohio.edu), 1425 Newark Rd, Zanesville, OH 43701. *Countable tightness of free topological groups over Lašnev spaces.* Preliminary report.

In this talk, I should discuss tightness between $F(X)$ and $F_n(X)$ over Lašnev spaces and present some results on countable tightness, k-space property of free topological groups. Some questions are posed. (Received August 12, 2016)

1124-54-41 **David J Lutzer*** (lutzer@math.wm.edu), **Sheldon W. Davis** and **Harold R. Bennett**.
Images of the countable ordinals. Preliminary report.

In this paper, we study spaces that are continuous images of the usual space $[0, \omega_1)$ of countable ordinals. We begin by showing that if Y is such a space and is T_3 then Y has a monotonically normal compactification, is monotonically normal, locally compact, and scattered. Examples show that regularity is needed in these results. We investigate when a regular continuous image of the countable ordinals must be compact, paracompact, and metrizable. For example, we show that metrizability of such a Y is equivalent to each of the following: Y has a G_δ-diagonal, Y is perfect, Y has a point-countable base, Y has countable cellularity, Y has a small diagonal in the sense of Hušek, and Y has a σ-minimal base. We give an example of a non-metrizable compact monotonically normal space every subspace of which is a paracompact p-space. We also obtain an absolute version of the Juhasz-Szentmiklossy theorem for small spaces by proving that if Y is any compact Hausdorff space having $|Y| \leq \aleph_1$ and having a small diagonal, then Y is metrizable, and we deduce a recent result by Gruenhage on scattered compact spaces with small diagonals from work of Mrowka, Rajagopalan, and Soundararajan. (Received August 14, 2016)

1124-54-68 **Jerry E Vaughan*** (vaughanj@uncg.edu), University of North Carolina at Greensboro, Department of Mathematics and Statistics, 116 Petty Building, Greensboro, NC 27402-6170. *Companions of directed sets and the Ordering Lemma.*

A well ordered set $(C, \preceq)$ is called a companion of a partially ordered set $(D, \leq)$ provided C is a cofinal subset of $(D, \leq)$ and for every $c_1, c_2 \in C$, if $c_1 \leq c_2$ then $c_1 \preceq c_2$. The ordering lemma is a version of the axiom of choice that says every directed set has a companion. If $f : D \to X$ is a net into a set X, the transfinite sequence $f \restriction C : (C, \preceq) \to X$ is called the companion (transfinte) sequence of the net f. We will give a proof of the Theorem: If $(D, \leq)$ does not have a well ordered cofinal subset (well ordered by the restriction of $\leq$) then there exists a topological space X and a net $f : D \to X$ such that the companion sequence $f \restriction C$ has a cluster point in X, but f does not have cluster point in X. This result points to a gap in the (now retracted) claimed proof by W. Sconyers and N. Howes that every normal linearly Lindleöf space is Lindelöf. (Received August 27, 2016)

1124-54-90 **Alan S. Dow*** (adow@uncc.edu), Department of Mathematics and Statistics, University ofNorth Carolina at Charlotte, 9201 University City Blvd, Charlotte, NC 28223-001.
Countably tight spaces are C-closed under PFA. Preliminary report.

A space has countable tightness providing a set is closed if it contains the closure of all its countable subsets. A space is said to be C-closed if every countably compact subset is closed. Sequential spaces are C-closed. The one-point compactification of the classical Ostaszewski space is an example (requiring special axioms) of a space of countable tightness that is not C-closed (the Ostaszewski subspace is dense and countably compact). The standard proof from PFA that compact spaces of countable tightness are sequential proceeds by showing that

they are C-closed. PFA is the proper forcing axiom. We prove the statement of the title. It was already known to be consistent with CH that countably tight spaces are C-closed and consistent with not CH that compact C-closed spaces do not have to be sequential. (Received August 30, 2016)

1124-54-124 **Akira Iwasa*** (iwasa@uscb.edu). *Forcing and Sequential Properties.* Preliminary report.
We consider six mutually disjoint classes of topological spaces:

1. First countable
2. Strongly Frechet but not first countable
3. Frechet but not strongly Frechet
4. Sequential but not Frechet
5. Countably tight but not sequential
6. Not countably tight

We study if a forcing can make a space in one of the above classes belong to another class. In particular, we discuss if a forcing can destroy strongly Frechetness while preserving countable tightness. (Received September 04, 2016)

1124-54-163 **Sara Kalisnik Verovsek*** (sara.kalisnik@gmail.com), Department of Mathematics, Box 1917, Brown University, Providence, RI 02912. *Tropical Coordinates on the Space of Persistence Barcodes.*
In the last two decades applied topologists have developed numerous methods for 'measuring' and building combinatorial representations of the shape of the data. The most famous example of the former is persistent homology. This adaptation of classical homology assigns a barcode, i.e. a collection of intervals with endpoints on the real line, to a finite metric space. Unfortunately, barcodes are not well-adapted for use by practitioners in machine learning tasks. We can circumvent this problem by assigning numerical quantities to barcodes and these outputs can then be used as input to standard algorithms. I will talk about max-plus polynomials and tropical rational functions that can be used as coordinates on the space of barcodes. All of these are stable with respect to the standard distance functions (bottleneck, Wasserstein) used on the barcode space. (Received September 06, 2016)

1124-54-180 **Steve Wheatley***, swheatle@gmu.edu. *Continuous Extensions of Autohomeomorphisms on Stone-Čech Remainders.*
If X^* denotes the Stone-Čech remainder of X, we look at the question of whether every autohomeomorphism of X^* extends continuously to a point of X. In particular, we answer this question in the affirmative when X is a nowhere locally compact, zero-dimensional, separable metric space that is not sigma-compact. (Received September 07, 2016)

1124-54-197 **John Porter*** (jporter@murraystate.edu), Department of Mathematics & Statistics, Faculty Hall 6c, Murray State University, Murray, KY 42071. *On Well-ranked Pair-bases.* Preliminary report.
Well-ranked pair-bases are introduced as a generalization of both Gruenhage and Nyikos' well-ranked bases and Chase and Gruenhage's property (A). Let $\mathcal{P}$ be the set of all pairs (B_1, B_2) of subsets of a topological space X with $B_1 \subset B_2$. If $\mathcal{B} \subset \mathcal{P}$, denote $\mathcal{B}(i) = \{B_i : (B_1, B_2) \in \mathcal{B}\}$. Let X be a topological space, then $\mathcal{B} \subset \mathcal{P}$ is a pair-base on X provided every element of $\mathcal{B}(1)$ is open and if U is an open neighborhood of a point x, then there is a $(B_1, B_2) \in \mathcal{B}$ such that $x \in B_1 \subset B_2 \subset U$.

A family of pairs of subsets of $\mathcal{A} \subset \mathcal{P}$ is said to be a NSR pair-family if for any $\mathcal{A}' \subset \mathcal{A}$ such that $\cap\mathcal{A}'(1) \neq \emptyset$, there is a finite $\mathcal{F} \subset \mathcal{A}'$ such that for every $(A_1, A_2) \in \mathcal{A}'$, $A_1 \subset F_2$ for some $(F_1, F_2) \in \mathcal{F}$. We say a pair-base $\mathcal{B}$ is a well-ranked pair-base if $\mathcal{B}$ is a countable union of NSR pair-families.

A space with a well-ranked pair-base is σ-metacompact and is a D-space. Furthermore, if a compact or separable space X has a well-ranked pair-base, then X is metrizable, generalizing recent results by Chase and Gruenhage and some older results of Gruenhage and Nyikos. (Received September 08, 2016)

1124-54-200 **Alexander Shibakov*** (asibakov@tntech.edu), Department of Mathematics, Tenn Tech Univ., Cookeville, TN 38505-0001. *A large non-reflecting sequential group.* Preliminary report.
We discuss a construction of an uncountable sequential group without non discrete countable sequential subgroups or non Fréchet quotients of countable pseudocharacter using $\diamondsuit$. (Received September 08, 2016)

1124-54-207 **John S Kulesza*** (jkulesza@gmu.edu). *A useful technique for converting esoteric spaces into N-compact ones.*

We present a technique for transforming certain esoteric spaces into N-compact ones with special properties and give two applications. Both examples are metrizable.

If X is E-compact, then $Exp_E X$ denotes the smallest cardinal κ for which X embeds in E^κ as a closed set. Also, $N([0,1])$ denotes the Novak number of $[0,1]$. The first example X, assuming $\omega_1 < \mathbf{c} = N([0,1])$, satisfies $Exp_R X < Exp_N X$, and thus gives a consistent solution to a problem of Mrowka and van Douwen (in his "Handbook of set theoretic topology" article). The second example Y illustrates, consistently, that there is no completion theorem for N-compact metrizable spaces. That is, assuming CH fails, Y is an N-compact metrizable space which admits no N-compact completion. (Received September 08, 2016)

1124-54-273 **Gary Gruenhage*** (garyg@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36830, and **David Lutzer**. *Perfect images of generalized ordered spaces.* Preliminary report.

We study the class of perfect images of generalized ordered (GO) spaces, which we denote by PIGO. Mary Ellen Rudin's celebrated result characterizing compact monotonically normal spaces as the continuous images of compact linearly ordered spaces implies that every space with a monotonically normal compactification is in PIGO. But PIGO is wider: every metrizable space is in the class, but not every metrizable space has a monotonically normal compactification. On the other hand, a locally compact space is in PIGO if and only if it has a monotonically normal compactification. Bennett and Lutzer had asked whether every (semi)stratifiable space with a monotonically normal compactification must be metrizable; we give a positive answer to this question by showing that every semistratifiable space in PIGO is metrizable. This also shows that there are monotonically normal spaces which are not in PIGO. (Received September 11, 2016)

1124-54-283 **John P. Reynolds*** (reynoldsj@hendrix.edu), Department of Mathematics, Hendrix College, 1600 Washington Ave., Conway, AR 72032. *Cardinal Invariants of Pretopologies.*

In 1969, Arhangel,skii proved that if X is a Hausdorff topological space, then $|X| \leq 2^{\chi(X)L(X)}$. This result has subsequently been generalized and adapted to provide a variety of cardinality bounds for different topological spaces. We extend this line of inquiry to convergence spaces and in particular to the so-called pretopological spaces.

If X is a Hausdorff topological space, then a subset A of X is called an H-set if every filter on A has a θ-adherent point in X. A particular use of cardinality bounds as described above is in characterizing which subsets of X can possibly be H-sets. Our hope is to further these characterizations by considering cardinal invariants of pretopological spaces. (Received September 11, 2016)

1124-54-366 **Peter Nyikos J. Nyikos*** (nyikos@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *Locally compact spaces: ω_1-compactness vs. σ-countable compactness.* Preliminary report.

A *space of countable extent*, also called an *ω_1-compact space*, is one in which every closed discrete subspace is countable. Obviously, every *σ-countably compact space* [i.e., the union of countably many countably compact spaces] is ω_1-compact. The addition of local compactness makes the converse sensitive to set-theoretic independence results. For example:

Theorem 1 [Lyubomir Zdomskyy]. If P-Ideal Dichotomy (PID) holds and $\mathfrak{p} > \aleph_1$, then every locally compact, ω_1-compact space of cardinality $\aleph_1$ is σ-countably compact.

Theroem 2. In MM(S)[S] models, every locally compact, hereditarily normal, ω_1-compact space is σ-countably compact.

If we replace "hereditarily normal" by the stronger "monotonically normal" in this theorem, then we only need the consequence PID of MM(S)[S]. But this is still only a consistency result:

Theorem 3. If $\clubsuit$, there is a monotonically normal, locally compact, locally countable (hence first countable, and scattered) ω_1-compact space of cardinality $\aleph_1$ which is not σ-countably compact.

(Received September 13, 2016)

1124-54-376 **Stewart Baldwin*** (baldwsl@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36849-5310. *Large Uniquely Homogeneous Spaces.* Preliminary report.

A topological space X is *uniquely homogeneous* if for every $a, b \in X$ there is *exactly one* homeomorphism $h : X \to X$ such that $h(a) = b$.

Theorem: There are arbitrarily large uniquely homogeneous Hausdorff spaces. In particular, every compact Hausdorff space can be embedded in a uniquely homogeneous Hausdorff space. (Received September 13, 2016)

55 ► Algebraic topology

1124-55-66 **Michael S Willis*** (msw3ka@virginia.edu), 141 Cabell Drive, Kerchof Hall, P.O. Box 400137, Charlottesville, VA 22904-4137. *A Colored Khovanov Homotopy Type.*

We define a Khovanov homotopy type for $\mathfrak{sl}_2(\mathbb{C})$ colored links and quantum spin networks and derive some of its basic properties. In the case of n-colored B-adequate links, we show a stabilization of the homotopy types as the coloring $n \to \infty$, generalizing the tail behavior of the colored Jones polynomial. Time permitting, we will also provide an alternative, simpler stabilization in the case of the colored unknot. (Received August 27, 2016)

1124-55-135 **Kathryn Bryant*** (kthrynbrynt@gmail.com), 14 E Cache la Poudre St, Colorado Springs, CO 80903. *Converting d-invariants into lattice points: A visualization trick to aid in knot slicing.*

This talk will focus on a particular technique used to prove/disprove knot sliceness and it will serve as an invitation to other researchers to help push the technique further. In the 2011 paper "The slice-ribbon conjecture for 3-stranded pretzel knots," Greene and Jabuka make use of Donaldson's diagonalization theorem and a theorem about d-invariants (due to Ozsváth and Szabó) from Heegaard-Floer theory in order to classify the slice knots within the family of 3-stranded pretzel knots. They give the necessary condition for a slice knot K that the number of vanishing d-invariants $d(Y, \mathfrak{s})$, where Y is the 2-fold branched cover of K and $\mathfrak{s}$ is a spin^c structure on Y, must exceed or equal $\sqrt{|\det K|}$, where $\det K$ is the knot determinant of K. The speaker used this criterion to study sliceness of 5-stranded pretzel knots and, after making a necessary refinement, translated the d-invariant criterion into one about lattice points. The goal of this talk is to explain this lattice point criterion and look for new ways to study it. (Received September 06, 2016)

1124-55-186 **Mehmet E Aktas*** (maktas@math.fsu.edu), 1234 Continental Ct., Tallahassee, FL 32304. *A polynomial invariant for plane curve complements: Krammer polynomials.*

A. Libgober defined an invariant of plane algebraic curves via representations of the braid groups and also showed that the this invariant coincides with the Alexander polynomial when one uses the Burau representation. In this paper, we construct a new polynomial invariant of plane algebraic curves using the Krammer representation of the braid groups in Libgober's invariant, called the Krammer Polynomial. We also find the local and global Krammer polynomials of n-gonal curves in some special cases. (Received September 08, 2016)

1124-55-225 **Saba Emrani*** (semrani@ncsu.edu). *Topo-Geometric Frameworks for Physiological Signal Processing.*

We first present our framework for exploiting the intrinsic topology of signals to detect quasi-harmonic behaviors. Using delay embeddings, we transform the signal into a point cloud, whose topology reflects its periodic behavior. Persistent homology is employed to determine the underlying manifold, and the Euler characteristic provides a fast computation method. We apply this approach to breathing sounds for wheeze detection. We also use this method to identifying cell-cycle regulated genes. We then invoke one more dimension to the point cloud and utilize 3D delay embedding for spectral estimation of highly transient data in order to estimate the frequencies in wheezes. We next present a topological framework for extracting the characteristic points of pulse pressure waves (PPW). Using persistence diagram, we locate key characteristic points on PPW, and use them for calculating a measure of arterial stiffness. Finally, we present a geometric causal interaction measure based on multivariate delay embedding and exploit it in MEG data to construct effective connectivity maps of brain activity in order to decode visual stimuli. Moreover, we show that these maps as a response to structured images are more geometric, as disclosed by the evolution of their topological structures. (Received September 09, 2016)

1124-55-261 **Dan Scofield*** (dscofie@ncsu.edu). *Torsion in Khovanov link homology via chromatic graph cohomology.*

The categorification of the chromatic polynomial by Helme-Guizon and Rong is isomorphic to Khovanov link homology over a range of homological gradings. Motivated by Hochschild homology, we compute torsion in chromatic homology for certain classes of graphs. As a consequence, we offer insight into Z2 torsion of certain classes of knots and links. (Received September 11, 2016)

1124-55-265 **Yunfeng Hu**, **Matthew Hudelson**, **Bala Krishnamoorthy*** (kbala@wsu.edu), **Altansuren Tumurbaatar** and **Kevin Vixie**. *Median Shapes.*

We introduce new ideas for the average of a set of general shapes, which we represent as currents from geometric measure theory. Using the flat norm to measure the distance between currents, we present a mean and a median shape. In the discrete setting, we model shapes as chains on a finite simplicial complex. We demonstrate that the median shape of chains can be found efficiently by solving a linear program. (Received September 11, 2016)

1124-55-276 **Józef H. Przytycki** and **Xiao Wang*** (wangxiao@gwmail.gwu.edu). *An example of torsion in Yang-Baxter homology.*

It is well known that one can get link invariants from Yang-Baxter operators (Jones, Turaev). We will introduce a homology theory of Yang-Baxter operator and discuss some computation results especially for the Yang-Baxter operator giving Jones polynomial. (Received September 11, 2016)

1124-55-336 **Ezra Miller*** (ezra@math.duke.edu). *Data structures for real multiparameter persistence.* Preliminary report.

Biological data, such as the images of fruit fly wing veins that drive the ongoing investigations reported in this talk, generate persistent homology with multiple parameters each of which varies continuously. Statistical analysis of persistence in this context presents fundamental challenges, such as how to encode persistence summaries for automatic computation and how to carry out statistical analyses with the summaries—theoretically and algorithmically—particularly in view of nontrivial moduli for multiparameter persistence diagrams. This talk presents an algebraic and geometric framework that renders these challenges surmountable while also clarifying the topological interpretation of each multiparameter persistence summary. The framework is new and useful already for two discrete parameters but works equally well for continuous parameters, or even for filtrations by arbitrary partially ordered sets. Joint work with David Houle (Biology, Florida State), Ashleigh Thomas (grad student, Duke Math), and Justin Curry (postdoc, Duke Math). (Received September 12, 2016)

57 ► Manifolds and cell complexes

1124-57-18 **Gaven J. Martin*** (g.j.martin@massey.ac.nz). *Siegel's problem on small volume lattices.*

We outline in very general terms the history and the proof of the identification of the minimal covolume lattice of hyperbolic 3-space as the 3-5-3 Coxeter group extended by the involution preserving the symmetry of this diagram. This gives us the smallest regular tessellation of hyperbolic 3-space.

This solves (in three dimensions) the problem posed by Siegel in 1945 (Siegel solved this problem in two dimensions by deriving the Signature formula identifying the (2,3,7)-triangle group as having minimal co-area).

There are strong connections with arithmetic hyperbolic geometry in The proof and the result has applications in the maximal symmetry groups Of hyperbolic 3-manifolds (in much the same way that Hurwitz 84g-84 theorem and Siegel's result do). (Received June 23, 2016)

1124-57-57 **Charles Frohman*** (charles-frohman@uiowa.edu), Department of Mathematics, The University of Iowa, Iowa city, IA 52245, and **Joanna Kania-Bartoszynska** and **Thang Le**. *The Unicity Theorem for the Kauffman Bracket Skein Algebra.*

Let F be finite type surface (including closed surfaces). Let ζ be a root of unity. The Kauffman bracket skein algebra of F at ζ, $K_\zeta(F)$, is an algebra built out of the vector space whose basis is isotopy classes of framed links in $F \times I$, modulo the Kauffman bracket skein relations. An irreducible representation of $K_\zeta(F)$ is an onto algebra homomorphism $\phi : K_\zeta(F) \to M_n(\mathbb{C})$, where $M_n(\mathbb{C})$ is the algebra of $n \times n$ matrices with coefficients in the complex numbers for some n. Bonahon and Wong prove that such a representation has a **classical shadow** which consists of a trace equivalence class of homomorphisms $\rho : \pi_1(F) \to SL_2(\mathbb{C})$ and a choice of a complex number for each puncture of the surface. They conjecture that there is a generic set of shadows for which the representation is determined up to equivalence by its shadow. We prove this to be the case.

Our approach is structural, and it follows from the fact that the Kauffman bracket skein algebra is **almost Azumaya**. That is there is $c \neq 0$ the center of $K_\zeta(F)$ so that the result of localizing $K_\zeta(F)$ at the powers of c is an Azumaya algebra. (Received August 24, 2016)

1124-57-61 **Adam Lowrance*** (adlowrance@vassar.edu) and **Radmila Sazdanovic**. *Chromatic homology, Khovanov homology, and torsion.* Preliminary report.

We show that the categorification of the chromatic polynomial only contains torsion of order two. As a consequence, for semi-adequate links, the torsion in either the first few or last few homological gradings of Khovanov homology must also have order two. (Received August 25, 2016)

1124-57-76 **Hao Wu*** (haowu@gwu.edu). *Dimension of the Khovanov-Rozansky homology.*

I will demonstrate that the degree of the Hilbert polynomial of the Khovanov-Rozansky homology of a link is its number of components minus 1. (Received August 29, 2016)

1124-57-80 **Deanna Needell** and **Sam Nelson*** (sam.nelson@cmc.edu). *Biquasiles and Dual Graph Diagrams.*

Biquasiles are algebraic structures arising from a way of representing oriented knot and link diagrams with a type of graph we called dual graph diagrams. In this talk we will introduce dual graph diagrams, derive the biquasile axioms and see some examples of biquasile counting invariants. (Received August 29, 2016)

1124-57-91 **Patricia Cahn*** (pcahn@smith.edu) and **Alexandra Kjuchukova** (kjuchukova@math.wisc.edu). *Computing linking numbers of curves in dihedral branched covers.* Preliminary report.

Let M be a p-fold irregular dihedral branched cover along a knot K in S^3, and $f : M \to S^3$ the corresponding covering map. The linking numbers of the components of the branch set $f^{-1}(K)$ are simple but powerful knot invariants. Building on an algorithm of Perko, which computes these linking numbers, we describe an algorithm for computing linking numbers of preimages of arbitrary curves in the complement of K. We will also discuss the motivation for our work, namely the classification of branched covers between four-manifolds with singular branching sets. This is joint work with Alexandra Kjuchukova. (Received August 30, 2016)

1124-57-129 **John B Etnyre*** (etnyre@math.gatech.edu) and **Marco Golla**. *Symplectic hats.* Preliminary report.

Given a symplectic cobordism between contact 3-manifolds, we will consider symplectic cobordisms between transverse knots in those contact manifolds. In particular we discuss cobordisms from a transverse knot to the empty set which we call a symplectic hat. We discuss properties of symplectic caps and "the hat trick" which is a method to use certain symplectic hats to build symplectic caps for contact manifolds which in turn can be used to study symplectic fillings. (Received September 05, 2016)

1124-57-141 **Daniel S Silver*** (silver@southalabama.edu), Department of Mathematics and Statistics, ILB 325, Mobile, AL 36688, and **Susan G Williams** (swilliam@southalabama.edu), Department of Mathematics and Statstics, ILB 325, Mobile, AL 36688. *Lehmer's Question and Graph Complexity.* Preliminary report.

D.H. Lehmer's question about roots of polynomials with integer coefficients has remained an important open question for more than 80 years. We show that Lehmer's question is equivalent to one about graph complexity and spanning trees. When planar graphs are considered, complexity is seen to be determinant density of knots and links. (Received September 05, 2016)

1124-57-142 **Susan G. Williams*** (swilliam@southalabama.edu) and **Daniel S. Silver** (silver@southalabama.edu). *Periodic planar graphs and links.*

A plane graph with signed edges is the Tait graph of a link diagram. We consider infinite, periodic link diagrams that arise from signed, plane graphs with free, cofinite action by $\mathbb{Z}$ or $\mathbb{Z}^2$. Such a graph determines a Laplace polynomial, with Mahler measure that gives an exponential growth rate of determinants of associated quotient links. We unify results using the framework of algebraic dynamics. (Received September 05, 2016)

1124-57-178 **J. Scott Carter*** (carter@southalabama.edu), Department of Mathematics and Statistics, ILB 325, Mobile, AL 36688. *Using globular in geometric and categorical contexts.*

Jamie Vicary's program globular give new freedoms to construct and compute with knotted surfaces, knotted 3-manifolds, and even embedding or immersed 4-manifolds in 6-dimensional space. The program allows explicit embeddings and immersions, and in many cases isotopies of these can be performed. In this talk, I will continue to present illustrations and examples of the utility and simplicity of the program, (Received September 07, 2016)

1124-57-216 **Seung Yeop Yang*** (syyang@gwu.edu). *On rack and quandle spaces and homotopy invariants of links.*

In 1993, Fenn, Rourke, and Sanderson introduced rack spaces and rack homotopy invariants, and modifications to quandle spaces and quandle homotopy invariants were introduced by Nosaka in 2011. We define the Cayley-type graph and the extended quandle space of a quandle in analogy to rack and quandle spaces. Moreover, we construct the shadow homotopy invariant of a classical link and prove that the shadow homotopy invariant is equal to the quandle homotopy invariant multiplied by the order of a quandle. (Received September 09, 2016)

1124-57-217 **W Edwin Clark** and **Masahico Saito*** (saito@usf.edu). *Rotations of spherical polygons and quandle cocycle invariants.* Preliminary report.

The 2-sphere has a quandle structure by rotations of a constant angle, corresponding to a conjugacy class of SO(3). We present examples of knot colorings by these quandles. For 2-strand torus knots, these correspond to spherical polygons, and for the figure-eight knot, to skew tetrahedra. These converge to Fox colorings. The obstruction to lifting these colorings to SO(3) with generalized Alexander quandle structures corresponds to the cocycle invariant. A relation to the roots of the Alexander polynomial is discussed, through Inoue's results on planar rotations. (Received September 09, 2016)

1124-57-228 **Heather A Dye*** (heatheranndye@gmail.com). *Khovanov homology for virtuals.*

In this talk, I define Khovanov homology for virtuals and compute some examples. (Received September 09, 2016)

1124-57-252 **Cağatay Kutluhan** and **Gordana Matić*** (gordanam@uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30605, and **Jeremy Van Horn-Morris** and **Andy Wand**. *Filtering the Heegaard Floer contact invariant.*

We define an invariant of contact structures in dimension 3 from Heegaard Floer homology. This invariant takes values in $\mathbb{Z}_{\geq 0} \cup \{\infty\}$. It is zero for overtwisted contact structures, ∞ for Stein fillable contact structures, non-decreasing under Legendrian surgery, and computable from any supporting open book decomposition. It gives a criterion for tightness of a contact structure stronger than that given by the contact invariant in Heegaard Floer homology, and an obstruction to existence of Stein cobordisms between contact 3-manifolds. We also use our invariant to give a somewhat simpler criterion for tightness, and exhibit examples with vanishing contact invariant in Heegaard Floer homology for which our invariant is finite and non-zero. (Received September 11, 2016)

1124-57-254 **Mikhail Khovanov*** (khovanov@math.columbia.edu), 2990 Broadway, Department of Mathematics, New York, NY 10463. *Hopfological algebra from nonsemisimple Hopf algebras.* Preliminary report.

We will discuss interesting stable triangulated categories of representations of certain finite-dimensional non-semisimple Hopf algebras. (Received September 11, 2016)

1124-57-255 **Moshe Cohen*** (mcohen@vassar.edu), **Chaim Even-Zohar** and **Sunder Ram Krishnan**. *Random 2-bridge Chebyshev billiard table diagrams.*

Koseleff and Pecker show that all knots can be parametrized by Chebyshev polynomials in three dimensions. These long knots can be realized as trajectories on billiard table diagrams. We use this knot diagram model to study random knot diagrams by flipping a coin at each 4-valent vertex of the trajectory.

We truncate this model to study 2-bridge knots together with the unknot. We give the exact probability of a knot arising in this model. Furthermore, we give the exact probability of obtaining a knot with crossing number c. (Received September 11, 2016)

1124-57-257 **John A. Baldwin**, **Adam Simon Levine*** (asl2@math.princeton.edu) and **Sucharit Sarkar**. *Khovanov homology and knot Floer homology for pointed links.*

There are spectral sequences relating reduced Khovanov homology to a variety of other homological link invariants, including the Heegaard Floer homology of the branched double cover and instanton knot homology. However, there is no known relationship between Khovanov homology and knot Floer homology, despite considerable computational evidence and numerous formal similarities. I will describe ongoing efforts to find a spectral sequence relating these two invariants. Specifically, we construct a variant of Khovanov homology for links with one or more basepoints on each component, which more closely parallels the behavior of knot Floer homology and which conjecturally fits into a spectral sequence as required. (Received September 11, 2016)

1124-57-267 **Thomas E. Mark***, PO Box 400137, Kerchof Hall, University of Virginia, Charlottesville, VA 22904, and **Bulent Tosun**. *Obstructing Stein structures on contractible 4-manifolds.*

A Stein manifold is a complex manifold with particularly nice convexity properties. In real dimensions above 4, existence of a Stein structure is essentially a homotopical question, but for 4-manifolds the situation is more subtle. We will show that there exist homotopically trivial smooth 4-manifolds that do not admit Stein structures, answering a question that has circulated among contact and symplectic topologists recently. Along the way we will provide new evidence for a conjecture of Gompf, which asserts that a nontrivial Brieskorn homology sphere cannot be embedded in complex 2-space as the boundary of a Stein submanifold. (Received September 11, 2016)

1124-57-269 **Sujoy Mukherjee*** (sujoymukherjee@gwu.edu). *A homology theory for associative shelves.* Preliminary report.

Rack and one term homology are very useful tools for studying self-distributive algebraic structures arising out of knot theory. However, it turns out that when these self-distributive algebraic structures are associative, rack and one term homology groups are not very interesting. Motivated by this, we introduce a new homology theory for these algebraic structures. Further, we study properties of this homology theory and discuss potential applications. (Received September 11, 2016)

1124-57-278 **Lev Rozansky*** (rozansky@math.unc.edu), Chapel Hill, NC 27599, and **Alexei Oblomkov**. *Flag varieties and HOMFLY-PT link homology.*

We construct a homomorphism from the braid group on N strands to a category of $\mathrm{GL}(N)$-equivariant matrix factorizations on the product of $\mathfrak{gl}(N)$ and two copies of the cotangent bundle to a flag variety. Based on this action we construct a triply graded link homology which categorifies the HOMFLY-PT polynomial. This construction is related to the geometric Langlands program and Gukov-Witten defects in Kapustin-Witten Yang-Mills TQFT. We will explain the details of this construction for two-strand torus knots and links. (Received September 11, 2016)

1124-57-296 **Uwe Kaiser*** (ukaiser@boisestate.edu), Department of Mathematics, Boise State University, 1910 University Drive, Boise, ID 83725. *From homotopy to isotopy in hyperbolic 3-manifolds.* Preliminary report.

We study link theory in closed hyperbolic 3-manifolds. In this case homotopy classes of links can be represented by links embedded in tubular neighborhoods of a set of links defined by resolving singularities of unions of prime geodesics. Using the hyperbolic metric we define integral length invariants and other invariants, and study how these relate to oriented skein theory in the 3-manifold. (Received September 12, 2016)

1124-57-307 **Charles D. Frohman** and **Joanna Kania-Bartoszynska*** (jkaniaba@nsf.gov). *Splitting of the Kauffman bracket skein algebra of a punctured surface.*

Kauffman bracket skein algebra of a surface is formed by taking linear combinations of framed links in a cylinder over the surface with complex coefficients, and modding out by the relations that define the Kauffman bracket link invariant. The multiplication comes from stacking one link above the other with the up and down direction given by the interval. We assume that the parameter involved in the Kauffman bracket skein relation is a root of unity. Unless that parameter is equal to 1 or -1 the algebra is non-commutative. We show that the appropriately localized skein algebra of a punctured surface can be split as a tensor product of two commutative sub-algebras. (Received September 12, 2016)

1124-57-326 **Matthew Hedden** (mhedden@math.msu.edu), Department of Mathematics, Michigan State University, D325 WH, East Lansing, MI 48824, and **Miriam Kuzbary*** (miriam.kuzbary@rice.edu), Department of Mathematics, Rice University, 6100 Main St, Houston, TX 77005. *Knotified Link Concordance.*

The knot concordance group has been the subject of much study since its introduction by Ralph Fox and John Milnor in 1966. One might hope to generalize the notion of a concordance group to links; however, the immediate generalization to the set of links up to concordance does not form a group since connected sum of links is not well-defined. In 1988, Jean Yves Le Dimet defined the string link concordance group, where a link is based by a disk and represented by embedded arcs in $D^2 \times I$. In 2012, Andrew Donald and Brendan Owens defined groups of links up to a notion of concordance based on Euler characteristic. However, both cases expand the set of links modulo concordance to larger sets and each link has many representatives in these larger groups. In this talk, I will present joint work with Matthew Hedden where we define a link concordance group based on the the "knotification" construction of Peter Ozsváth and Zoltan Szabó, giving a definition of a link concordance group where each link has a unique group representative. (Received September 12, 2016)

1124-57-329 **Ian M Zemke*** (ianzemke@math.ucla.edu), 520 Portola Plaza, UCLA, Department of Mathematics, Los Angeles, CA 90095. *Link cobordisms and functoriality in link Floer homology.* Preliminary report.

We will describe an approach to defining cobordism maps in link Floer homology. To link cobordisms with decoration, we can define maps on a version of the full link Floer complex, which are invariants up to filtered chain homotopy. In this talk we will discuss some basic examples, and some properties of the maps. (Received September 12, 2016)

1124-57-340 **Michael A Abel*** (maabel@math.duke.edu). *HOMFLY-PT homology of general link diagrams up to braidlike isotopy and its decategorification.*

In the construction of HOMFLY-PT homology, one must start with a link presented as a braid closure. This restriction was expected by Khovanov and Rozansky to be required for the homology to be an isotopy invariant. In this talk we explore the consequences of dropping this requirement and allowing general link diagrams. We explicitly show that the Reidemeister IIb move (where the strands have opposite orientations) fails, and discuss the effect on defining a virtual link invariant. Finally we will show that the Euler characteristic of this homology theory is a deformed version of the HOMFLY-PT polynomial which detects "braidlike" isotopy of tangles and links. This new polynomial agrees with the HOMFLY-PT polynomial on link diagrams which are presented as closed braid diagrams. (Received September 12, 2016)

1124-57-341 **Cagatay Kutluhan**, **Gordana Matic** and **Jeremy Van Horn-Morris***, Department of Mathematical Sciences, 1 University of Arkansas, Fayetteville, AR 72701-1201, and **Andy Wand**. *Incorporating genus into the Heegaard Floer differential.*

Utilizing work of Hutchings, one can incorporate the genus of holomorphic curves into the Heegaard Floer differential of the Honda-Kazez-Matic description of the Heegaard Floer complex associated to an open book decomposition. We will describe how to use this to get an improved contact invariant as well as present a few examples. (Received September 12, 2016)

1124-57-382 **Christopher Scaduto** (cscaduto@brandeis.edu) and **Matthew Stoffregen*** (mstoffregen@math.ucla.edu). *Two-fold Quasi-Alternating Links.*

We introduce a class of links, called "Two-fold Quasi-Alternating Links", strictly containing quasi-alternating links, and 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. This is joint work with Chris Scaduto. (Received September 13, 2016)

1124-57-387 **Chris Cornwell*** (ccornwell@towson.edu), Department of Mathematics, Towson University, 8000 York Road, Towson, MD 21252-0001. *KCH representations: A new point of view.* Preliminary report.

Augmentations in Knot Contact Homology are known to correspond to a certain class of representations of the fundamental group of the knot's complement. The original proof of this correspondence involved constructing these representations algebraically. We will discuss a new interpretation of the representations using linearized contact homology. (Received September 13, 2016)

1124-57-392 **Juanita Pinzon-Caicedo*** (jpinzon@uga.edu), **N. Castro** and **D. Gay**. *Diagrams of Relative Trisections.*

In 2012 Gay and Kirby introduced a new decomposition of 4–manifolds and described diagrams for closed 4–manifolds. In joint work with Gay and Castro, we extended the diagramatic approach to include the relative case. In this talk I will define trisection diagrams for 4–manifolds with boundary, describe a few (families of) examples, and describe a method to recognize the open book decomposition of the boundary from the diagrams themselves. (Received September 13, 2016)

1124-57-406 **Thang Le***, School of Mathematics, Atlanta, GA 30332, and **Jon Paprocki**, School of Mathematics, Atlanta, GA 30332. *Surgery for skein algebras of surfaces.*

We show how the skein algebras of marked surfaces change under surgeries of surfaces. (Received September 13, 2016)

1124-57-412 **Krzysztof K. Putyra** and **Alexander N. Shumakovitch*** (shurik@gwu.edu), 801 22nd St., NW, Phillips Hall, Suite 739, Department of Mathematics, The George Washington University, Washington, DC 20052. *On unified Khovanov homology and its computations.* Preliminary report.

It was shown by Putyra that even and odd Khovanov homology can be combined into a unified Khovanov homology theory. Unified Khovanov homology groups have the structure of modules over the group ring $\mathbb{Z}\mathbb{Z}_2$ which has a pullback presentation. We start by showing that these modules are always separated. As such, they admit algorithmic classification as a direct product of indecomposable $\mathbb{Z}\mathbb{Z}_2$-modules which, in turn, were classified by Levy. This allows one to compare unified Khovanov homology for different knots and links. We present evidence that the unified Khovanov homology is a stronger knot invariant than the even and odd Khovanov homology combined. (Received September 13, 2016)

58 ► Global analysis, analysis on manifolds

1124-58-83 **Xiaolong Han*** (xiaolong.han@csun.edu), Department of Mathematics, California State University, 18111 Nordhoff Street, Northridge, CA 91330. *Global harmonic analysis on compact manifolds.*

Harmonic analysis is the study of the basic harmonics and representation of functions and operators as superpositions of these harmonics. For example, on the torus, the harmonics are Fourier modes and appropriate functions can be written as Fourier series. On general compact manifolds, the harmonics are Laplacian eigenfunctions and they form an orthonormal basis. The analysis of Laplacian eigenfunctions has close relation to geometry of the manifold, particularly its global geometric structure (e.g. symmetry of the torus); global harmonic analysis is the study of the relation between the Laplacian analysis and global geometric structure of the manifold.

I will talk about global harmonic analysis on different manifolds: spheres (positive curvature), tori (zero curvature), and negatively curved manifolds (negative curvature). In each case, we will see how global symmetry, probability, or dynamics of geodesic flow has impact on the oscillation of Laplacian eigenfunctions. We will also apply the analysis of Laplacian eigenfunctions to some other areas and propose future research directions in global harmonic analysis. (Received August 31, 2016)

1124-58-123 **Christopher Sogge*** (sogge@jhu.edu), Baltimore, MD 21093. *On the concentration of eigenfunctions.*

I shall present some results in global harmonic analysis that concern properties of eigenfunctions on compact Riemannian manifolds. (Received September 03, 2016)

1124-58-211 **Boris Hanin*** (bhanin@mit.edu) and **Yaiza Canzani**. *Scaling Limits of Spectral Projectors on a Compact Riemannian Manifold.*

Let (M, g) be a compact smooth Riemannian manifold. This talk concerns new off-diagonal estimates for the remainder in the pointwise Weyl Law. A corollary is that, when rescaled around a non self-focal point, the kernel of the spectral projector of the Laplacian onto the frequency interval $(\lambda, \lambda + 1]$ has a universal scaling limit as lambda goes to ∞ (depending only on the dimension of M). This is joint work with Y. Canzani. (Received September 09, 2016)

1124-58-292 **Yaiza Canzani*** (canzani@email.unc.edu). *Averages of Laplace eigenfunctions over curves.*

In this talk we will discuss conditions on a sequence of Laplace eigenfunctions so that their averages over a given closed curve go to zero as their eigenvalues grows to infinity. We will also discuss the averages of the normal derivatives of the eigenfunctions along the curve. Everything will be done on smooth compact manifolds without boundary. The conditions needed to address these problems are on the defect measure associated to the sequence of eigenfunctions and on how this defect measure behaves near the given curve. This is joint work with John Toth. (Received September 12, 2016)

60 ► Probability theory and stochastic processes

1124-60-50 **John Harlim*** (jharlim@psu.edu), 109 McAllister Bldg, Penn State, University Park, PA 16802. *The Diffusion Forecasting Method.*

I will discuss a nonparametric modeling approach for forecasting stochastic dynamical systems on smooth manifolds embedded in Euclidean space. In the limit of large data, this approach converges to a Galerkin projection

of the semigroup solution of the backward Kolmogorov equation of the underlying dynamics on a basis adapted to the invariant measure. This approach, which we called the "diffusion forecast", allows one to evolve the probability distribution of non-trivial dynamical systems with an equation-free modeling. If time permitted, I will also discuss a semi-parametric modeling framework to compensate for model error by learning an auxiliary dynamical model for the unknown parameters. (Received August 19, 2016)

1124-60-51 **Sixian Jin*** (sixian.jin@cgu.edu), 710 N. College Ave., Claremont, CA 91711. *Dyson type formula for pure jump Lévy processes and applications.* Preliminary report.

In this talk, we obtain a Dyson type formula for pure jump Lévy processes, that is, we represent the conditional expectation of a functional of pure jump Lévy processes as a convergent series in terms of the Malliavin derivatives evaluated along a "frozen path". When the target random variable depends on a discrete trajectory of Lévy processes, this series can be simplified to a backward Taylor expansion. These series representations turn out to be useful for different applications. In particular in Quantitative Finance, we present the application on the option pricing problem of Lévy quadratic model. (Received August 19, 2016)

1124-60-59 **Andrew Brown** (ab7@g.clemson.edu), Clemson, SC 29634, **Arvind Saibaba*** (asaibab@ncsu.edu), Raleigh, NC 27606, and **Sarah Vallelian** (scvallel@ncsu.edu), Raleigh, NC 27606. *Computationally Efficient Markov Chain Monte Carlo Methods for Bayesian Inverse Problems.* Preliminary report.

Many imaging modalities in neuroscience, such as Computer Tomography (CT) and Electroencephalography (EEG) can be described mathematically as inverse problems. To deal with the ill-posedness associated with the inverse problems, we adopt a Hierarchial Bayesian approach, in which we impose a prior distribution on both the unknowns of interest, as well as on the regularization parameters to make inference on the posterior distribution. Much work has been done on computing the maximum a posteriori (MAP) estimate, but to quantify the reconstruction uncertainty, it is desirable to generate samples from this distribution. The standard approach is to use a Markov Chain Monte Carlo sampling method; however, a straightforward implementation may be computationally expensive. We develop a proposal distribution for a Metropolis-Hastings-within-Gibbs algorithm, that is both computationally efficient to sample from, and also has high acceptance rate. We derive theoretical results that shed light into the acceptance rate and discuss an efficient implementation of the sampler. The performance of our algorithms will be demonstrated on simulated examples from neuroimaging applications in EEG and CT. (Received August 24, 2016)

1124-60-103 **Michael Salins*** (msalins@bu.edu), 111 Cummington Mall, Boston, MA 02215, and **Konstantinos Spiliopoulos** (kspiliop@bu.edu), 111 Cummington Mall, Boston, MA 02215. *Rare event simulation via importance sampling for linear SPDEs.*

We develop provably efficient importance sampling methods for estimating rare events for linear stochastic partial differential equations exposed to small noise. We use a spectral method to identify a one-dimensional linear span where the rare event likely occurs and we project our change of measure onto that direction. The scheme we develop works well for a wide variety of different intensities of noise, time horizons, and finite dimensional Galerkin approximations of the infinite dimensional system. Simulations support the theoretical results. (Received August 31, 2016)

1124-60-145 **Jose H. Blanchet*** (jose.blanchet@columbia.edu), 500 W 120th St., Mudd Building, IEOR, 3rd Floor, New York, NY 10027, and **Mike Giles** (mike.giles@maths.ox.ac.uk), Oxford University, Oxford, United Kingdom. *Multilevel Monte Carlo for Spatial Extremes.*

Applications such as weather models call for extrapolation techniques of extremes with spatial dependence. To preserve the standard univariate extreme value theory, one must consider random fields, M, which are characterized by a stochastic fixed point equation involving n i.i.d. (centered and scaled) copies of M. The solution of such fixed point equation is said to be a max-stable field, which can be represented as infinite maxima of randomly weighted i.i.d. copies of a so-called generator. A generator is any random field satisfying mild regularity conditions. For example, a Gaussian random field can serve as a generator, also the solution of a PDE with random input can be used as a generator.

In this talk, after discussing basic properties of max-stable fields, we will show how recently developed Multilevel Monte Carlo methods can be used to estimate sample path expectations of max-stable fields, without any bias, and with the same computational cost which as that of its generator. Simply put, we provide computational tools that make max-stable processes as easy-to-work-with as working with its generator. We discuss max-stable fields generated by stochastic PDEs, for which exact estimation procedures of independent interest are also presented in this talk. (Received September 06, 2016)

1124-60-149 **Katherine A Newhall***, Phillips Hall, Chapel Hill, NC 27599-3250. *Metastability of the Nonlinear Wave Equation.*

I will discuss the long-time dynamics of the nonlinear wave equation in one-space dimension, with stochastic initial data. When the nonlinearity is a double-welled potential, the infinite energy solutions not only preserve a natural Gibbsian invariant measure, they can also display metastability due to the existence of two small disjoint sets that contain most of the system's measure. I will quantify this phenomenon by calculating exactly via transition state theory (TST) the mean frequency at which the solutions cross a dividing surface lying in between the metastable sets. Numerical results suggest that the dynamics of the nonlinear wave equation is ergodic and rapidly mixing with respect to the Gibbs invariant measure when the wave-speed parameter is small enough. For larger parameter values, the dynamics either stops being ergodic, or its mixing time becomes larger than the inverse of the TST frequency, indicating that successive transitions between the metastable sets are correlated and the coarse-graining to a Markov chain fails. (Received September 06, 2016)

1124-60-287 **Kostis Gourgoulias*** (gourgoul@math.umass.edu). *Quantification of the bias in approximate inference via information-theoretical bounds.*

A core problem in statistics and machine learning is the construction of a probability distribution, Q, that approximates another, P. For example, consider the case of approximate inference, with P representing the posterior probability of the parameters. We want to use P to carry out inference but, especially in the case of high-dimensional parameter spaces, normalizing and sampling from the posterior is inefficient. Another option is to construct a mean-field approximation to P, selected by minimizing the Kullback-Leibler divergence over a class of distributions of our choosing. Using samples generated from the optimal Q, we can then estimate quantities of interest, such as the expected value of a parameter, its variance, etc. But how much trust should we place on the accuracy of a given Q?

The goal of our project, done jointly with Markos A. Katsoulakis, Luc Rey-Bellet, and Jie Wang, is to quantify the quality of such approximations, both theoretically and practically. Given an observable f, we provide confidence bounds for the bias, $E_P[f] - E_Q[f]$, via *sharp* information-theoretic inequalities. We expect that such bounds will be applicable in a variety of situations outside of approximate inference. (Received September 12, 2016)

1124-60-360 **Santanu Chakraborty*** (santanu.chakraborty@utrgv.edu), School of Math and Stat Sciences, University of Texas Rio Grande Valley, 1201 West University Drive, Edinburg, TX 78539. *Limit Distributions of Products of I.I.D. Random* 2×2 *Stochastic Matrices: a Special Situation.*

Consider a sequence $(X_n)_{n\geq 1}$ of i.i.d. 2×2 stochastic matrices with each X_n distributed as μ. This μ is described as follows. Let (C_n, D_n) denote the first column of X_n and for a given real r with $0 < r < 1$, let $r^{-1}C_n$ and $r^{-1}D_n$ be each Bernoulli with parameters p_1 and p_2 respectively, $0 < p_1, p_2 < 1$ (which means, $C_n \sim p_1\delta_{\{r\}} + (1-p_1)\delta_{\{0\}}$ and $D_n \sim p_2\delta_{\{r\}} + (1-p_2)\delta_{\{0\}}$). Thus (C_n, D_n) is valued in $\{0, r\}^2$.

Then fact: the weak limit of the sequence μ^n exists whose support is contained in the set of all 2×2 rank one stochastic matrices. We denote the limit distribution of the sequence $X_nX_{n-1}\cdots X_1$ by λ. In a previous article, we considered $0 < r \leq \frac{1}{2}$ and showed that $S(\lambda)$, the support of λ, consists of the end points of a countable number of disjoint open intervals and we calculated the λ-measure of each such point. Then, in a subsequent article, we considered the case $r > \frac{1}{2}$ and obtained some partial results for the special case $r = \frac{\sqrt{5}-1}{2}$ (the reciprocal of the golden ratio). Here we completely solve this special case. (Received September 13, 2016)

1124-60-413 **Henry Lam*** (khlam@umich.edu), Ann Arbor, MI 48109, and **Clementine Mottet** (cmottet@math.bu.edu), Boston, MA 02134. *Rare Event Analysis via Optimization.*

One recurrent issue in extreme event estimation is the limited data size in the tail region of a distribution. Conventional approaches such as extreme value theory, though mathematically justified, may encounter model misspecification issues due to difficulties in the simultaneous control of bias and variance. In this talk, I will present an alternate approach to compute tail quantities of interest. The approach relies on infinite-dimensional optimizations posited over probability distributions, and mitigate the model misspecification issue via suitable shape and moment constraints. I will develop the solution schemes using some tools in modern high-dimensional optimizations. I will numerically compare this approach to extreme value theory, and discuss some implications in rare-event simulation. (Received September 13, 2016)

1124-60-417 **Jonathan C Mattingly***, physics building, science drive, Durham, NC 27701. *Analysis for some numerical methods for sampling stochastic systems both in and out of equalibium.*
I will describe some methods more more efficiently sampling stochastic systems. I will include the analysis of some stratified sampling which which allow one to sample some regions of interest more and in a parallelizable fashion. I may also discuss some hire order methods and approximate sampling methods which improve efficiency. (Received September 14, 2016)

62 ► Statistics

1124-62-42 **Hau-tieng Wu*** (hauwu@math.toronto.edu), **Chen-Yun Lin** and **Arin Minasian**. *Combining Riemannian manifolds embedding and vector nonlocal median to study cytometry.* Preliminary report.
We will discuss the vector nonlocal mean/median, a generalization of the nonlocal mean/median image denoising scheme. Its feasibility is theoretically justified by the finite dimensional embedding theory of connection Laplacian and statistical arguments. In addition to a simulated study, an application to the cytometry will be reported if time permits. (Received August 15, 2016)

1124-62-78 **Edgar Lobaton***, edgar.lobaton@ncsu.edu, and **Qian Ge**. *A Consensus-Based Framework for Image Segmentation using Topological Persistence.* Preliminary report.
It is unlikely for a single algorithm with a fixed set of parameters to segment a group of images successfully due to the broad variety of content that can be present in each image. However, it can be observed that the desired segmentation boundaries are often detected more consistently than other boundaries in the output of state-of-the-art segmentation results. We propose a new approach to capture the consensus of information from a set of segmentations generated by varying parameters of different algorithms. First, a probabilistic model is introduced which captures the likelihood of the discrete combinatorial structure present in a segmentation, as well as the variability of a specific segmentation as bounded perturbations of their boundaries. This model is used to construct a disconnectivity probability map which identifies the likelihood of having a segmentation boundary present in a small neighborhood. A formal analysis illustrates the conditions under which we can recover a covering set for the boundaries of a good segmentation from this probability map. In order to identify some candidates for good segmentations from real images, we analyze the level-sets of the disconnectivity probability map using tools from topological persistence. (Received August 29, 2016)

1124-62-156 **J. A. De la Cruz** (jdelacruz@barry.edu), Dept. of Math. Comp. Sc., Barry University, 11300 N. E. Second Avenue, Miami Shores, FL 33161, **Jai N. Singh*** (jsingh@barry.edu), Dept. of Math. Comp. Sc., Barry University, 11300 N. E. Second Avenue, Miami Shores, FL 33161, and **Mohammad Shakil** (mshakil@mdc.edu), Department of Mathematics Miami-Dade College, Hialeah Campus, Hialeah, FL 33012. *Some Remarks on the Convexity of the Shakil-Kibria-Singh Distribution.*
In this paper, we investigate the conditions for the convexity and the logarithmic convexity of the probability density function (PDF) of the Shakil-Kibria-Singh (SKS) distribution. We also, establish a relation between the median of the Gamma distribution and the median of Shakil-Kibria-Singh(SKS) distribution and use this relation for proving the convexity of the median of the Shakil-Kibria-Singh distribution. (Received September 06, 2016)

1124-62-259 **Tingran Gao*** (trgao10@math.duke.edu), Department of Mathematics, Duke University, Durham, NC 27707. *The Diffusion Geometry of Shape Spaces.*
Kernel-based non-linear dimensionality reduction methods, such as Local Linear Embedding (LLE) and Laplacian Eigenmaps, rely heavily upon pairwise distances or similarity scores, with which one can construct and study a weighted graph associated with the data set. When each individual data object carries structural details, the correspondence relations between these structures provide additional information that can be leveraged for studying the data set using the graph. In this talk, we will introduce the framework of Horizontal Diffusion Maps (HDM), a generalization of Diffusion Maps in manifold learning. This framework models a data set with pairwise structural correspondences as a fibre bundle equipped with a connection. We further demonstrate the advantage of incorporating such additional information and study the asymptotic behavior of HDM on general fibre bundles. In a broader context, HDM reveals the sub-Riemannian structure of high-dimensional data sets, and provides a nonparametric learning framework for data sets with structural correspondences. We will also discuss some applications of HDM arising from the emerging field of automated geometric morphometrics. (Received September 11, 2016)

1124-62-331 **Lek-Heng Lim** (lekheng@galton.uchicago.edu) and **Jose Israel Rodriguez*** (joisro@uchicago.edu). *Introducing the GMM degree.*

In econometrics, the generalized method of moments (GMM) combines data with population moment conditions to estimate the unknown population parameters. For Pearson's classic method of moments, one determines the common root(s) of n nonlinear polynomials, called cost functions, where n is the number of population parameters. In GMM, one can have more cost functions than population parameters. To account for this, the common root condition is replaced by minimizing a positive definite quadratic form of cost functions. The quadratic form may have multiple local minima. However, the number of local minima of the quadratic form is bounded above by the GMM degree, a generalization of maximum likelihood and method of moments degree. (Received September 12, 2016)

65 ► Numerical analysis

1124-65-15 **Eka Oche Ogbaji***, Department of Mathematics and Statistics, Federal university Wukari, Wukari, **E.S Onah**, Department of Maths/Stat/Comp.Sc, and **A.R Kimbir**. *Simplified Stochastic Runge-Kutta (SSR-K) scheme for a Stock Market Model.*

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)

1124-65-32 **Jia Zhao*** (zhaojia@email.unc.edu), 3250 Phillips Hall, PH324J, Chapel Hill, NC 27599, and **Qi Wang** (qwang@math.sc.edu). *On Energy-stable Schemes for Complex-fluid Models.*

Complex fluids are fluids whose micro-structure have impact on the fluid macroscopic properties, which include complex fluid mixtures of different types. In this talk, I will first present a systematic development of a general hydrodynamic model for complex fluid system using the generalized Onsager relation. Then, a semi-discrete scheme to solve this general model, which satisfies the discrete energy dissipation law, will be presented. Specific tricks on linearizing and decoupling the schemes will be presented for particular reduced models. In the end, several 3D simulations will be shown to illustrate the effectiveness of our schemes. (Received August 06, 2016)

1124-65-35 **Puja Rattan*** (prattan@uncc.edu) and **Dr. Hae Soo Oh** (hso@uncc.edu). *Enrichment and multi-iterative approaches in the framework of IGA collocation to deal with elliptic PDEs containing singularities.* Preliminary report.

In this talk, we present two different approaches to solve PDEs with singularities using IGA collocation method. Since collocation reduces the cost and time taken in integrating each element of the stiffness matrix therefore by using these methods we can optimize the computational cost and also take the advantage of geometrical flexibility and accuracy of IGA method.

First approach is to modify basis functions using partition unity functions. Then the neighborhood of singularity will be enriched by these modified basis functions so that they can capture the singular behavior of the solution. Second approach is to use multi-iterative domain decomposition technique to handle singularity. This technique has been applied to problems using overlapping as well as non-overlapping domains. Numerical results for both proposed methods are presented and compared with the results obtained by IGA-galerkin method. (Received August 09, 2016)

1124-65-37 **Xiaobing Feng**, **Michael Neilan** and **Stefan Schnake*** (schnake@math.utk.edu). *Interior Penalty Discontinuous Galerkin Finite Element Methods for Linear Elliptic PDEs in Non-divergence Form.* Preliminary report.

This talk will focus on discontinuous Galerkin methods to approximate strong solutions for linear elliptic PDEs in non-divergence form whose coefficients are only continuous. These PDEs present themselves in the nonlinear Hamilton-Jacobi-Bellman equations, which have applications in stochastic optimal control and mathematical finance, as well as the linearization of the Mange-Amprere equations. We introduce a few interior penalty, discontinuous Galerkin, finite element methods which are simple in construction. The highlight of the talk will

be to show the stability of these methods through a discrete Calderon-Zygmund estimate. Several numerical tests will be shown towards the end of the talk. (Received August 10, 2016)

1124-65-47 **Ricardo Cortez*** (rcortez@tulane.edu). *Mathematical and Computational Modeling of Microorganism Swimming.*

Microscopic swimmers like bacteria and spermatozoa live in highly viscous environments. Their locomotion and the fluid flows they generate around them have been actively investigated for the last 60 years motivated by questions about effective locomotion strategies, the organism's interaction with the surrounding environment, patterns of collective motion, propulsion, and more. These issues are typically addressed through a combination of theory, experiments, mathematical modeling and simulation. I will describe the method of regularized Stokeslets, a computational technique based on fundamental solutions of PDEs designed for simulating these viscous flows, and will present recent collaborative mathematical work, some of it done with undergraduate students, that sheds light on these biological systems and challenges ahead. (Received August 18, 2016)

1124-65-48 **Deanna Needell*** (dneedell@cmc.edu), 850 Columbia Ave, Claremont, CA 91711, and **Rachel Ward**. *Batched Stochastic Gradient Descent with Weighted Sampling.*

We analyze a batched variant of Stochastic Gradient Descent (SGD) with weighted sampling distribution for smooth and non-smooth objective functions. We show that when the batches can be distributed computationally that a significant speedup in the convergence rate is possible. We propose several computationally efficient schemes to approximate the optimal weights, and compute the proposed sampling distribution for the least-squares and hinge loss problems. We show both analytically and experimentally that substantial gains can be obtained using this hybrid approach. (Received August 18, 2016)

1124-65-54 **Bongsoo Jang**, **Hyunju Kim** and **Hae-Soo Oh*** (hso@uncc.edu), 9201University City Boulevard, Charlotte, NC 28223, and **Sinae Kim**. *Partition of unity isogeometric analysis of two dimensional elliptic singular perturbation problems.*

The design basis functions on the reference domain in IGA are diversified and enhanced by extra enrichment functions and various local refinements with the use of partition of unity function with flat-top. These reconditioned and modified basis functions are pushed forward to the physical domain by the original design mapping for analysis. With this method, the corresponding stiffness matrix has a small bandwidth and local refinement is simple. Moreover, we construct the partition of unity functions in the reference domain and then move them to a physical domain through a geometric mapping to be used for the generation of global basis functions on a physical domain. Therefore, we also have several advantages in calculating stiffness matrices and load vectors. Here we apply this method to various boundary layer problems. (Received August 22, 2016)

1124-65-60 **Sinae Kim**, **Hae-Soo Oh**, **Birce Palta*** (pbirce@uncc.edu) and **Hyunju Kim**. *B-Spline basis functions modified through partition of unity with flat-top for numerical solutions of biharmonic equations containing singularities.*

Using Partition of unity (PU) functions with flat-top, we modify B-spline functions to satisfy boundary conditions of biharmonic equations. Since the standard isogeometric analysis (IGA) has limitations to deal with biharmonic equations containing singularities, we consider enrichment methods in the framework of the p-, the k, and the h-refinements of IGA. In this talk, we demonstrate that these enriched IGA yield good approximate solutions, but they have large (almost singular) matrix condition numbers. To alleviate these limitations, we propose a mapping method to deal with singularity. To show the effectiveness of the proposed mapping method, we also compare the accuracy, the number of degrees of freedom (DOF), and condition numbers for the p-refinement, the h-refinement, and the k-refinement of IGA combined with PU with flat-top. The proposed mapping method is tested to one-dimensional singular problems and extended this method for two-dimensional biharmonic equation on cracked domain. (Received August 25, 2016)

1124-65-62 **Cody S Lorton*** (clorton@uwf.edu), Pensacola, FL 32514. *A Posteriori Error Estimates Applied to Unconditionally Stable IPDG Methods for the Helmholtz Equation.* Preliminary report.

Unconditionally stable interior penalty discontinuous Galerkin (IPDG) methods for the Helmholtz equation were developed and analyzed by X. Feng and H. Wu (2009, 2014). In this talk, we discuss the performance of residual-based a posteriori error estimates applied to this class of IPDG methods. Numerical experiments are included to demonstrate key features. (Received August 26, 2016)

1124-65-87 **Jonathan D Hauenstein*** (hauenstein@nd.edu), 152C Hurley Hall, University of Notre Dame, Notre Dame, IN 46556, and **Heather Harrington**, **Helen Byrne** and **Dhagash Mehta**. *Decomposing the parameter space.*

Many systems in applications can be described by systems of ordinary differential equations containing large numbers of parameters. When studying the dynamic behavior of these large, nonlinear systems, it is useful to identify and characterize the steady-state solutions as the model parameters vary, a technically challenging problem in a high-dimensional parameter landscape. Rather than simply determining the number and stability of steady-states at distinct points in parameter space, we decompose the parameter space into finitely many regions, the number and structure of the steady-state solutions being consistent within each distinct region. From a computational algebraic viewpoint, the boundary of these regions is contained in the discriminant locus. We develop global and local numerical algorithms for constructing the discriminant locus and classifying the parameter landscape. We showcase our numerical approaches by applying them to molecular and cell-network models. (Received August 30, 2016)

1124-65-126 **Zhu Wang*** (wangzhu@math.sc.edu), Department of Mathematics, University of South Carolina, Columbia, SC 29208. *Structure-Preserving Galerkin POD Reduced-Order Modeling of Hamiltonian Systems.*

The proper orthogonal decomposition reduced-order models (POD-ROMs) have been widely used as a computationally efficient surrogate models in large-scale numerical simulations of complex systems. However, when it is applied to a Hamiltonian system, a naive application of the POD method can destroy its Hamiltonian structure in the reduced-order model. In this talk, we develop a new reduce-order modeling approach for the Hamiltonian system, which uses the traditional framework of Galerkin projection-based model reduction but modifies the ROM so that the appropriate Hamiltonian structure is preserved. We develop a rigorous a priori error estimate of the new ROM and demonstrate its effectiveness in several numerical examples. This approach can be readily extended to dissipative Hamiltonian systems, port-Hamiltonian systems etc. (Received September 05, 2016)

1124-65-150 **Xingjie Helen Li*** (xli47@uncc.edu), **Chi-Wang Shu** and **Yang Yang**. *Local discontinuous Galerkin method for the Keller-Segel chemotaxis model.*

In this paper, we apply the local discontinuous Galerkin (LDG) method to 2D Keller–Segel (KS) chemotaxis model. We improve the results upon (Y. Epshteyn and A. Kurganov,SIAM Journal on Numerical Analysis, 47 (2008), 368-408) and give optimal rate of convergence under special finite element spaces. Moreover, to construct physically relevant numerical approximations, we develop a positivity-preserving limiter to the scheme, extending the idea in (Y. Zhang, X. Zhang and C.-W. Shu, Journal of Computational Physics, 229 (2010), 8918-8934). With this limiter, we can prove the L1-stability of the numerical scheme. Numerical experiments are performed to demonstrate the good performance of the positivity-preserving LDG scheme. Moreover, it is known that the chemotaxis model will yield blow-up solutions under certain initial conditions. We numerically demonstrate how to find the numerical blow-up time by using the L2 norm of the L1-stable numerical approximations. (Received September 06, 2016)

1124-65-181 **Timo Heister**, **Muhammad Mohebujjaman*** (mmohebu@g.clemson.edu) and **Leo G. Rebholz**. *Efficient Numerical Methods for Magnetohydrodynamics Flow.*

Firstly we propose, analyze, and test a θ-timestepping-method for MHD which decouples the system into two Oseen problems at each timestep, yet maintains unconditional stability with respect to the time step size. The proposed method chooses $\theta \in [0,1]$, dependent on the viscosity ν and magnetic diffusivity ν_m, so that unconditionally stability is achieved and gives temporal accuracy $O(\Delta t^2 + (1-\theta)|\nu - \nu_m|\Delta t)$. In practice ν and ν_m are small, and so the method behaves like second order. We show the θ-method provides excellent accuracy in cases where usual BDF2 is unstable. We also proposed another algorithm for computing flow ensembles under uncertainties in initial or boundary data. The ensemble average of J realizations is approximated through a clever algorithm that, at each time step, uses the same matrix for each of the J system solves. Hence, preconditioners need built only once per time step, and the algorithm can take advantage of block linear solvers. Additionally, an Elsässer variable formulation is used, which allows for a stable decoupling of each MHD system at each time step. We prove stability and convergence of the algorithm, and test it with two numerical experiments. (Received September 07, 2016)

1124-65-202 **Anton Leykin**, **Jose I Rodriguez** and **Frank Sottile*** (sottile@math.tamu.edu), Department of Mathematics, Texas A&M University, TAMU-3368, College Station, TX 77840-3368. *Trace Test.*

We give a brief derivation of the trace test to verify completeness of a witness set of an irreducible variety in affine or projective space. We then consider the trace test for subvarieties of products of projective spaces working with multihomogeneous witness sets. We show how a dimension reduction based on Bertini's Theorem leads to a practical trace test in this case involving a curve in a small-dimensional affine space. (Received September 08, 2016)

1124-65-205 **Jianfeng Lu** and **Zhennan Zhou*** (zhennan@math.duke.edu), 120 Science Drive, Durham, NC 27708-0320. *Towards a mathematical understanding of surface hopping methods.*

We develop a surface hopping algorithm based on frozen Gaussian approximation for semiclassical matrix Schrödinger equations. The algorithm is asymptotically derived from the Schrödinger equation with rigorous approximation error analysis. The resulting algorithm can be viewed as a path integral stochastic representation of the semiclassical matrix Schrödinger equations. Our results provide mathematical understanding to and shed new light on the important class of surface hopping methods in theoretical and computational chemistry. Also, I would like to report our recent progress on the improved surface hopping algorithm with various numerical tests. (Received September 08, 2016)

1124-65-212 **Amanda E Diegel*** (adiegel@lsu.edu), 2009 Stanford Avenue, Baton Rouge, LA 70808, and **Steve Wise**, **Cheng Wang** and **Xiaoming Wang**. *A Second Order in Time Finite Element Scheme for the Cahn-Hilliard-Navier-Stokes Equation.*

We present a novel second order in time mixed finite element scheme for the Cahn-Hilliard-Navier-Stokes equations with matched densities. The scheme combines a standard second order Crank-Nicholson method for the Navier-Stokes equations and a modification to the Crank-Nicholson method for the Cahn-Hilliard equation. In particular, a second order Adams-Bashforth extrapolation and a trapezoidal rule are included to help preserve the energy stability natural to the Cahn-Hilliard equation. We show that our scheme is unconditionally energy stable with respect to a modification of the continuous free energy of the PDE system. Specifically, the discrete phase variable is shown to be bounded in $\ell^\infty(0,T;L^\infty)$ and the discrete chemical potential bounded in $\ell^\infty\left(0,T;L^2\right)$, for any time and space step sizes, in two and three dimensions, and for any finite final time T. We subsequently prove that these variables along with the fluid velocity converge with optimal rates in the appropriate energy norms in both two and three dimensions. (Received September 09, 2016)

1124-65-227 **Qi Wang*** (qwang@math.sc.edu), Dept of Math, Columbia, SC 29063-9297, **Xueping Zhao**, Dept of Math, Columbia, SC 29208, and **Jia Zhao**, Chapel Hill, NC 27599. *Active matter models and their applications to cell motility.*

Active matter includes cytoskeleton of an eukaryotic cell. Modeling and simulation of active matter is an emerging research field. Models at microscopic, mesoscipic and macroscopic scales have been developed to study the active matter system. In this talk, I will give an overview on how to derive active matter models using the generalized Onsager principle. Then, I will discuss a simple active model and its mathematical properties when applied to simple geometries. Then, I will present some multiphase field models for cell motility. Numerical treatment of the models and predictions will be discussed as well. (Received September 09, 2016)

1124-65-253 **Lei Li*** (leili@math.duke.edu), 120 Science Drive, Durham, NC 27708, and **Jianguo Liu**. *Filtered Fourier method for Euler drops under a conformal mapping formulation.*

The Euler equations for a drop without gravity are closely related to optimal transformation. We then find a conformal mapping formulation for them. The filtered-Fourier method is developed for this formulation. The stability and convergence for small perturbation is proved with surface tension being present. Several numerical examples have been performed to verify our analysis. (Received September 11, 2016)

1124-65-279 **Susanne C Brenner** (brenner@math.lsu.edu), Department of Mathematics, Center for Computation and Technology, Louisiana State University, Baton Rouge, LA 70803, **Christopher B Davis*** (cbdavis@tntech.edu), Department of Mathematics, Tennessee Technological University, Cookeville, TN 38505, and **Li-yeng Sung** (sung@math.lsu.edu), Department of Mathematics, Center for Computation and Technology, Louisiana State University, Baton Rouge, LA 70803. *A two level additive Schwarz domain decomposition preconditioner for a partition of unity method.*

In this talk, we investigate the use of a two level additive Schwarz domain decomposition preconditioner applied to a partition of unity method as it is applied to the biharmonic problem. The numerical algorithm will be

presented and analyzed and numerical examples will be given to demonstrate the effectiveness of the method. (Received September 11, 2016)

1124-65-285 **Dinh-Liem Nguyen*** (dnguye70@uncc.edu), **Michael Klibanov**, **Loc Nguyen**, **Aleksandr Kolesov**, **Michael Fiddy** and **Hui Liu**. *A globally convergent numerical method for an inverse scattering problem with multi-frequency data.*

We consider the inverse problem of determining the spatially distributed dielectric constant of three-dimensional scattering objects from experimental multi-frequency data corresponding to a single incident wave. The challenges for the inverse problem under consideration are not only from its nonlinearity and high ill-posedness but also from the fact that the experimental data have a huge misfit with data obtained in simulations. We present in this talk how the raw data can be preprocessed and successfully inverted using a globally convergent numerical method. More precisely, we are able to reconstruct the dielectric constant of the scattering medium with a reasonable accuracy as well as its geometric information such as location and size without using any detailed a priori knowledge of physical and geometrical properties of the medium. We note that the latter feature is the essential difference between our globally convergent approach and nonlinear optimization approaches, which are often referred to as locally convergent methods for inverse problems. (Received September 12, 2016)

1124-65-300 **Catherine Payne*** (capayne2@uncg.edu) and **Richard Fabiano**. *Approximation of linear neutral delay differential equations.* Preliminary report.

We consider semidiscrete approximation of a linear neutral delay differential equation of the form

$$\frac{d}{dt}\left[x(t)+\sum_{k=1}^{n} C_k x(t-r_k)\right] = Ax(t)+\sum_{k=1}^{n} B_k x(t-r_k)$$

with appropriate initial data. We assume that A, $B_1, B_2, \ldots, B_n$ and $C_1, C_2, \ldots, C_n$ are complex $m \times m$ matrices. We reformulate the neutral equation as an abstract Cauchy problem $\dot{z}(t) = \mathcal{A}z(t)$ and discuss the construction of an approximation scheme which yields convergence for both the operator $\mathcal{A}$ and its adjoint. This property is needed in some control problems. Finally, we discuss some examples to compare this result with existing approximation schemes. (Received September 12, 2016)

1124-65-324 **Paul Sinz*** (psinz1@lsu.edu), Louisiana State University, Department of Mathematics, 304 Lockett Hall, Baton Rouge, LA 70803-4918, and **Robert Lipton** and **Michael Stuebner**. *Multiscale GFEM for High Contrast Suspensions Using Optimal Local Basis Functions.* Preliminary report.

We evaluate a multiscale GFEM using optimal spectral basis functions developed in recent work by I. Babuska, R. Lipton, and X. Huang. This method is applied to compute local fields inside high contrast particle suspensions. We evaluate the method's performance for various examples with different contrasts between reinforcement particles and matrix material. For suspensions of particles with a minimum distance between neighboring particles the numerical experiments agree with new theoretical estimates that show the convergence rate is exponentially decreasing and independent of the elastic properties of particles and matrix materials. (Received September 12, 2016)

1124-65-332 **Slimane Adjerid*** (adjerids@vt.edu), Virginia Tech, Department of Mathematics, MC 0123, 225 Stanger St. 460 McBryde Hall, Blacksburg, VA 24060, and **Tao Lin**, **Nabil Chaabane** and **Kihyo Moon**. *High Order Immersed Finite Element Methods for Interface Problems.*

In this presentation we will give an overview of recent advances in immersed continuous and discontinuous finite methods for interface problems modeled by partial differential equations. We will discuss extensions of immersed finite element spaces and methods to obtain high order approximations of solutions for problems with curved interfaces. We will present results for linear elasticity, Stokes flow and wave propagation problems. (Received September 12, 2016)

1124-65-349 **Evan Gawlik** and **Melvin Leok*** (mleok@ucsd.edu). *Interpolation on Symmetric Spaces via the Generalized Polar Decomposition.*

We construct interpolation operators for functions taking values in a symmetric space – a smooth manifold with an inversion symmetry about every point. Key to our construction is the observation that every symmetric space can be realized as a homogeneous space whose cosets have canonical representatives by virtue of the generalized polar decomposition – a generalization of the well-known factorization of a real nonsingular matrix into the product of a symmetric positive-definite matrix times an orthogonal matrix. By interpolating these canonical

coset representatives, we derive a family of structure-preserving interpolation operators for symmetric space-valued functions. As applications, we construct interpolation operators for the space of Lorentzian metrics, the space of symmetric positive-definite matrices, and the Grassmannian. In the case of Lorentzian metrics, our interpolation operators provide a family of finite elements for numerical relativity that are frame-invariant and have signature which is guaranteed to be Lorentzian pointwise. We illustrate their potential utility by interpolating the Schwarzschild metric numerically. (Received September 13, 2016)

68 ► Computer science

1124-68-299 **Mireille Boutin*** (mboutin@purdue.edu), School of ECE, 465 Northwestern Avenue, West Lafayette, IN 47907. *The Unexpected Geometry of "Real" High-Dimensional Data.* Preliminary report.

We describe a surprising property of high-dimensional data sets, which we first observed while studying large sets of images and subsequently found in many other "real" data sets as well. Our observations suggest that real high-dimensional data sets have a tremendous amount of structure, so much so that a mere projection onto a random 1D subspace of the data space is likely to uncover some of that structure. This has important implications in the area of automatic recognition and database indexing. For example, we have developed an ultra-fast method based on random 1D projections for clustering a high-dimensional data set. We have also developed methods for automatic recognition of patterns; the random heuristic behind these methods is very simple, yet they can lead to very accurate results. Building on these simple heuristics, we proposed pattern recognition benchmarks that can be used to determine if an automatic classifier with a pre-determined error rate can be obtained from a given training dataset without the need to use any sophisticated method such as support vector machines or deep neural networks.

This work is in collaboration with my graduate student Sangchun Han (now at Google) and Tarun Yellamraju. (Received September 12, 2016)

1124-68-322 **Marc Niethammer*** (mn@cs.unc.edu), Department of Computer Science, Campus Box 3175, Sitterson Hall, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599-3175. *Predictive Image Registration.* Preliminary report.

Image registration is an important tool in image analysis to spatially align pairs of images. For example, in medical image analysis, registrations to a common atlas space are frequently computed to provide a spatial reference frame for population-based analyses. Image registration approaches are typically based on a suitable model of deformation and a measure for image similarity. Deformation models range from simple affine transformations to general diffeomorphic transformations, allowing for fine-grained local deformations of space. While diffeomorphic transformations are often desired they may be costly compute. For example, while the large displacement diffeomorphic metric mapping (LDDMM) model results in diffeomorphic transformations it requires the optimization over high-dimensional spaces. This talk will therefore focus on how to learn regression models to predict deformations between images quickly. (Received September 12, 2016)

70 ► Mechanics of particles and systems

1124-70-122 **Mark Levi*** (levi@math.psu.edu), Mathematics Department, Penn State University, University Park, PA 16870, and **Graham Cox**. *Gaussian curvature and the gyroscopic effect.* Preliminary report.

I will give a brief description of the connection between the the gyroscopic effect and Gaussian curvature. In particular, Gaussian curvature appears in the equations of motion of the Lagrange top, as a very special example of a more general phenomenon. This is based on our joint work with Graham Cox. (Received September 03, 2016)

1124-70-284 **Dmitry V. Zenkov*** (dvzenkov@ncsu.edu), **Donghua Shi**, **Yakov Berchenko-Kogan** and **Anthony M. Bloch**. *Infinite-Dimensional Constrained Mechanics.*

Constraints in infinite-dimensional mechanics typically appear as velocity constraints (incompressibility, electromechanical constraints, etc). This talk will introduce a rather universal formalism for studying such systems. Dynamics of constrained flexible solids will illustrate the theory. (Received September 12, 2016)

76 ► Fluid mechanics

1124-76-385 **Christiaan F Ketelaar*** (ketelaar@udel.edu), 11 Thorn Ln, Apt 6, Newark, DE 19711, and **Lan Zhong** and **R J Braun**. *Mathematical Modeling of Blob-Driven Tear Film Breakup.* Preliminary report.

Tear film break up (TBU) can occur after imperfections in the lipid layer arise. The imperfections may cause elevated evaporation, which causes TBU for large enough spots and grooves and for fast enough evaporation. TBU also occurs near smaller features in the lipid layer. These are apparently blobs of lipids that do not spread and which are too small for the evaporative mechanism to account for the dynamics. We investigate the tear film dynamics near a model rigid blob with a fixed constant surfactant concentration. We develop the lubrication-type equations that govern the tear film thickness, surfactant concentration, and osmolarity in the tear film beneath and near the blob. We perform numerical simulations for the evolution of the tear film thickness and analyze how the size of the blob, as well as the surfactant properties and transport, affect tear film dynamics. The thinning induced by the blob is of the correct time scale to compare with in vivo observations, and close comparison with the experiments will be made. (Received September 13, 2016)

80 ► Classical thermodynamics, heat transfer

1124-80-355 **François Gay-Balmaz*** (gaybalma@lmd.ens.fr), LMD Ecole Normale Supérieure, 24, Rue Lhomond, 75005 Paris, France, and **Hiroaki Yoshimura**. *A variational Lagrangian formulation for nonequilibrium thermodynamics.*

We present a Lagrangian variational formulation for nonequilibrium thermodynamics. This formulation extends the Hamilton principle of classical mechanics to include irreversible processes in both discrete and continuum systems. The irreversibility is encoded into a nonlinear nonholonomic constraint given by the expression of entropy production associated to the irreversible processes involved. The introduction of the concept of thermodynamic displacement allows the definition of a corresponding variational constraint. We also present the geometric structures underlying nonequilibrium thermodynamics. We illustrate our theory with both finite and infinite dimensional examples, including mechanical systems with friction, chemical reactions, electric circuits, and reacting fluids. (Received September 13, 2016)

81 ► Quantum theory

1124-81-147 **Abhijit Gadde** and **Pavel Putrov*** (putrov@ias.edu). *Exact solutions of N=(0,2) 2d Landau-Ginzburg models.*

In my talk I will present a few families of 2d Landau-Ginzburg models with N=(0,2) supersymmetry for which the conformal field theory at the IR fixed point can be explicitly identified. (Received September 06, 2016)

1124-81-153 **Michele Del Zotto***, Simons Center for Geometry and Physics, State University of New York, Stony Brook, NY 11794-3636, and **Guglielmo Lockhart**. *On Exceptional Instanton Strings.*

There are only six "pure" 6d gauge theories which have a superconformal UV completion. The corresponding gauge groups are $SU(3)$, $SO(8)$, F_4, E_6, E_7, and E_8. These exceptional models have BPS strings which are also instantons for the corresponding gauge groups. The ADHM construction, however, does not capture the corresponding worldsheets. For G simply-laced, we determine the 2d $\mathcal{N} = (0, 4)$ worldsheet theories of such BPS instanton strings by a simple geometric engineering argument. These are given by a twisted S^2 compactification of well-known families of non-lagrangian 4d $\mathcal{N} = 2$ SCFTs, where the 6d instanton number is mapped to the rank of the corresponding 4d SCFT. This determines their anomaly polynomials and, via topological strings, establishes an interesting relation among the corresponding $T^2 \times S^2$ partition functions and the Hilbert series for moduli spaces of G instantons. Such relations allows to "bootstrap" the corresponding elliptic genera by modularity. As an example of such procedure, the elliptic genera of the one-instanton strings are determined. As an aside, these results unveil a rather surprising relation with the Schur index of the corresponding 4d $\mathcal{N} = 2$ models. (Received September 06, 2016)

1124-81-162 **Iana I. Anguelova*** (anguelovai@cofc.edu), Department of Mathematics, College of Charleston, 66 George Street, SC 29424. *The two bosonizations of the CKP hierarchy.* Preliminary report.

Although instances of bosonization are rare (the best known is the bosonization of the charged free fermions related to the KP hierarchy), there is not one, but two bosonizations connected to the CKP hierarchy. In this talk I will present the second bosonization, via an untwisted Heisenberg algebra. I will discuss the resulting relations to various (twisted) vertex algebras and applications to the symmetries of the CKP hierarchy. (Received September 06, 2016)

1124-81-172 **Clay Cordova**, 1 Einstein Dr., Princeton, NJ 08540, and **Shu-Heng Shao***, 1 Einstein Dr., Princeton, NJ 08540. *Superconformal Indices, BPS Particles, and Chiral Algebras.*

We conjecture a precise relationship between the Schur limit of the superconformal index of four-dimensional N=2 field theories, which counts local operators, and the spectrum of BPS particles on the Coulomb branch. We verify this conjecture for the special case of free field theories, N=2 QED, and SU(2) gauge theory coupled to fundamental matter. Assuming the validity of our proposal, we compute the Schur index of all Argyres-Douglas theories. Our answers match expectations from the connection of Schur operators with two-dimensional chiral algebras. (Received September 07, 2016)

1124-81-234 **Oscar Chacaltana*** (chacaltana@ift.unesp.br), Charles St, Baltimore, MD 21218. *Defects of the 6D (2,0) theories and class-S theories of type E.*

We describe properties of the defects of the 6D (2,0) theories in the context of their compactification on Riemann surfaces. Some of these physical properties have interesting counterparts in the theory of nilpotent orbits. As an application, we construct examples of class-S (4D $\mathcal{N} = 2$) superconformal theories of type E. (Received September 10, 2016)

1124-81-345 **Tomoki Ohsawa*** (tomoki@utdallas.edu), 800 W Campbell Rd, Richardson, TX 75080-3021. *Geometry and Dynamics of Gaussian Wigner Functions.*

I will talk about how to exploit geometry to relate the dynamics of the Gaussian wave packet (wave function) with that of the corresponding Gaussian Wigner function. The key geometric fact is that the momentum map corresponding to the action of the symplectic group $\mathsf{Sp}(2d, \mathbb{R})$ on the Siegel upper half space gives rise to the covariance matrix of the Gaussian Wigner function. As a result, the momentum map provides a bridge between the symplectic/Hamiltonian structures of the two dynamics. This is a joint work with Cesare Tronci. (Received September 12, 2016)

90 ► Operations research, mathematical programming

1124-90-152 **Jai N. Singh*** (jsingh@barry.edu), Dept. of Math. and Comp. Sc., Barry University 11300 N. E. Second Avenue, Miami Shores, FL 33161. *Curvature of the Central-Path and the Iteration Complexity of Linear Optimization.*

In this paper, we discuss various measures for the curvature of the central path in linear optimization and use Sonnevend curvature of the central path and its integral to obtain a measure of the iteration complexity of the interior-point methods in Linear Optimization. (Received September 06, 2016)

1124-90-222 **Tao Pang** and **Cagatay Karan*** (ckaran@ncsu.edu). *A Black Litterman Model With Conditional Value At Risk Optimization.*

The Black Litterman Model (BLM) has contributed to modern portfolio theory a new perspective where the investor views and market equilibrium expected excess returns are combined in a Bayesian manner to get the optimal portfolio. We use the Conditional Value at Risk (CVaR) instead of variance as the risk measure. In addition to that, elliptical uncertainty sets are used to model uncertainty of asset returns in order to capture the non-normal behavior of the asset returns. For constrained problem, deriving the optimal solution analytically is extremely difficult. Hence, we propose an efficient algorithm for the BLM type optimization problems under CVaR and we have established the convergence results. (Received September 09, 2016)

1124-90-245 **Diego Cifuentes*** (diegcif@mit.edu), 77 Massachusetts Avenue, Office 32-D760, Cambridge, MA 02139, and **Pablo A Parrilo**. *Sampling Algebraic Varieties for Sum-Of-Squares Programs.*

We study sum of squares (SOS) relaxations to optimize polynomial functions over a set $\mathcal{V} \cap \mathbb{R}^n$, where $\mathcal{V}$ is a complex algebraic variety. We propose a new methodology that, rather than relying on some algebraic

description, represents $\mathcal{V}$ with a generic set of complex samples. This approach depends only on the geometry of $\mathcal{V}$, avoiding representation issues such as multiplicity and choice of generators. It also takes advantage of the dependencies in the coordinate ring of $\mathcal{V}$ to reduce the size of the corresponding semidefinite program (SDP). Our methods are particularly appealing for varieties which are easy to sample from but for which the defining equations are complicated, such as $SO(n)$, Grassmannians or rank k tensors. Nonetheless, for arbitrary varieties we can obtain the samples by using the tools of numerical algebraic geometry. In this way we connect the areas of SOS optimization and numerical algebraic geometry. (Received September 10, 2016)

1124-90-330 **Mert Gurbuzbalaban***, Rutgers University, Piscataway, NJ. *Randomized Incremental Methods for Additive Convex Cost Optimization.*

Motivated by machine learning problems over large data sets and distributed optimization over networks, we consider the problem of minimizing the sum of a large number of convex functions. We develop and study randomized and deterministic incremental methods for solving such problems, in particular for the random reshuffling method we provide a sharp convergence rate result which answers an open question. This is joint work with Asu Ozdaglar and Pablo Parrilo. (Received September 12, 2016)

91 ► Game theory, economics, social and behavioral sciences

1124-91-108 **P. Jameson Graber*** (jameson_graber@baylor.edu), One Bear Place #97328, Ione Drive, Waco, TX 76798. *Linear Quadratic Mean Field Type Control and Mean Field Games with Common Noise.*

We study a general linear quadratic mean field type control problem and connect it to mean field games of a similar type. The solution is given both in terms of a forward/backward system of stochastic differential equations and by a pair of Riccati equations. In certain cases, the solution to the mean field type control is also the equilibrium strategy for a class of mean field games. We use this fact to study an economic model of production of exhaustible resources. (Received September 01, 2016)

92 ► Biology and other natural sciences

1124-92-29 **Ranadhir Roy*** (ranadhir.roy@utrgv.edu), University of Texas Rio Grande Valley, School of Mathematics and Statstical Sciences, 1201 W University Drive, Edinburg, TX 78539. *ILL-POSED INVERSE PROBLEMS IN MOLECULAR IMAGING.*

Inverse problems arise in medical (molecular) imaging. The inverse problems are posed as a nonlinear optimization where the unknown parameters are found by minimizing the difference between the predicted data and the measured data. In inverse problems, the Tikhonov's regularization method is generally used and the determination of the Tikhonov regularization parameter is very time consuming. To alleviate these difficulties we have applied the penalty/modified barrier function (PMBF) method instead of Tikhonov regularization technique to make the inverse problems well-posed. Unlike the Tikhonov regularization method, the constrained optimization technique, which is based on simple bounds of the optical parameter properties of the tissue, can easily be implemented in the PMBF method. The PMBF method limits the size of the condition number of the Hessian matrix of the given objective function. The accuracy and the rapid convergence of the PMBF method require a good initial guess of the Lagrange multipliers. To obtain the initial guess of the multipliers, we use a least square unconstrained minimization problem. Three dimensional images of fluorescence absorption coefficients and lifetimes were reconstructed from contact and noncontact experimentally measured data. (Received August 03, 2016)

1124-92-53 **Jemal Mohammed-Awel*** (jmohammedawel@valdosta.edu), 1500 North Patterson Street, Hahira, GA 31698, and **Eric Numfor**. *Optimal insecticide-treated bed-net coverage and malaria treatment in a malaria-HIV co-infection model.*

We propose and study a mathematical model for malaria-HIV coinfection transmission and control, in which malaria treatment and insecticide-treated nets are incorporated. The existence of a backward bifurcation is established analytically, and the occurrence of such backward bifurcation is influenced by disease-induced mortality, insecticide-treated bed-net coverage and malaria treatment parameters. To further assess the impact of malaria treatment and insecticide-treated bed-net coverage, we formulate an optimal control problem with

malaria treatment and insecticide-treated nets as control functions. Using reasonable parameter values, numerical simulations of the optimal control suggest the possibility of eliminating malaria and reducing HIV prevalence significantly, within a short time horizon. (Received August 22, 2016)

1124-92-69 **David M Chan*** (dmchan@vcu.edu), 1015 Floyd Avenue, P.O. Box 842014, Richmond, VA 23284-2014, and **Candace Kent** and **Derek Johnson**. *Management of Invasive Allee Species.* Preliminary report.

In this study we use a discrete, two-patch population model of an Allee species to examine different strategies in managing invasions. We first analytically examine the model to show the presence of the strong Allee effect, and then we numerically explore the model to test the effectiveness of different management strategies. We find invasion is facilitated by lower Allee thresholds, greater carrying capacities, and greater proportions of dispersers, but these effects are interacting and moderated by population growth rate. Using the gypsy moth as an example species, we demonstrate that the most effective invasion management is context dependent, may require complementary strategies, and may differ geographically in the same species. Specifically, we find methods for restricting movement to be more effective in areas of high dispersal and high Allee thresholds, where methods involving mating disruptions and raising Allee thresholds are more effective in areas of low diffusion rates. (Received August 27, 2016)

1124-92-71 **Libin Rong*** (rong2@oakland.edu), Department of Math and Stats, Rochester, MI 48309. *Modeling viral control by CD8+ T cells.* Preliminary report.

CD8+ T cells play an important role in controlling HIV or SIV (simian immunodeficiency viruses) replication. The most convincing evidence comes from the experiment of CD8+ T cell depletion in SIV-infected nonhuman primates. Despite an obvious temporal relationship between CD8 decrease (increase) and viral load increase (decrease), there are still debates about the underlying explanation for the experimental data. In this talk, I will use a mathematical model to study the dynamics of both T cells and virus during CD8+ T cell depletion and subsequent recovery. The relative contributions to viral control by the target cell availability and specific CD8+ T cell immune responses (direct cell killing vs. non-killing) will be evaluated. (Received August 28, 2016)

1124-92-85 **Carsten Conradi** and **Anne Shiu*** (annejls@math.tamu.edu). *Multisite phosphorylation systems: bistability, oscillations, and a rational parametrization of steady states.* Preliminary report.

Reaction networks taken with mass-action kinetics arise in many settings, from epidemiology to population biology to systems of chemical reactions. This talk focuses on certain biological signaling networks, namely, multisite phosphorylation networks. Many of these systems exhibit "toric steady states" (that is, the ODEs generate a binomial ideal), and more generally the set of steady states admits a rational parametrization (Thomson and Gunawardena 2009). We describe how this parametrization allows us to investigate the dynamics of two multisite phosphorylation networks: the emergence of bistability in a network underlying ERK regulation, and the capacity for oscillations in a mixed processive/distributive phosphorylation network. (Received August 30, 2016)

1124-92-96 **Caleb Adams*** (cadams5@radford.edu), PO Box 6942, Radford University, Radford, VA 24142, and **David DeLara**. *Dynamics of a Two-Vector, Two-Pathogen, Single Host Model.* Preliminary report.

In this talk, the speaker will present recent theoretical results from the dynamics of a two-vector, two-pathogen, single host model. A system of ordinary differential equations is used to model the dynamics of two vector-borne pathogens (*Rickettsia parkeri* and *Rickettsia amblyommii*) that are increasingly found within tick populations of Virginia spread by two species of ticks (*Amblyomma maculatum* and *Dermacentor variabilis*), within a single host system. Three methods of transmission are included in the model: vector-borne, transovarial, and co-feeding. Results of numerical simulations are presented and determine a range of parameter values which lead to coexistence of the two pathogens and values which lead to the extinction of one pathogen and persistence of the other. (Received August 31, 2016)

1124-92-114 **Amber M Smith*** (amber.smith@stjude.org). *Modeling Host-Pathogen Interactions During Influenza-Pneumococcal Coinfection.*

Influenza virus infections are often complicated by coinfection with bacterial pathogens like pneumococcus. Bacterial coinfections significantly increase influenza-associated morbidity and mortality. The host immune response plays a large role in driving bacterial establishment and the progression to pneumonia. However, how the host response is regulated and works to modulate pathogen growth is not well understood. To better characterize the regulatory mechanisms driving influenza-pneumococcal coinfection, we use an integrative analysis that combines

data-driven mathematical models with model-driven experiments. Through this approach, we identified and detailed how virus-induced depletion of alveolar macrophages regulates bacterial invasion and leads to differential dynamics dependent on the time of bacterial acquisition. We also show how bacterial infection alters viral kinetics and the role of interferon in this process. Together, our models and data provide insight into the kinetics and mechanisms of coinfection and identify potential treatment strategies that abrogate the secondary infection. (Received September 02, 2016)

1124-92-143 **Sivan Leviyang*** (sr286@georgetown.edu) and **Igor Griva**. *Haplotype Reconstruction Using Next Generation Sequencing Data with Applications to Acute HIV Infection.*

In recent years, HIV studies have increasingly used next generation sequencing (NGS) technologies to characterize viral diversity and evolution. NGS datasets contain a large number of sequence reads, allowing for a more precise estimation of viral population genetics than previously possible, but NGS sequence reads are very short, creating challenges in correlating genetic information across different sites in the viral genome. In this talk, we will give an outline of NGS methods as applied to HIV and explain the mathematical challenges, in particular, of using NGS datasets to understand acute HIV infection, a period of time composing the first few months of infection. We will then present a novel approach to analyzing NGS data and compare the approach to existing methods. (Received September 05, 2016)

1124-92-166 **Yan Wang*** (ywang36@email.wm.edu), 1421 N Mount Vernon Avenue, Apt A, Williamsburg, VA 23185, and **Junping Shi** and **Jinfeng Wang**. *Persistence and Extinction of Population in Reaction-Diffusion Models with Advection and Strong Allee Effect Growth.*

we consider a reaction-diffusion-advection equation with strong Allee effect ($f(x,u)$) on a one-dimensional bounded heterogeneous habitat $(0,L)$, where individuals are exposed to unidirectional flow. It is well known that the nonlinear $f(x,u)$ with a strong Allee effect is also called the bistable type as $u=0$ and $u=r(x)$ are both stable solutions to the ordinary differential equation (ODE). We show that for certain boundary conditions, system only possesses zero steady state when the positive steady state is more stable ($\int_0^{u(x)} f(x,s)ds>0$). When the zero steady state is more stable ($\int_0^{u(x)} f(x,s)ds<0$), we discuss the existence of the positive steady state under different parameter set. For both diffusion rate d and advection rate q are small, we get the existence of two distinct positive steady state via mountain pass theory. Performing the multiplicity of positive steady states for sufficiently small advection rate q and getting the global extinction for large advection rate q. For a species with Allee effect type growth, multiple stable states are possible and different initial conditions can lead to different asymptotic behavior. And in a bistable spatial system, various spatial stationary patterns can coexist. (Received September 06, 2016)

1124-92-167 **Wenjie Ni*** (wenjienixl@gmail.com), 1326 S Mount Vernon Ave. Apt.G, Williamsburg, VA 23185, and **Mingxin Wang**. *Dynamics and patterns of a diffusive Leslie-Gower prey-predator model with strong Allee effect in prey.*

This paper is devoted to study the dynamical properties and stationary patterns of a diffusive Leslie-Gower prey-predator model with strong Allee effect in the prey population. We first analyze the nonnegative constant equilibrium solutions and their stabilities, and then study the dynamical properties of time-dependent solutions. Moreover, we investigate the stationary patterns induced by diffusions (Turing pattern). Our results show that the impact of the strong Allee effect essentially increases the system spatiotemporal complexity. (Received September 06, 2016)

1124-92-173 **Jessica M. Conway*** (jmconway@psu.edu), **Alan S. Perelson** and **Jonathan Z. Li**. *HIV viral rebound: patient-specific stochastic model predictions.* Preliminary report.

Antiretroviral therapy (ART) effectively controls HIV infection, suppressing HIV viral loads to levels undetectable by routine testing. Suspension of therapy is typically followed by rebound of viral loads to high, pre-therapy levels. Using data from AIDS Clinical Trials Group (ACTG) treatment interruption trials, Li et al. (2015) report that the size of the expressed HIV reservoir and a patient's drug regimen correlate with the time between ART suspension and viral rebound. We have developed a multi-type, branching process model to gain insight into HIV post-treatment dynamics and viral rebound across patients. Using maximum likelihood methods, we parametrize our model using the ACTG clinical trials data discussed in Li et al. (2015). Our results represent first steps towards a model that can make predictions of a patient's rebound time distribution based on personal characteristics and help identify patients with expected long viral rebound delays. (Received September 07, 2016)

1124-92-204 **Hien T Tran*** (tran@math.ncsu.edu), Department of Mathematics, Campus Box 8205, North Carolina State University, Raleigh, NC 27518. *A Stochastic Approach to Nonlinear Mixed Effects Modeling: Applications to Pharmacokinetics Modeling of Metformin.*

Nonlinear mixed effects modeling (NLME) is a statistical framework involving both fixed-effects and random effects for population parameters incorporating uncertainty associated with intra- and inter-subject variability. Using stochastic differential equations (SDE) within the NLME framework allows the decoupling of the measurement error from the model misspecification. In this talk, we will compare the model development results using an SDE approach to common practice of using ordinary differential equations for the Metformin clinical pharmacokinetic data. (Received September 08, 2016)

1124-92-263 **Garnett Kelsoe*** (ghkelsoe@duke.edu), Department of Immunology, Human Vaccine Institute, Duke University, Durham, NC 27710. *Darwin Writ Small: Population dynamics and selection in germinal centers.*

Germinal center (GC) B cells interact with local T cells to acquire somatic mutations and evolve by a Darwinian process towards increased affinity for antigen. The GC is a complex structure that facilitates this cellular evolution and has been studied primarily in genetically restricted, hapten-specific responses. Such responses are experimentally tractable but focus on intraclonal competition and selection. Recently, we described the population dynamics of genetically diverse GC responses to complex antigens, Bacillus anthracis protective antigen and influenza hemagglutinin, in which B cells competed both intra- and interclonally for distinct epitopes. These responses were significantly different from those to haptens and characterized by increasing clonal diversity as early "winners" were replaced by rarer, high-affinity B-cell clones. Despite affinity maturation, inter- and intraclonal avidities varied greatly, and half of GC B cells did not bind the immunogen but nonetheless exhibited the hallmarks of antigen selection, clonal expansion and competition. GC reactions to complex antigens permit a range of specificities and affinities, with potential advantages for broad protection. (Received September 11, 2016)

1124-92-293 **Rustom Antia*** (rantia@emory.edu). *Dynamics of immune responses to influenza.*

We will use simple models to explore why we do not naturally generate strain-transcending immunity to influenza. These models will include models of antibody and T cell responses. We will briefly consider the implications of these models for the design of "universal" influenza vaccines. (Received September 12, 2016)

1124-92-311 **Burcu Adivar*** (badivar1@uncfsu.edu), 1200 Murchison Rd., Fayetteville, NC 28301, and **Kursad Tosun** (kursadtosun@mu.edu.tr), , Turkey. *Simulation of Control Policies for Bioterrorist Smallpox Epidemic.* Preliminary report.

In this study, we focus on modelling potential responses to bioterrorist smallpox attack. Our goal is to predict the impacts of vaccination, quarantine and isolation, and thereby to provide guidance to policy makers on how to efficiently allocate resources during smallpox epidemic. We developed models by considering disease transmissions between Susceptible, Exposed, Quarantined, Prodromal, Infected, Isolated, Vaccinated, and Removed classes. Although these models are designed for smallpox, they can be easily adapted for similar diseases. We studied asymptotic stability of disease free equilibria, and relationship between the stability conditions and the basic reproduction numbers. Simulation results under realistic scenarios and potential policies are presented. (Received September 12, 2016)

1124-92-316 **Stanca M Ciupe*** (stanca@vt.edu), Blacksburg, VA 24060, and **Andrea Carracedo Rodriguez** and **Matthias Chung**. *Complex Hepatitis B virus profiles during antiviral therapy - mathematical and numerical investigation.* Preliminary report.

In this study, we investigate the hepatitis B virus dynamics following initiation of drug therapy. Data from human clinical trials have shown that HBV DNA follow complex profiles such as biphasic, triphasic, stepwise decay and rebound. We utilized a deterministic model of hepatitis B virus dynamics following antiviral therapy to uncover the mechanistic interactions behind the hepatitis B virus dynamics. Analytical investigation of the model was used to separate the parameter space describing virus decay and rebound. Uniform Monte Carlo sampling of the parameter space was used to determine the virological, pharmacological and immunological factors that separate the types of virus decay. We found that the level of liver infection at the start of therapy best separates the decay patterns. Moreover, drug efficacy, ratio between division of uninfected and infected cells, and the strength of cytotoxic immune response are important in assessing the amount of liver damage experienced over time and the duration of therapy leading to virus resolution in each of the observed profiles. (Received September 12, 2016)

1124-92-319 **Katia Koelle*** (katia.koelle@duke.edu), Durham, NC 27708, **Christopher Brooke**, Urbana, IL 61801, **Diana Vera Cruz**, Durham, NC 27708, and **Ruian Ke**, Raleigh, NC 27695. *Reconceptualizing within-host disease models to characterize the roles of cellular coinfection and viral complementation in the replication dynamics of influenza.*

Within-host models of viral pathogens are key to better understand the virological and immunological processes regulating these infections. For influenza, models range from simple target cell limited models to models that include aspects of the immune response. At their core, however, these models are structurally similar in that they classify target cells as being simply infected or uninfected. Recent research, however, has shown that only a small subset of virions express the full set of viral genes required for productive infection and are thus fully-infectious (capable of productive infection when singly infecting cells). The vast majority of virions are only capable of expressing a limited subset of essential viral genes and are thus semi-infectious (incapable of productive infection when singly infecting cells, yet capable of replicating through complementation). Here, we propose a structurally different, yet low dimensional, modeling approach based on epidemiological macroparasite models to more accurately represent influenza virus within-host dynamics. We define the structures of these models, with cells akin to hosts and virus particles akin to macroparasites, and discuss ongoing work to identify the parameters that are measurable through experiments. (Received September 12, 2016)

1124-92-327 **Marija Vucelja*** (mvucelja@virginia.edu), Department of Physics, University of Virginia, 382 McCormick Rd, Charlottesville, VA 22904. *Modelling CRISPR, the adaptive immune system of bacteria.*

The CRISPR mechanism serves as an adaptive defense mechanism of bacteria against phages and other invading genomic elements. It takes parts of genomic sequences from the "invaders" and in this way builds up a memory of past infections. The acquired sequences are stored among Clustered Regularly Interspaced Short Palindromic Repeats, aka CRISPR. With a new encounter of an invading sequence, this memory is accessed, and in a successful outcome, the invader is neutralized. I will introduce a population dynamics model where immunity can be both acquired and lost. Two key parameters of the model are the ease of acquisition and the effectiveness in conferring immunity. Next, I will describe the predictions of this model and suggest potential experiments. (Received September 12, 2016)

1124-92-333 **Samantha Erwin*** (sherwin@vt.edu), Blacksburg, VA 24060, and **Meghna Verma**, **Vida Abedi**, **Raquel Hontecillas**, **Stefan Hoops**, **Josep Bassaganya-Riera** and **Stanca Ciupe**. *Modeling the mechanisms by which HIV-associated immunosuppression influences HPV persistence at the oral mucosa.*

Human immunodeficiency virus (HIV)-infected patients are at an increased risk of co-infection with human papilloma virus (HPV), and subsequent malignancies such as oral cancer. To determine the role of HIV-associated immune suppression on HPV persistence and pathogenesis, we developed a mathematical model of HIV/HPV co-infection and used it to investigate the mechanisms underlying the modulation of HPV infection and oral cancer by HIV. Our model captures known immunological and molecular features such as impaired HPV-specific effector T helper 1 (Th1) cell responses, and enhanced HPV infection due to HIV. We used the model to determine HPV prognosis in the presence of HIV infection, and identified conditions under which HIV infection alters HPV persistence in the oral mucosal system. The model predicts that conditions leading to HPV persistence during HIV/HPV co-infection are the permissive immune environment created by HIV and molecular interactions between the two viruses. The model also determines when HPV infection continues to persist in the short run in a co-infected patient undergoing antiretroviral therapy. Lastly, the model predicts that under efficacious antiretroviral treatment HPV infections will decrease in the long run due to the restoration of CD4+ T cell levels. (Received September 12, 2016)

1124-92-342 **Swati Debroy*** (sdebroy@uscb.edu), **Olivia F. Prosper**, **Austin Mishoe** and **Anuj Mubayi**. *Mathematical Model to Estimate Underreporting and Asymptomatic Visceral Leishmaniasis Cases in Bihar, India.* Preliminary report.

Visceral Leishmaniasis (VL), also known as 'kala-azar', is a vector-borne disease that primarily affects impoverished tropical regions of the world. The WHO reports 300,000 new cases of VL world-wide each year. Although VL is curable if treated, it causes over 20,000 deaths in developing countries annually. These statistics are highly under-estimated mainly due to ignorance and lack of proper surveillance. In regions with limited resources where authorities are struggling to combat several other infectious diseases, annual flooding, infrastructural deficiencies etc., it is important to bring attention to the actual morbidity and mortality due to VL, so that the problem is handled with appropriate urgency. In this project we apply two ordinary differential equation models to official count of VL cases from 21 worst affected districts in Bihar (state which hosts 90% of VL cases in India) from

2003-2012. We estimate the infection rate, rate of cure and percentage of underreporting of deaths due to VL for each district. This model also aims at estimating the count of the asymptomatically infected people in the population, data on which is very limited. Least-square parameter fitting along with local sensitivity analysis is performed to achieve these estimation. (Received September 12, 2016)

1124-92-344 **Lauren M Childs***, 460 McBryde Hall, Blacksburg, VA 24061, and **Jane Heffernen** and **Caroline Buckee**. *Modeling the dynamics of immunological memory to malaria.* Preliminary report.

Each year nearly 200 million people are infected with the malaria parasite, Plasmodium falciparum. One of the most notable features of infection with malaria is the inability of individuals to acquire sterilizing immunity to the parasite. The failure of protection is in part due to parasite strategies to avoid and limit host immune response including antigenic variation; however, recent evidence suggests that in addition to these parasite-mediated strategies there may be deficiency in the ability of the immune system itself to create long-lived protection against P. falciparum. Here, we develop a mathematical model of the generation and maintenance of B cell and antibody response to P. falciparum. We analyze simulated output to understand the origin of protective as well as ineffective immune responses in the presence of a multitude of varied proteins as well as antigenically varying proteins. We find that the level of persistent antibodies depends upon assumptions on the relative production of different type of antibody producing cells. Understanding the development and maintenance of protective immune responses to malaria is key in the on-going push towards elimination and eradication. (Received September 12, 2016)

1124-92-361 **Cliburn Chan*** (cliburn.chan@duke.edu), 11078 Hock Suite 1102, 2424 Erwin Road, Durham, NC 27710. *CMV infection after solid organ transplantation.* Preliminary report.

Most people are infected with cytomegalovirus (CMV) during their lifetimes, and the dormant virus can reactivate following solid organ transplantation, when the immune system is suppressed to prevent graft rejection. CMV is the most common infection in both lung and kidney transplant recipients, and leads to increased rates of chronic graft rejection and poor long-term outcomes. In this presentation, we evaluate statistical predictors of CMV infection from cross-sectional and longitudinal data, and investigate dynamical models for the failure of immune control and CMV reactivation. (Received September 13, 2016)

1124-92-362 **Ruian Ke*** (rke2@ncsu.edu), 2311 Stinson Drive, SAS Hall, Raleigh, NC 27695, and **Ricardo Wehrhahn** and **Kai Deng**. *On the turnover rate of the HIV latent reservoir in untreated patients.*

The stability of the HIV latent reservoir, a population of cells latently infected by replication competent HIV but do not actively produce viruses, represents a major barrier to cure HIV infection. The mechanism underlying this stability is not clear. It may be due to a low death rate of latently infected cells; alternatively, it may be due to a dynamical balance between high production and high death rate. Recent data shows that the frequency of cytotoxic T lymphocyte (CTL) escape mutant viruses in the latent reservoir rises to 98% in a majority of untreated patients between 6 months to 2 years after HIV infection. Here, we construct mathematical model to describe the dynamics of transmitted founder virus and CTL escape mutants in the plasma and the reservoir, and use the model to estimate the rate of turnover of the HIV latent reservoir from the recent data. The results suggest that the half-life of the reservoir is at least 10 times shorter in untreated patients than the half-life estimated from treated patients. We further explore possible mechanisms that drive a fast turnover rate in untreated patients. This work sheds light on the dynamic nature of the reservoir and has implications for HIV eradication strategies. (Received September 13, 2016)

1124-92-405 **Amanda J. Mangum*** (amangum@niagara.edu), Niagara University, 5795 Lewiston Rd, Niagara University, NY 14109, and **Mansoor Haider**. *Comparison of k-means, self-organizing maps, and relational self-organizing maps clusterings in data of atherosclerotic cardiovascular tissues Preliminary Report.* Preliminary report.

Atherosclerosis is a cardiovascular disease in which plaque accumulates along the wall of an artery, altering blood flow and increasing the risk for heart attack or stroke. Acoustic Radiation Force Impulse (ARFI) is an ultrasound imaging technique in which acoustic waves are focused at a point, causing displacement of the tissue that is then tracked over time to measure elastic and viscoelastic material properties from the imaging data. We investigate the application of data clustering algorithms, K-Means, Self-Organizing Maps (SOMs), and Relational SOMS to ARFI imaging for early detection and characterization of atherosclerotic plaques. In this context, we hope to cluster images based on similar patterns in the data set. Based on the dimension, size and scope of image patterns considered in this work, the clustering configuration used for each clustering algorithm considered was

a 3x3 lattice of nine neurons. We will discuss two metrics that were used to compare the performance of these three clustering methods on the porcine atherosclerotic data set. (Received September 13, 2016)

1124-92-410 **Nargesalsadat Dorratoltaj*** (nargesd@vt.edu), 8 Museum Way, Cambridge, MA 02141, and **Stanca Ciupe**, **Ryan Nikin-Beers**, **Stephen Eubank**, **Pierre Pellegrino**, **Ian Williams**, **Persephone Borrow** and **Kaja Abbas**. *Viral and Immune System Dynamics of HIV-1, CD4+ T Cells and Macrophages during Acute, Clinically Latent and Late Phases of HIV Infection.*

The objective is to analyze the dynamics of HIV, CD4+ T cells and macrophages during the acute, clinically latent and late phases of HIV infection to predict their dynamics in treatment naive HIV-infected individuals. While the viral-host dynamics of HIV and CD4+ T cells are well studied, our understanding of the role macrophages in HIV progression to AIDS is limited. This study incorporates the macrophage dynamics and studies their role during all stages of HIV infection. We develop a deterministic mathematical model of virus-host dynamics that incorporates the HIV, CD4+ T cell and macrophage populations. We calibrate the model against longitudinal clinical data from a cohort of 39 treatment naive HIV-infected individuals. Based on model calibration to rapidly-progressing patient cohort, we infer that the mean HIV progression timeline from time of infection to AIDS stage is 5.75 years. The model predicts that the peak in viral load during acute HIV infection is due to virus production by infected CD4+ T cells, while during the latent and late phases of HIV, infected macrophages dominate the overall viral production. This leads to the conclusion that macrophage-induced virus production is the driver of HIV progression from asymptomatic phase to AIDS in infected individuals. (Received September 13, 2016)

1124-92-411 **Alison L Hill***, alhill@fas.harvard.edu, and **Jeffrey M Gerold**, **Daniel IS Rosenbloom** and **Martin A Nowak**. *Modeling the dynamics of HIV latency and rebound.* Preliminary report.

HIV infection can be treated, but not cured, with antiretroviral drugs. Long-lived latent virus persists despite years of treatment, meaning drugs must be taken daily, for life. If treatment is stopped, viral loads rapidly rebound to high levels. Research is underway to find new therapies that can permanently control the infection, and therefore improve the prospects for eradicating HIV worldwide. These therapies aim to either clear latent virus from the body, or, to boost the immune system's ability to control the infection. Currently, the only way to assess the efficacy of these investigational therapies is to stop antiretroviral drugs and to observe if, when, and how viral rebound occurs. Here I will discuss our work developing mathematical models to characterize the kinetics of viral rebound and the effect that various interventions have on these dynamics. This works shows how viral dynamics models can be used to help understand the mechanisms of action of new drugs and virus-host interactions. I will demonstrate how modeling can shed light on aspects of viral pathogenesis that are poorly understood and suggest which quantities are most important to measure experimentally in order to narrow uncertainty in predictions of drug effects. (Received September 13, 2016)

1124-92-416 **Marc D Ryser***, ryser@math.duke.edu, and **Patti E Gravitt**. *Sexual Behavior, HPV Exposure and Cancer Incidence: Connecting the Dots.* Preliminary report.

The U.S. has experienced an increase in the incidence of human papillomavirus (HPV)-related cancers that are not screen detectable, e.g., cervical adenocarcinoma, oropharyngeal and anal cancers. An association between population-level changes in sexual behavior and cancer burden has been hypothesized, yet there is no direct evidence for HPV exposure as the mediator. In this talk we seek to bridge this gap by combining mechanistic mathematical models with population-level data on sexual behaviors and HPV serology from the National Health and Nutrition Examination Survey (NHANES). (Received September 14, 2016)

93 ► Systems theory; control

1124-93-11 **Robert Sizemore*** (rsizem2@lsu.edu), Department of Mathematics, Louisiana State University, 301 Lockett Hall, Baton Rouge, LA 70803-4918. *Adaptive Planar Curve Tracking Control and Robustness Analysis under State Constraints and Unknown Curvature.*

We provide adaptive controllers for curve tracking in the plane, under unknown curvatures and control uncertainty, which is a central problem in robotics. The system dynamics include a nonlinear dependence on the curvature, and are coupled with an estimator for the unknown curvature, to form the augmented error dynamics. We prove input-to-state stability of the augmented error dynamics with respect to an input that is represented

by additive uncertainty on the control, under polygonal state constraints and under suitable known bounds on the curvature and on the control uncertainty. When the uncertainty is zero, this gives tracking of the curve and convergence of the curvature estimate to the unknown curvature. Our curvature identification result is a significant improvement over earlier results, which do not ensure parameter identification, or which identify the control gain but not the curvature. This work is joint with Profs. Michael Malisoff from the Louisiana State University Department of Mathematics and Fumin Zhang from the Georgia Institute of Technology School of Electrical and Computer Engineering. (Received April 26, 2016)

1124-93-21 **Debanjana Mitra*** (debam87@vt.edu), 8600 Hunters Mill Road, Apt B, Blacksburg, VA 24060. *Control of compressible Navier-Stokes system.*

We consider the one dimensional compressible Navier-Stokes system near a constant steady state with the periodic boundary conditions. The linearized system around the constant steady state is a hyperbolic-parabolic coupled system. We discuss some of the properties of the linearized system and its spectrum. Next we study some controllability results of the system. (Received July 12, 2016)

1124-93-268 **Scott W. Hansen*** (shansen@iastate.edu), Department of Mathematics, Iowa State University, Ames, IA 50011. *Locally Distributed Controllability of a Class of Cochlea Models.*

Two variations of a basic model for a cochlea are described which consist of the basilar membrane coupled with a linear potential fluid. The basilar membrane is modeled as an array of oscillators which may or may not include longitudinal elasticity. Approximate controllability with locally distributed control on a portion of the basilar membrane is proved for both models and moreover exact controllability is shown to hold when longitudinal stiffness is included. (Received September 11, 2016)

97 ► Mathematics education

1124-97-363 **Mulugeta Markos*** (mmarkos@atlm.edu), 3980 Embassy Way, Lilburn, GA 30047. *My Experience in Teaching Proofs.*

Most students think there is only one way to prove a mathematical statement. Many mathematics teachers tend to prove a theorem in the classroom using one method, but approaching the proof of a theorem or any mathematical statement in different ways helps the teacher to deliver more concepts to students. In an article addressing several questions about proofs, Eric Knuth (2002) indicates the central role of proofs in mathematics. Students learn to appreciate proofs when they see proofs from different angles though the different methods could sometimes be challenging to them. In constructing multiple proofs students learn more connections among numbers, algebraic operations, definitions, mathematical facts and formulas. Teaching proofs in different ways helps teachers to improve their teaching ability and creativity. In this paper I will share my experience of teaching proofs to undergraduate students for long period. The teaching approach introduced in this paper encourage teachers to apply different ways when dealing with proofs. (Received September 13, 2016)

2010 MATHEMATICS SUBJECT CLASSIFICATION

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00 General
01 History and biography
03 Mathematical logic and foundations
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General algebraic systems
11 Number theory
12 Field theory and polynomials
13 Commutative rings and algebras
14 Algebraic geometry
15 Linear and multilinear algebra; matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory; homological algebra
19 *K*-theory
20 Group theory and generalizations
22 Topological groups, Lie groups
26 Real functions
28 Measure and integration
30 Functions of a complex variable
31 Potential theory
32 Several complex variables and analytic spaces
33 Special functions
34 Ordinary differential equations
35 Partial differential equations
37 Dynamical systems and ergodic theory
39 Difference and functional equations
40 Sequences, series, summability
41 Approximations and expansions
42 Fourier analysis
43 Abstract harmonic analysis
44 Integral transforms, operational calculus
45 Integral equations
46 Functional analysis
47 Operator theory
49 Calculus of variations and optimal control; optimization
51 Geometry
52 Convex and discrete geometry
53 Differential geometry
54 General topology
55 Algebraic topology
57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
65 Numerical analysis
68 Computer science
70 Mechanics of particles and systems
74 Mechanics of deformable solids
76 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
85 Astronomy and astrophysics
86 Geophysics
90 Operations research, mathematical programming
91 Game theory, economics, social and behavioral sciences
92 Biology and other natural sciences
93 Systems theory; control
94 Information and communication, circuits
97 Mathematics education

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