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PAPERS PRESENTED AT MEETINGS

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

MEETING #	DATE	PLACE	ABSTRACT DEADLINE	ABSTRACT ISSUE
1145	January 16–19, 2019	Baltimore, MD	EXPIRED	Vol 40, No. 1
1146	March 15–17, 2019	Auburn, AL	January 29	Vol 40, No. 2
1147	March 22–24, 2019	Honolulu, HI	January 29	Vol 40, No. 2
1148	April 13–14, 2019	Hartford, CT	February 5	Vol 40, No. 2
1149	June 10–13, 2019	Quy Nhon City, Vietnam	TBA	NONE
1150	September 14–15, 2019	Madison, WI	July 16	Vol 40, No. 3
1151	October 12–13, 2019	Binghamton, NY	August 20	Vol 40, No. 3
1152	November 2–3, 2019	Gainesville, FL	September 10	Vol 40, No. 4
1153	November 9–10, 2019	Riverside, CA	September 3	Vol 40, No. 4
1154	January 15–18, 2020	Denver, CO	TBA	TBA

FAYETTEVILLE, AR, November 3–4, 2018

Abstracts of the 1142nd Meeting.

00 ► General

1142-00-13 **Grant Fickes**, **Dylan Green*** (dpgreen@trevecca.edu), **Karen McCready**, **Kathleen Ryan**, **Nathaniel Sauerberg** and **Jill Stifano**. *Exploring Upper Bounds of Proper Diameter of Graphs.* Preliminary report.

A properly colored path is a path in which no two consecutive edges have the same color. A properly connected coloring of a graph is one in which there exists a properly colored path between every pair of vertices. Given a graph G with a properly connected coloring, the proper distance between any two vertices is the length of a shortest properly colored path between them. Furthermore, the proper diameter of G is the largest proper distance between any pair of vertices in G. Since the proper diameter of G is a function of its coloring, we can refer to the maximum proper diameter of G, that is, the maximum value of the proper diameter across all properly connected colorings of G.

If G has n vertices, a natural upper bound for its maximum proper diameter is $n-1$, though this value is not attainable for all graphs, such as graphs without a Hamiltonian path. We introduce a new family of graphs, $\mathcal{T}_n$ graphs, and we show that a 2-connected graph on n vertices with a properly connected 2-coloring has a maximum proper diameter of $n-1$ if and only if the graph is a $\mathcal{T}_n$ graph. (Received July 23, 2018)

1142-00-211 **Daiki Ikami*** (ikami@hal.t.u-tokyo.ac.jp). *Residual Expansion Algorithm: Fast and Effective Optimization for Nonconvex Least Squares Problems.*

We present the residual expansion (RE) algorithm for obtaining near-global optimum in nonconvex least squares problems. Unlike most existing global optimization techniques, the RE algorithm is a deterministic algorithm not based on either stochastic or multi-point searches. Our results demonstrate high optimization performance in many problems such as k-means clustering. This is joint work with Kiyoharu Aizawa and Toshihiko Yamasaki. (Received September 04, 2018)

05 ► Combinatorics

1142-05-26 **Hailong Dao**, **Joseph Doolittle**, **Ken Duna**, **Bennet Goeckner**, **Brent J Holmes*** (brentholmes@ku.edu) and **Justin Lyle**. *Higher Nerves, Depth and the f-vector.*

Let $A = \{A_1, A_2, \ldots, A_r\}$ be a family of sets. Then $N(A) := \{F \subseteq [r] \colon \cap_{i\in F} A_i \neq \emptyset\}$ is the *Nerve Complex* of A. This simplicial complex contains valuable connectivity information and has been studied for many years;

however, this complex does not retain any information about the size of the intersections. In this talk, I introduce generalized notions of this nerve complex for the case where A is the set of facets of a simplcial complex. Together, these complexes provide a plethora of connectivity information. I will show that the homologies of these higher nerve complexes determine the depth of the Stanley-Reisner ring $k[\Delta]$ as well as the f-vector and h-vector of Δ. (Received August 09, 2018)

1142-05-59 **Claus Ernst** and **Van Pham***, apham11@uncc.edu. *How loop numbers relate to some known knot invariants?*

For a given knot diagram D, one can traverse the diagram and count the number of loops created along it. We have shown that loops numbers are invariant under flypes for a large family of knots. In this talk, we discuss relationship of loop numbers with some known knot invariants. (Received August 25, 2018)

1142-05-129 **M. M. Jaradat*** (mmjst4@qu.edu.qa), Department of Mathematics, Statistics and Phy, Qatar University, Doha, 2713, Qatar, and **M S Bataineh** and **T. Vetrik**. *The Ramsey numbers for theta graphs versus the wheel of order* 5.

The study of exact values and bounds on the Ramsey numbers of graphs forms an important family of problems in the extremal graph theory. For a set of graphs S and a graph F, the Ramsey number $R(S, F)$ is the smallest positive integer r such that for every graph G on r vertices, G contains a graph in S as a subgraph or the complement of G contains F as a subgraph. Ramsey numbers of various graphs including theta graphs and wheels have been extensively studied. We extend known results in the area by presenting exact values of the Ramsey numbers $R(\theta_n, W_5)$ for $n \geq 5$, where θ_n is the set of theta graphs of order n and W_5 is the wheel graph of order 5. (Received August 31, 2018)

08 ► General algebraic systems

1142-08-165 **James Garrett**, **Natasa Jonoska** and **Masahico Saito*** (saito@usf.edu). *Variations of Temperley-Lieb algebras for DNA origami.* Preliminary report.

DNA origami is a method to construct desired planar shapes by DNA, which will be explained without technical details. We propose an algebraic approach to represent and study DNA origami structures by monoids that are variations of Temperley-Lieb algebras. We identify two types of basic building blocks of DNA origami structures and use them as generators of monoids, called origami monoids. The concatenation of building blocks corresponds to the monoid operation. We identify a set of relations that reflect feasible DNA structures and their simplifications. The origami monoids project to the product of the monoid version of Temperley-Lieb algebras. We present several computational results and observations about Green's relations for the origami monoids. (Received September 02, 2018)

1142-08-222 **Jonathan D Hauenstein** (hauenstein@nd.edu), Notre Dame, IN 46556, and **Tingting Tang*** (ttang@nd.edu). *Markov Chain Monte Carlo assisted method for finding real solutions of nonlinear polynomial system.*

In this talk, we propose a new approach for finding all the real solutions of a nonlinear system. First, we transform the nonlinear system into a optimization problem. Then, we further transform the objective function into a probability density function where probability one is achieved at every real solution of the nonlinear system. Finally, we use Markov-chain Monte-Carlo to improve the selection of initial parameters for the appropriate optimization method which we use to solve the optimization problem. Examples are given to demonstrate the performance of this new method of solving nonlinear system. (Received September 04, 2018)

13 ► Commutative rings and algebras

1142-13-25 **Brent J Holmes*** (brentholmes@ku.edu). *A Generalized Serre Condition.*

Let R be a commutative Noetherian ring. A ring R satisfies Serre's condition (S_ℓ) if for all $\mathfrak{p} \in \mathrm{Spec}R$, $\mathrm{depth}R_\mathfrak{p} \geq \min\{\ell, \dim R_\mathfrak{p}\}$. Serre's condition has been a topic of expanding interest. In this talk, I will examine a generalization of Serre's condition (S_ℓ^j). A ring satisfies (S_ℓ^j) when $\mathrm{depth}R_\mathfrak{p} \geq \min\{\ell, \dim R_\mathfrak{p} - j\}$ for all $\mathfrak{p} \in \mathrm{Spec}R$. I will present generalizations of results for rings satisfying Serre's condition. (Received August 09, 2018)

1142-13-34 **Arindam Banerjee** and **Selvi Kara Beyarslan***, selvi@southalabama.edu, and **Huy Tai Ha**. *Regularity of powers of edge ideals: from local properties to global bounds.*

Let $I = I(G)$ be the edge ideal of a graph G. We give various general upper bounds for the regularity function $\operatorname{reg} I^s$, for $s \geq 1$, addressing a conjecture made by the authors and Alilooee. When G is a gap-free graph and locally of regularity 2, we show that $\operatorname{reg} I^s = 2s$ for all $s \geq 2$. This is a slightly weaker version of a conjecture of Nevo and Peeva. Our method is to investigate the regularity function $\operatorname{reg} I^s$, for $s \geq 1$, via local information of I. (Received August 16, 2018)

1142-13-47 **Daniel Erman*** (derman@math.wisc.edu), 480 Lincoln Drive, Madison, WI 53711, and **Jay Yang**. *Syzygies and Random Monomial Ideals.*

We use the probabilistic method to construct examples of conjectured phenomenon about asymptotic syzygies. Our model for a random monomial ideals comes from the Stanley-Reisner ideal of certain random flag complexes. (Received August 22, 2018)

1142-13-55 **Mohsen Gheibi***, 411 S. Nedderman Dr., 445 Pickard Hall, Arlington, TX 76019. *On the structure of large homomorphisms of local rings.*

Levin in 1980 introduced the notion of the large homomorphisms of local rings. Recall that a surjective homomorphism $f : R \to S$ of local rings is called *large* if the induced homomorphism of graded algebras $\operatorname{Tor}_R(k,k) \to \operatorname{Tor}_S(k,k)$ is surjective. In this talk, I give a characterization of large homomorphisms over complete intersections. Also, I will address examples and ongoing open questions. (Received August 24, 2018)

1142-13-60 **Zachary Greif** and **Jason McCullough*** (jmccullo@iastate.edu). *Linear Syzygies of Toric Edge Ideals of Bipartite Graphs.*

Let G be a finite, simple, bipartite graph and let K be a field. We consider the toric edge ideal of G, defined as the defining ideal of the K-algebra generated by all quadratic monomials associated to edges of G. Hibi and Ohsugi showed that G is generated by quadratic binomials if and only if G is chordal bipartite. We extend their result by giving a combinatorial characterization of graphs whose toric edge ideal is generated by quadratics and has linear first syzygies. I will discuss connections between this result and a question of Varbaro regarding the existence of families of quadratic ideals with linear syzygies and regularity growing linearly with embedding dimension. (Received August 26, 2018)

1142-13-66 **Giulio Caviglia** and **Alessio Sammartano*** (asammart@nd.edu). *Maximal syzygies in Hilbert schemes of complete intersections.* Preliminary report.

Abstract. Let $d_1, \dots, d_c$ be positive integers and consider the monomial complete intersection $Y \subseteq \mathbb{P}^n$ defined by the vanishing of $x_1^{d_1}, \dots, x_c^{d_c}$. For each Hilbert polynomial $p(\zeta)$ we construct a distinguished point in the Hilbert scheme $\operatorname{Hilb}^p(Y)$, which we call the expansive point. This point achieves the largest possible syzygies among all subschemes $Z \in \operatorname{Hilb}^p(Y)$. Assuming the validity of the lex-plus-powers conjecture, the expansive point provides uniform sharp upper bounds for the syzygies of subschemes $Z \in \operatorname{Hilb}^p(X)$ for all complete intersections $X = X(d_1, \dots, d_c) \subseteq \mathbb{P}^n$. In some cases, the expansive point achieves extremal Betti numbers for the infinite free resolutions associated to a subscheme in $\operatorname{Hilb}^p(Y)$. Our approach is new even in the special case $Y = \mathbb{P}^n$, where it provides new results and simpler proofs of known theorems. (Received August 27, 2018)

1142-13-67 **Giulio Caviglia*** (gcavigli@purdue.edu), Department of Mathematics, Purdue University, 150 N. University Street, West Lafayette, IN 47907, and **Alessio Sammartano**, Department of Mathematics, University of Notre Dame, 255 Hurley, Notre Dame, IN 46556. *On the Lex-plus-powers Conjecture.*

Let S be a polynomial ring over a field and $I \subseteq S$ a homogeneous ideal containing a regular sequence of forms of degrees $d_1, \dots, d_c$. In this paper we prove the Lex-plus-powers Conjecture when the field has characteristic 0 for all regular sequences such that $d_i \geq \sum_{j=1}^{i-1}(d_j - 1) + 1$ for each i; that is, we show that the Betti table of I is bounded above by the Betti table of the lex-plus-powers ideal of I. (Received August 27, 2018)

1142-13-79 **Tai Ha*** (tha@tulane.edu), Tulane University, New Orleans, LA 70118. *Containments between powers of monomial ideals and optimal solutions to linear programming problems.*

We present a close relationship between membership criteria for powers of a monomial ideal and the optimal solutions to certain linear programming problems. This relationship allows us to use known gap estimates for these optimal solutions to derive new containments between powers of a monomial ideal and, at the same time, use known containments between powers of an ideal to get new estimates for those gaps. (Received August 28, 2018)

1142-13-83 **Ashwini Bhat*** (ashwini.bhat@okstate.edu). *Generalized Borel Ideals.* Preliminary report.

In 2013, Francisco, Mermin, and Schweig introduced a generalization of Borel ideals called Q-Borel ideals. We extend their work and describe some homological and combinatorial properties of these ideals. (Received August 29, 2018)

1142-13-84 **Ian M Aberbach*** (aberbachi@missouri.edu), MO , and **Parangama Sarkar**. *Frobenius Betti numbers and syzygies of finite length modules.* Preliminary report.

Let (R, m) be a local (Noetherian) ring of dimension d and M a finite length R-module. De Stefani, Huneke, and Núñez-Betancourt explored two questions about the properties of resolutions of M. Q 1: in char $p > 0$, what vanishing conditions on the Frobenius Betti numbers (FBn) force $pd\ M < \infty$? Q 2: if $pd\ M = \infty$, do $d + 2$nd or higher syzygies have infinite length?

For Q 1, they showed, under restrictive hypotheses, that $d + 1$ consecutive vanishing FBn forces $pd\ M < \infty$. When $d = 1$ and R is CM then one vanishing FBn suffices. We show that these results hold in general, i.e., $d+1$ consecutive vanishing FBn force $pd\ M < \infty$, and, under the hypothesis that R is CM, d consecutive vanishing FBn suffice.

For Q 2, they obtain very interesting results when $d = 1$. No third syzygy of M can have finite length. Their main tool is, if $d = 1$, to show, if the syzygy has a finite length, then it is an alternating sum of lengths of Tors. We are able to prove this fact for rings of arbitrary dimension, which allows us to show that if $d = 2$, no third syzygy of M can be finite length! We also show Q 2 holds if the socle dimension of $H^0_m(R)$ is large relative to the rest of the module, generalizing the case of Buchsbaum rings. (Received August 29, 2018)

1142-13-86 **Alessandra Costantini*** (costanta@purdue.edu) and **Tan Dang**. *On the Cohen-Macaulay property of the Rees algebra of the module of differentials.* Preliminary report.

Let R be a Noetherian ring, E a finite R-module having a rank e (i.e. E is free of rank e locally at every associated prime). We say that E satisfies condition F_t if the minimal number of generators of $E_{\mathfrak{p}}$ is at most $\dim R_{\mathfrak{p}} + e - t$ for every prime ideal $\mathfrak{p}$ such that $E_{\mathfrak{p}}$ is not free.

It is known by work of Avramov, Huneke, and Simis and Vasconcelos that if E has projective dimension one and satisfies F_1, then the Rees algebra of E is Cohen-Macaulay. While the converse does not hold in general, Simis, Ulrich and Vasconcelos proved it holds in the case when E is the module of differentials of a complete intersection over a field of characteristic zero, satisfying F_0. It is an open question whether the assumption that E is F_0 can be removed. In this talk I will describe how to reduce the problem to a linear algebra question about the presentation matrix of E. This is a joint work in progress with Tan Dang. (Received August 29, 2018)

1142-13-89 **Sonja Mapes***, 255 Hurley Hall, Notre Dame, IN 46556, and **Kuei-Nuan Lin**. *Computing projective dimension of monomial ideals via associated hypergraphs and lcm-lattices.*

Given a square-free monomial ideal I in a polynomial ring R over a field k, we would like to know the projective dimension of R/I. We recall the definition of the lcm-lattice of a monomial ideal introduced by Gasharov, Peeva and Welker, and the definition of the dual hypergraph of a square-free monomial ideal introduced by Kimura, Terai and Yoshida. Our work focuses on the relationship between the lcm-lattice and the dual hypergraph of a given square-free monomial ideal. We use the properties of lcm-lattice to find whether two different dual hypergraphs have the same projective dimension, and thus are able to extend some of the results by Lin and Mantero which compute the projective dimensions for ideals with certain hypergraphs. (Received August 30, 2018)

1142-13-91 **Josh H Pollitz*** (jpollitz@huskers.unl.edu), 904 S S 17TH St, APT C2, Lincoln, NE 68508. *The derived category of a locally complete intersection ring.*

Let R be a commutative noetherian ring. It is well known that R is regular if and only if every complex with finitely generated homology is a perfect complex. The goal of this talk is to explain how one can characterize whether R is locally a complete intersection in terms of how each complex with finitely generated homology relates to the perfect complexes. Namely, R is locally a complete intersection if and only if each nontrivial complex with finitely generated homology can build a nontrivial perfect complex in the derived category using finitely many cones and retracts. This characterization gives a completely triangulated category characterization of locally complete intersection rings. In this talk, we will introduce a theory of support varieties and discuss how they can be applied to yield this characterization. (Received August 30, 2018)

1142-13-93 **Jesse S. Keyton***, jskeyton@uark.edu. *On Non-Sequentially Bounded Licci Ideals.* Preliminary report.

In algebraic linkage, significant effort has been made to study the ideals which are in the linkage class of a complete intersection (called licci ideals). For a homogeneously licci ideal, C. Huneke and B. Ulrich asked whether there exists a licci monomial ideal with the same Hilbert function as the given ideal. The question is still open, but K. F. E. Chong formalized the notion of sequentially bounded links and used this idea to identify a class of ideals satisfying the Eisenbud-Green-Harris conjecture, all of which fits into the narrative of the question raised by Huneke and Ulrich. The aim of this talk is to provide evidence that there are examples of licci ideals that are not sequentially bounded licci, which come from a class of ideals constructed by Huneke, Migliore, Nagel, and Ulrich. (Received August 30, 2018)

1142-13-96 **Lars W Christensten**, **Andrew R Kustin** and **Adela N Vraciu*** (vraciu@math.sc.edu). *G-regularity of rings of embedding codepth 3.*

A local ring of embedding codepth 3 is up to completion a quotient of a regular local ring Q by an ideal I of grade 3. These rings have been classified based on the algebra structure of $\operatorname{Tor}^Q_*(Q/I,k)$, where k is the residue class field of Q. It is known that every Poincaré series of a finitely generated module over such a ring can be expressed as a rational function with denominator depending only of the ring. These denominators have been explicitly calculated by L. Avramov. We take advantage of these calculations to prove that all non-Gorenstein local rings of embedding codepth 3 are either embedded deformations or G-regular. (Received August 30, 2018)

1142-13-107 **Hailong Dao***, Department of Mathematics, 405 Snow Hall, 1460 Jayhawk Blvd, Lawrence, KS 66049. *Regularity bounds on linearly presented monomial ideals.*

Let R be a polynomial ring over a field and I a monomial ideal in R with linear presentation. I will discuss recent results giving upper bounds for the Castelnuovo-Mumford regularity of I, and some open questions. Based on joint works with Craig Huneke, Jay Schweig and Thanh Vu. (Received August 30, 2018)

1142-13-117 **Nicholas R Packauskas*** (packauskas@huskers.unl.edu), **Luchezar L Avramov** and **Mark E Walker**. *Quasi-polynomial growth of Betti numbers over local rings.* Preliminary report.

Let Q be a regular local ring and I an ideal generated by a regular sequence of c elements in the square of the maximal ideal. It is known that over the complete intersection $R = Q/I$ that any finitely generated module M has Betti numbers eventually given by quasi-polynomial of degree less than c. That is, there are integer-valued polynomial functions p^M_+ and p^M_- with the same leading term such that $\beta^R_{2i}(M) = p^M_+(2i)$ and $\beta^R_{2i+1}(M) = p^M_-(2i+1)$ for i sufficiently large. We will show that if q is the height of the ideal generated by the quadratic initial forms of I in the associated graded ring of Q, then the degree of $p^M_+ - p^M_-$ is less than $c-q-1$. (Received August 31, 2018)

1142-13-118 **Susan M. Cooper*** (susan.cooper@umanitoba.ca), Department of Mathematics, University of Manitoba, 464 Machray Hall, Winnipeg, MB R3T 2N2, Canada. *Minimum Distance Functions.* Preliminary report.

Motivated by the generalized Hamming weight of a linear code, we consider the generalized minimum distance function (gmd function) of a graded ideal in a polynomial ring. In general, this function is very difficult to compute. We will use commutative algebra to investigate the asymptotic behaviour of the gmd function and techniques to compute it. This is joint work with A. Seceleanu, Ş. Tohăneanu, M. Vaz Pinto and R. Villarreal. (Received August 31, 2018)

1142-13-121 **Rebecca R.G.*** (rrebhuhn@gmu.edu), **Claudia Miller** and **Hamidreza Rahmati**. *Betti numbers of Frobenius powers of ideals in characteristic $p > 0$.* Preliminary report.

Let $R = k[x_1, ..., x_d]/(f)$ where k is a field of characteristic $p > 0$, and f a nonzero element of R. In the case where $d = 3$ and $f = x_1^n + x_2^n + x_3^n$, work of Kustin, Rahmati, and Vraciu indicates that the syzygies of p^eth bracket powers $I^{[p^e]}$ of $I = (x_1^N, x_2^N, x_3^N)$ cycle through a finite number of modules as e increases. We examine the behavior of the betti numbers of $I^{[p^e]}$ when $d = 3$ but f is chosen generically, using the method of finding resolutions via inverse systems as developed by El Khoury-Kustin and Miller-Rahmati. (Received August 31, 2018)

1142-13-133 **Justin Lyle*** (justin.lyle@ku.edu) and **Jonathan Montaño**. *c-Ulrich Modules.* Preliminary report.

Let $(R, \mathfrak{m}, k)$ be a Noetherian local ring. We study Cohen-Macaulay R-modules with the property that $e_R(M) \leq c\mu_R(M)$, which we call c-Ulrich modules. We prove existence in some cases for small values of c, and prove some consequences of existence, extending results of Ulrich and Hanes-Huneke. (Received August 31, 2018)

1142-13-148 **Kriti Goel** and **Vivek Mukundan*** (vm6y@virginia.edu), 141 Cabell Drive, Office 131, Charlottesville, VA 22902, and **Jugal K Verma**. *Tight closure of powers of ideals and tight Hilbert polynomials.*

Let $(R, \mathfrak{m})$ be an analytically unramified local ring of positive prime characteristic p. For an ideal I, let I^* denote its tight closure. We introduce the tight Hilbert function $H_I^*(n) = \ell(R/(I^n)^*)$ and the corresponding tight Hilbert polynomial $P_I^*(n)$ where I is an $\mathfrak{m}$-primary ideal. It is proved that F-rationality can be detected by the vanishing of the first coefficient of $P_I^*(n)$. We find the tight Hilbert polynomial of certain parameter ideals in hypersurface rings and Stanley-Reisner rings of simplicial complexes. (Received September 01, 2018)

1142-13-150 **Michael DiPasquale*** (michael.dipasquale@colostate.edu), 1874 Campus Delivery, Fort Collins, CO 80523, and **Christopher Francisco**, **Jeff Mermin** and **Jay Schweig**. *Asymptotic Resurgence and Integral Closures.*

The symbolic powers of an ideal I, denoted $I^{(s)}$, are an important geometric analogue of taking regular powers. There is significant interest in the containment problem; that is studying which pairs (r, s) satisfy that $I^{(s)} \subset I^r$. A celebrated result of Ein,Lazarsfeld, and Smith and Hochster and Huneke states that $I^{(hr)} \subset I^r$ if I is an ideal with big height h in a regular ring. In an effort to quantify these containment results more precisely, the notions of resurgence and asymptotic resurgence of an ideal were introduced by Bocci and Harbourne and Guardo, Harbourne, and Van Tuyl. We show that the asymptotic resurgence of an ideal can be computed using integral closures, which leads to a characterization of asymptotic resurgence as the maximum of finitely many Waldschmidt-like constants. This is joint work with Chris Francisco, Jeff Mermin, and Jay Schweig. (Received September 01, 2018)

1142-13-152 **Youngsu Kim*** (yk009@uark.edu), 850 W Dickson ST, Fayetteville, AR 72701, and **Lance Edward Miller** and **Wenbo Niu**. *The generic link of a determinantal variety.*

We study singularities of the generic link of a determinantal variety. Let $A := \mathbb{A}^n_{\mathbb{C}}$, and let X and Y be equidimensional subschemes of A. We say that X and Y are *linked* via V if there exists a complete intersection V in A such that $\mathcal{I}_Y/\mathcal{I}_V \cong \mathrm{Hom}_{\mathcal{O}_A}(\mathcal{O}_X, \mathcal{O}_V)$ and $\mathcal{I}_X/\mathcal{I}_V \cong \mathrm{Hom}_{\mathcal{O}_A}(\mathcal{O}_Y, \mathcal{O}_V)$.

Two linked subschemes have many properties in common, and it is believed that the generic link of a variety improves singularities of the variety. Let X be a variety and Y the generic link of X. Recently, W. Niu showed that the log canonical threshold, lct for short, "improves" under taking the generic link, i.e., $\mathrm{lct}\, Y \geq \mathrm{lct}\, X$. It is not known if equality holds in general. In this talk, we show that in the case where X is a determinantal variety, then $\mathrm{lct}\, X = \mathrm{lct}\, Y$. This is joint work with Wenbo Niu and Lance Miller. (Received September 01, 2018)

1142-13-153 **Youngsu Kim*** (yk009@uark.edu), 850 W Dickson ST, Fayetteville, AR 72701, and **Andrew Walker**. *On the Cohen-Macaulayness of non-Noetherian rings.*

The Cohen-Macaulayness of rings and modules is one of the most desired properties in commutative algebra and algebraic geometry. The definition for the Noetherian case, the depth of the module is equal to the dimension of the module, does not extend well to the non-Noehterian case. Under this definition, important classes of non-Noetherian rings, for instance, valuation rings, are not Cohen-Macaulay.

There have been several attempts to extend the definition of Cohen-Macaulay to the non-Noetherian case. We will talk about the definition by Hamilton-Marley, and present a couple of results. This is joint work with A. Walker. (Received September 01, 2018)

1142-13-155 **Michael DiPasquale**, **Christopher A Francisco**, **Jeff Mermin*** (mermin@math.okstate.edu) and **Jay Schweig**. *Asymptotic resurgence via integral closures (the squarefree case).*

Let I be a squarefree monomial ideal. The symbolic powers of I, denoted $I^{(s)}$, are a geometric analog of the regular powers which are in general larger. An important question in the study of symbolic powers is the opposite containment, that is, for which r and s do we have $I^{(s)} \subset I^r$? The statistics *resurgence* and *asymptotic resurgence* describe the ratios $\frac{r}{s}$ which guarantee this containment. We determine the asymptotic resurgence from a study of the Newton and symbolic polyhedra, and show that it is equal to the maximum of a collection

of Waldschmidt-like constants. This is a special case of a more general result on asymptotic resurgence, which will be described by Michael DiPasquale in a separate talk. (Received September 01, 2018)

1142-13-162 **Arindam Banerjee*** (123.arindam@gmail.com), , India, and **Selvi Kara Bayerslan** and **Huy Tai Ha**. *Regularity of powers of edge ideals: from local properties to global bounds.*
In this talk we shall discuss a recent joint work with Selvi Kara Beyarslan and Huy Tai Ha. Let $I = I(G)$ be the edge ideal of a graph G. We give various general upper bounds for the regularity function reg I^s, for $s \geq 1$, addressing a conjecture made by the authors and Alilooee. When G is a gap-free graph and locally of regularity 2, we show that reg $I^s = 2s$ for all $s \geq 2$. This is a slightly weaker version of a conjecture of Nevo and Peeva. Our method is to investigate the regularity function reg I^s, for $s \geq 1$, via local information of I. (Received September 02, 2018)

1142-13-163 **Rasoul Ahangari Maleki** and **Liana M Şega*** (segal@umkc.edu). *Homological properties of spaces of quadrics of low codimension and their applications to local rings.* Preliminary report.
We consider a local ring R with maximal ideal $\mathfrak{m}$ and residue field k whose associated graded ring $A = \mathrm{gr}_{\mathfrak{m}} R$ is a quadratic k-algebra with $\dim_k A \leq 3$. We show that the Poincaré series of all finitely generated R-modules are rational, sharing a common denominator. (Received September 02, 2018)

1142-13-164 **Huy Tai Ha** (tha@tulane.edu), **Selvi Beyarslan Kara** (selvi@southalabama.edu) and **Augustine O'Keefe*** (aokeefe@conncoll.edu). *Algebraic properties of toric rings of graphs.*
Let $G = (V, E)$ be a simple graph. We investigate the Cohen-Macaulayness and algebraic invariants, such as the Castelnuovo-Mumford regularity and the projective dimension, of the toric ring $k[G]$ via those of toric rings associated to induced subgraphs of G. (Received September 02, 2018)

1142-13-166 **Jay Schweig***, jayschweig@gmail.com, and **Russ Woodroofe**. *Order partition lattices.*
We discuss order partition lattices, which are common generalizations of Boolean lattices and classical partition lattices. We show that all such lattices are shellable, generalizing several well-known results. We also prove that their h-vectors satisfy certain enumerative constraints. This is done using a convex-ear decomposition, which is a technique that should be useful to many researchers working in commutative algebra. No prior knowledge of such topics will be assumed. (Received September 02, 2018)

1142-13-178 **Paolo Mantero** and **Matthew Mastroeni*** (mmastro@okstate.edu). *Koszul algebras defined by four quadrics.* Preliminary report.
Let I be an ideal generated by quadrics in a standard graded polynomial ring S over a field. A question of Avramov, Conca, and Iyengar asks whether the Betti numbers of $R = S/I$ over S can be bounded above by binomial coefficients on the minimal number of generators of I if R is Koszul. This question has been answered affirmatively for Koszul algebras defined by three quadrics and Koszul almost complete intersections with any number of generators. We discuss progress towards an affirmative answer to the above question in the case of four quadrics. In the process, we prove structure theorems for the possible height two ideals of four quadrics defining Koszul algebras. (Received September 02, 2018)

1142-13-179 **Jennifer Biermann*** (biermann@hws.edu), **Morgan Gauvin**, **Hugh Mckenny** and **Carlos Munoz**. *Star ideals of graphs.* Preliminary report.
We study a generalization of the edge ideal of a graph called a star ideal in which the minimal monomial generators of the ideal come from subgraphs which are isomorphic to the complete bipartite graph $K_{1,t}$ for a fixed value of t. Unlike the case of edge ideals, there is not a bijection between finite simple graphs and star ideals of graphs. We discuss combinatorial criteria for when a given ideal is the star ideal of a graph as well as algebraic properties of the ideals. (Received September 03, 2018)

14 ► Algebraic geometry

1142-14-42 **Brian Harbourne**, **Juan Migliore*** (migliore.1@nd.edu), **Uwe Nagel** and **Zach Teitler**. *Unexpected Hypersurfaces.*
A flurry of activity has taken place in the last half decade or so on the topic of configurations of points that admit unexpected curves and unexpected hypersurfaces. This work began in the setting of the projective plane, but more recently has moved in interesting ways into the more general setting of higher dimensional projective space.

This work has shown unexpectedness to be related to rank 2 vector bundles on the plane, line arrangements, Terao's conjecture, the Weak and Strong Lefschetz Properties, hyperplane arrangements, and root systems. Also, interesting geometric properties of our configurations have recently presented themselves. I will give an overview of this work, with a slight emphasis on a recent preprint of B. Harbourne, U. Nagel, Z. Teitler and myself. (Received August 20, 2018)

1142-14-76 **David Eklund*** (daek@kth.se). *The numerical algebraic geometry of bottlenecks.*
I will talk about bottlenecks of algebraic varieties in complex affine space. Bottlenecks are lines which are normal to the variety at two distinct points. I will discuss relations to the data analysis of real varieties and the so-called reach of a smooth variety. I will address the enumerative problem of counting the number of bottlenecks as well as the computational problem of formulating efficient numerical homotopies to compute bottlenecks. (Received August 28, 2018)

1142-14-92 **Omprokash Das***, University of California, Los Angeles, Math Science Building 6363, Los Angeles, CA 90095. *Weak-Boundedness of Fano 3-folds in characteristic p>5.*
Constructing the *moduli* of Fano varieties is one of the central problems in the moduli theory and the Minimal Model Program (MMP) in general. The first challenge towards constructing the moduli is proving the boundedness of the moduli functor. This problem is known as the Borisov-Alexeev-Borisov or the BAB conjecture. A weaker version of this conjecture roughly says that the top self-intersection of the anti-canonical divisors $(-K_X)^{\dim X}$ for all Fano varieties X is bounded from above; this is known as the Weak-BAB conjecture. Lots of people have contributed to the proofs of various special cases of these two conjectures in dimension at most 3 in characteristic 0. It is only in the recent years (2016) when Birkar made a breakthrough progress on the BAB conjecture, which lead to his Field Medal this year; In a series of papers, he proved that the BAB conjecture holds in full generality in characteristic 0 and in arbitrary dimension. On the other hand, very little is known on either of these two conjectures in positive characteristic in dimension 3 or higher. In this talk, I will show that a special case of the Weak-BAB conjecture holds for 3-folds in characteristic $p > 5$. (Received August 30, 2018)

1142-14-94 **Samantha Sherman*** (ssherma1@nd.edu) and **Tamara G. Kolda**. *Implicit decomposition of symmetric tensors corresponding to higher-order moments.*
There has lately been interest in tensor decompositions of symmetric tensors that correspond to higher-order moments. These represent mixture models and have applications in signal separation and data analysis. Given a set of p observations of length n, the dth order moment is formed as follows. For each observation, form its d-way outer product, and then sum the d-way outer products for all p observations. Forming this explicitly requires n^d space and $O(pn^d)$ floating point operations (flops). Instead, we show that the moment tensor can be decomposed using only the original $n \times p$ observation matrix, reducing the total space to $O(np)$ and the number of flops to $O(pnr)$. Numerical results confirm our analyses: the implicit method produces the same results as the explicit method and is significantly faster. In fact, the implicit method can solve problems that are prohibitively expensive in the explicit case. (Received August 30, 2018)

1142-14-154 **Fumiaki Suzuki*** (fsuzuk2@uic.edu). *A remark on a 3-fold constructed by Colliot-Thélène and Voisin.*
A classical question asks whether the Abel-Jacobi map is universal among all regular homomorphisms. In this talk, we prove that we can construct a 4-fold which gives the negative answer in codimension 3 if the generalized Bloch conjecture holds for a 3-fold constructed by Colliot-Thélène and Voisin in the context of the study of the defect of the integral Hodge conjecture in degree 4. (Received September 01, 2018)

1142-14-157 **Christopher Chiu**, **Tommaso de Fernex*** (defernex@math.utah.edu) and **Roi Docampo**, UT. *Embedding codimension of spaces of arcs.*
We define a notion of embedding codimension at k-rational points of an arbitrary scheme over a field k. If the scheme is locally of finite type, then this notion agrees with the usual definition given by the difference of the embedding dimension at a point with the local dimension of the scheme. The main theorem is a converse of the Grinberg-Kazhdan-Drinfeld theorem: the two results, combined, provide a characterization of the k-valued arcs on a variety that are not fully contained in the singular locus of the variety as those defining k-rational points on the arc space of the variety where the embedding codimension is finite. (Received September 01, 2018)

1142-14-160 **Joaquin Moraga*** (moraga@math.utah.edu). *Good elephants and tigers.*
Given a projective morphism of normal quasi-projective varieties $X \to Z$ such that X has ϵ-log canonical singularities and K_X is ample (resp. anti-ample) over Z, it is natural to try to find the smallest n so that the

linear system $|nK_X|$ (resp. $|-nK_X|$) contains an element B with *good singularities* over a fixed point $z \in Z$, i.e. the pair (X, B) is δ-log canonical over z. Such B will be called a **good tiger** (resp. **elephant**).

The problem of bounding good elephants and/or tigers consists of proving that such n can be bounded by some invariants of $X \to Z$. In the case where $Z = \mathrm{Spec(k)}$, these problems are implied by boundedness results due to Birkar and Hacon-McKernan-Xu respectively. In this talk, we will present some general conjectures in the case that $\dim(Z) \geq 1$ and some partial results towards these conjectures. (Received September 02, 2018)

1142-14-168 **Takumi Murayama*** (takumim@umich.edu), Department of Mathematics, University of Michigan, 530 Church St, Ann Arbor, MI 48109-1043. *Seshadri constants and singularities.*

Frobenius–Seshadri constants are positive characteristic analogues of Seshadri constants, which were introduced by Mustaţă–Schwede and the presenter as a way to measure local positivity of line bundles in positive characteristic. We describe how Frobenius–Seshadri constants can be used to study Seshadri constants on singular varieties, giving new results even over the complex numbers. In particular, we will explain the interaction between Seshadri constants and log canonical thresholds, and how Frobenius–Seshadri constants can be used to prove a weak version of Fujita's conjecture that asserts generic global generation for big and nef Cartier divisors in characteristic zero or ample and free Cartier divisors in positive characteristic. (Received September 02, 2018)

1142-14-172 **Zhixian Zhu*** (zhixianz@ucr.edu) and **Fei Ye** (feye@qcc.cuny.edu). *Cutting down minimal log canonical centers.*

Let X be a smooth projective variety of dimension n and A any ample line bundle. Fujita conjectured that the adjoint line bundle $\mathcal{O}(K_X + mA)$ is globally generated for any m greater or equal to $\dim(X) + 1$. One of the standard technique in the study of Fujita's freeness conjecture is an induction method, so called cutting down minimal log canonical center. More explicitly, we constructed an effective $\mathbb{Q}$–divisor D linearly equivalent to λmA for some positive number $\lambda < 1$ such that the minimal log canonical center at a point is 0-dimensional. We applied this method to prove the Fujita's freeness conjecture for 5-folds. By cutting down minimal log canonical center, Ito recently obtained a Reider-type theorem for higher syzygies on abelian surfaces. We now are working on prove a similar result on abelian 3-folds. (Received September 02, 2018)

1142-14-173 **Luigi Lombardi*** (luigi.lombardi@unifi.it), Viale Morgagni 67/A, 50134 Florence, FI, Italy. *Derived equivalence of varieties and fibrations over curves and surfaces.*

The bounded derived category of coherent sheaves on a smooth projective variety has two basic features: on one hand it is a natural object where to perform cohomological computations, on the other hand it encodes several aspects of the birational geometry of the variety itself. In this talk I will show how an equivalence of derived categories of two smooth projective varieties induces a base-preserving bijection between their sets of fibrations over curves of genus at least two. Moreover, I will show how this result can be extended to the case of fibrations over surfaces of maximal Albanese dimension and positive holomorphic Euler characteristic if the Hodge number $h^{0,2}$ were a derived invariant. (Received September 02, 2018)

1142-14-181 **Daniel Hernandez**, **Mordechai Katzman** and **Karl Schwede*** (schwede@math.utah.edu), Department of Mathematics, University of Utah, Salt Lake City, UT 84112, and **Pedro Teixeira** and **Emily Witt**. *The TestIdeals.m2 and FThresholds.m2 packages for Macaulay2.*

I will discuss two new and updated packages for the Macaulay2 computer algebra system. I will discuss and demonstrate both what these packages can do and some of the mathematics behind their algorithms. (Received September 04, 2018)

1142-14-199 **Wenrui Hao**, **Jonathan D Hauenstein**, **Margaret H Regan*** (mregan9@nd.edu) and **Tingting Tang**. *Numerically solving elliptic PDEs on real algebraic curves and surfaces.*

There exist many methods for solving elliptic PDEs on manifolds, but fewer when it comes to real closed curves and surfaces defined by a system of polynomial equations. Our method is based on a finite difference numerical scheme with numerical algebraic geometry using a local parameterization near the singularities. This talk will present several examples to highlight the method. (Received September 03, 2018)

1142-14-244 **Jae Mo Shin***, CRG, Cresskill, NJ, NJ , and **Richard Kyung**, CRG, Cresskill, NJ. *Study on the Calculus of Variations and Lagrange multipliers to Solve Isoperimetric Problems.*

In this paper, Lagrange multipliers and a few theorems were stated to prove the isoperimetric inequality.

The idea of Lagrange multipliers can be used to maximize or minimize a certain function under a constraint assuming that such extrema exist. The theorem of Lagrange multipliers is the main method that we discussed throughout this paper. Also we stated how the theorem was applicable to specific example.

Fundamental Lemma of the Calculus of Variations and Euler Lagrange equation were explained, thereafter the isoperimetric inequality in 3D case under certain restrictions was stated. The surface area of a surface of revolution was considered and the volume was calculated. The final solution of derived differential equation was found to be a sphere after the rotation. (Received September 05, 2018)

16 ► Associative rings and algebras

1142-16-126 **Luigi Ferraro*** (ferrarl@wfu.edu), **Ellen Kirkman**, **Frank Moore** and **Robert Won**. *Hopf algebra actions on some AS regular algebras of small GK dimension.*

The classical Chevalley-Shephard-Todd Theorem gives a characterization of when a group acting linearly on the commutative polynomial ring has a ring of invariants that is isomorphic to a polynomial ring. Understanding when group actions (or more generally, Hopf actions) on AS regular algebras give AS regular invariant rings has proven to be a difficult problem. We provide some new examples of Hopf actions on some AS regular algebras such that the ring of invariants is also AS regular. (Received August 31, 2018)

17 ► Nonassociative rings and algebras

1142-17-37 **Fatemeh Bagherzadeh** and **Murray Bremner*** (bremner@math.usask.ca). *Cohomology of totally associative n-ary algebras.*

The cup product in the cohomology of an algebra over a quadratic operad has usually been considered only in an abstract setting, using Koszul duality, without explicit calculations in particular cases. For totally associative n-ary algebras, the cup product endows the cochain complex with the structure of a partially associative n-ary algebra. The defining relations for n-ary partial associativity depend on the parity of n. For $n = 2$, total and partial associativity coincide, and we obtain the classical cohomology theory of associative algebras. For $n = 3$ and $n = 4$, we provide an explicit definition of the cup product, and prove that it satisfies partial associativity. (Received August 17, 2018)

1142-17-149 **Mohamed Elhamdadi**, **Masahico Saito** and **Emanuele Zappala*** (zae@mail.usf.edu), 4202 E Fowler Ave, CMC 342, Tampa, FL 33620-5700. *Continuous Cohomology of Topological Quandles.*

Quandles are algebraic objects whose defining axioms are inspired by the Reidemeister moves on knot diagrams. Their main application, not surprisingly, comes from the classification of knots: The knot quandle is in fact known to be a complete invariant of knots, up to orientation and reversed mirror image. Their topological counterpart, called topological quandles, has been introduced by R.L. Rubinzstein to produce invariants of knots and links. In this talk, I will give the definition of continuous cohomology groups of topological quandles and investigate their main features such as: extensions of topological quandles and their correspondance with continuous second cohomology groups, inverse limits of quandles and their continuous cohomology groups. (Received September 01, 2018)

1142-17-184 **Liudmila Sabinina*** (liudmila@uaem.mx), av. Universidad 1001, 62209 Cuernavaca, Morelos, Mexico. *On one variety of binary Lie algebras.*

I will discuss the properties of the binary Lie algebras defined by the additional identity J(x, y, zt) = 0, where J(a, b, c) = a(bc) + b(ca) + c(ab). En particular the structure of the free algebra of this variety will be described. I will use the material from our joint work with R. Carrillo-Catalan, A.Grishkov, O.Guajardo Garza and M. Rasskazova. (Received September 03, 2018)

1142-17-225 **Kayla Murray***, 5210 Grand Ave, P.O. Box 3649, Fort Smith, AR 72913-3649. *Graded Representations of Current Algebras.*

One motivation for studying graded representation of current algebras is the desire to understand irreducible representations for quantum affine Lie algebras. The representations of current algebras we will focus on are Chari-Venkatesh modules, which are associated to a partition. In the case of a simply laced Lie algebra, this family of modules includes both Demazure modules and local Weyl modules. In this talk, we will discuss what is known about the structure of these representations. (Received September 04, 2018)

18 ► Category theory; homological algebra

1142-18-38 **Jonathan Smith***, 411 Morrill Road, Dept. of Math., ISU, Ames, IA 50011-2104.
Cohomology for Maltsev varieties.

We present a cohomology theory for Maltsev varieties that embraces classical algebras such as groups, Lie algebras, and nonunital (not necessarily associative) rings, as well as more exotic structures such as loops and quasigroups. The theory is based on Duskin's triple or monadic cohomology, but exploits special properties of Maltsev varieties, including the well-behaved theory of centrality, the commuting of congruences, and an abstract version of the Kan filler condition. It provides a classification of both singular and nonsingular extensions, as well as obstructions to extensions. (Received August 19, 2018)

1142-18-220 **Radmila Sazdanovic*** (rsazdan@ncsu.edu), Department of Mathematics NC State Univeristy, Raleigh, NC 27695-8205, and **Mikhail Khovanov**. *A categorification of the polynomial ring $\mathbb{Z}[x]$.* Preliminary report.

We introduce a categorification of the one-variable polynomial ring $\mathbb{Z}[x]$, based on the geometrically defined graded algebra. This construction is generalized to the categorification of some basic special functions. (Received September 04, 2018)

1142-18-229 **Peter W. Ulrickson*** (ulrickson@cua.edu), Department of Mathematics, 620 Michigan Ave N.E., Washington, DC, DC 20064, and **Markus Szymik**. *Categorical Perspectives on Quandles and Racks.* Preliminary report.

We present principal features of the categories of racks and quandles and sketch relations of these categories with noteworthy elementary categories. (Received September 04, 2018)

19 ► K-theory

1142-19-88 **Mladen Bestvina**, **Koji Fujiwara** and **Derrick Wigglesworth*** (derrick.wigglesworth@gmail.com). *The Farrell-Jones conjecture for free-by-cyclic groups.*

The Farrell-Jones conjecture for a group G is an important conjecture in manifold theory that provides a means of computing several obstructions (e.g., Whitehead torsion) that are important for using surgery theory on non-simply connected manifolds. I will review some of its consequences and will discuss several classes of groups for which it is known, (e.g., 3-manifold groups, hyperbolic groups, solvable groups). Finally, I will discuss a proof that free-by-cyclic groups satisfy FJC, answering a question of Lueck. This is joint work with Mladen Bestvina and Koji Fujiwara. (Received August 30, 2018)

20 ► Group theory and generalizations

1142-20-70 **Ben Stucky*** (bwstucky@ou.edu). *Cubulating one-relator products with torsion.*

In 2013, Joseph Lauer and Daniel Wise showed that a one-relator group whose defining relator has exponent at least 4 admits a proper, cocompact action on a CAT(0) cube complex, thus verifying a powerful non-positive curvature condition for these groups. To do this, they build a system of nicely-behaved codimension-1 subspaces ("walls") in the universal cover and invoke a construction due to Sageev. After introducing the necessary background material, I will describe a generalization of this result to one-relator products, namely, that a one-relator product of locally indicable groups whose defining relator has exponent at least 4 admits a geometric action on a CAT(0) cube complex if the factors do. (Received August 27, 2018)

1142-20-74 **Matt Clay** and **Caglar Uyanik*** (caglar.uyanik@yale.edu). *An atoroidal subgroup alternative for $Out(F_N)$.*

We prove an analog of Ivanov's subgroup alternative theorem for mapping class groups in the $Out(F_N)$ setting. Precisely, we show that every subgroup $\mathcal{H}$ of $Out(F_N)$ either contains an atoroidal element or a finite index subgroup $\mathcal{H}'$ of $\mathcal{H}$ fixes a nontrivial conjugacy class in F_N. The techniques involve hyperbolic geometry, dynamics and ergodic theory. (Received August 28, 2018)

1142-20-77 **Sahana H Balasubramanya*** (hbsahana@gmail.com). *Hyperbolic Structures on Wreath Products.*

The poset of hyperbolic structures on a group G; denoted $\mathcal{H}(G)$; is still very far from being understood and several questions remain unanswered. In this talk, I will speak about some new results that describe some

hyperbolic structures on the wreath product $G \operatorname{wr} \mathbb{Z}$, for any group G. As a consequence, I answer two open questions regarding quasi-parabolic structures: I will give an example of a group with an uncountable chain of quasi-parabolic structures and give examples of groups that have finitely many quasi-parabolic structures. (Received August 28, 2018)

1142-20-78 **Pallavi Dani**, **Matthew Haulmark** and **Genevieve Walsh***, genevieve.walsh@gmail.com. *Non-planar boundaries of right-angled Coxeter groups.* Preliminary report.

We give some conditions on the defining graph Γ of a right-angled Coxeter group $G(\Gamma)$ which ensures that the boundary $\partial G(\Gamma)$ is non-planar. The proof uses (in a mild way) the dynamics of a group action on its boundary. We will also give some interesting and perhaps surprising examples. (Received August 28, 2018)

1142-20-85 **Jean Pierre Mutanguha*** (jpmutang@uark.edu). *Hyperbolic Endomorphisms of Free Groups.*

We show that the fundamental group of a mapping torus of a graph immersion $f : \Gamma \to \Gamma$ is word-hyperbolic if and only if it has no Baumslag-Solitar subgroups. Bestvina-Feighn and Brinkmann studied the case when f is a homotopy equivalence; Kapovich and Gautero studied special types if π_1-injective maps f; we extend these previous results to maps f that induce fully irreducible endomorphisms $f_* : F_n \to F_n$. (Received August 29, 2018)

1142-20-97 **Robert W Bell*** (rbell@math.msu.edu) and **Rita Gitik** (ritagtk@umich.edu). *Quasi-positivity and recognition of products of conjugacy classes in free groups.*

We formulate an algorithm for recognizing whether a given word in a free group $F(X)$ is equal to a product of conjugates of positive powers of basis elements. Such a word is called quasi-positive. The study of quasi-positivity in braid groups has important connections to contact topology and knot theory. Our investigation is motivated by this problem. The algorithm we construct is based on a theorem of Gersten that gives a topological characterization of when, for a given finite sequence $(w_1, \ldots, w_k)$ of words in $F(X)$, there exist elements $c_1, \ldots, c_k \in F(X)$ such that $w_1^{c_1} \cdots w_k^{c_k} = 1$. (Received August 30, 2018)

1142-20-143 **Carolyn Abbott*** (c_abbott@math.berkeley.edu) and **Francois Dahmani**. *Property P_{naive} for acylindrically hyperbolic groups.*

We show that under mild hypotheses, an acylindrically hyperbolically group satisfies a strong ping-pong condition, called property P_{naive}, which, roughly speaking, allows one to construct many free subgroups in such a group. I will describe this property and discuss various consequences of it. (Received September 01, 2018)

1142-20-171 **Justin Lanier*** (jlanier8@gatech.edu) and **Dan Margalit**. *Normal generators for mapping class groups are abundant.*

For mapping class groups of surfaces, we provide a number of simple criteria that ensure that a mapping class is a normal generator—that is, its normal closure equals the whole group. We then apply these criteria to show that every nontrivial periodic mapping class that is not a hyperelliptic involution is a normal generator whenever genus is at least 3. We also show that every pseudo-Anosov mapping class with stretch factor less than $\sqrt{2}$ is a normal generator. That pseudo-Anosov normal generators exist at all answers a question of Darren Long from 1986. In addition to discussing these results, we will describe several ways in which they can be leveraged to answer other questions about mapping class groups. This is joint work with Dan Margalit. (Received September 04, 2018)

1142-20-176 **Marissa Kawehi Loving*** (mloving2@illinois.edu). *Length spectra of flat metrics coming from q-differentials.*

When geometric structures on surfaces are determined by the lengths of curves, it is natural to ask *which* curves' lengths do we really need to know? It is a classical result of Fricke that a hyperbolic metric on a surface is determined by its marked simple length spectrum. More recently, Duchin–Leininger–Rafi proved that a flat metric induced by a unit-norm quadratic differential is also determined by its marked simple length spectrum. In this talk, I will describe a generalization of the notion of simple curves to that of *q-simple curves*, for any positive integer q, and show that the lengths of q-simple curves suffice to determine a non-positively curved Euclidean cone metric induced by a q-differential metric. (Received September 03, 2018)

1142-20-185 **Nick Salter** and **Bena Tshishiku*** (tshishikub@gmail.com). *Surface bundles, monodromy, and arithmetic groups.*

In the 1960s Atiyah and Kodaira constructed surface bundles over surfaces with many interesting properties. The topology of such a bundle is completely encoded in its monodromy representation (a homomorphism to a mapping class group), and it is an interesting problem to understand precisely how the topology of the bundle is reflected in algebraic properties of the monodromy. The main result of this talk is that the Atiyah–Kodaira bundles have arithmetic monodromy groups. As an application, using work of L. Chen, one can show that Atiyah–Kodaira bundles fiber in exactly two ways. This is joint work with Nick Salter. (Received September 03, 2018)

1142-20-188 **Emily Stark***, emily.stark@technion.ac.il. *Cannon–Thurston maps in non-positive curvature.*

Two far-reaching methods for studying the geometry of a finitely generated group with non-positive curvature are (1) to study the structure of the boundary of the group, and (2) to study the structure of its finitely generated subgroups. Cannon–Thurston boundary maps allow one to combine these approaches. Mitra (Mj) generalized work of Cannon and Thurston to prove the existence of Cannon–Thurston maps for any normal hyperbolic subgroup of a hyperbolic group. I will explain why a similar theorem fails for certain CAT(0) groups and how we use Cannon–Thurston maps to obtain structure on the boundary of certain hyperbolic groups. This is joint work with Algom-Kfir–Hilion and Beeker–Cordes–Gardham–Gupta. (Received September 03, 2018)

1142-20-202 **J. D. Phillips*** (jophilli@nmu.edu). *On the structure of AG (and related) groupoids.* Preliminary report.

We give some structure theorems for AG groupoids and related structures. We also organize some of these algebras in a fitting setting. (Received September 03, 2018)

1142-20-208 **Alex W Nowak*** (anowak@iastate.edu). *Quasigroup modules and extensions of Mendelsohn triple systems.* Preliminary report.

In the representation theory of quasigroups, modules arise as representations of the quotient of an integral group ring. The nature of this ring depends on the (universal algebraic) variety in which the quasigroup is situated. Of interest to us is the variety of Mendelsohn quasigroups, denoted **MTS** and specified by the identities $(yx)y = x$ (semisymmetry) and $x^2 = x$ (idempotence). These quasigroups offer algebraic descriptions of a class of balanced incomplete block designs known as Mendelsohn triple systems. The ring of representation for a Mendelsohn quasigroup factorizes as a coproduct of rings, and it does so in a manner that reflects the geometry of the corresponding block design. After describing these rings, we present results on extensions of Mendelsohn quasigroups in the module-theoretic context. (Received September 04, 2018)

1142-20-217 **Ken Bromberg*** (ken.w.bromberg@gmail.com), **Mladen Bestvina** and **Koji Fujiwara**. *Embedding groups in finite products of quasi-trees.*

We describe a construction for embedding residually finite hyperbolic groups in a finite product of quasi-trees. If time permits we will also discuss how the method can be extended to the mapping class group. (Received September 04, 2018)

1142-20-230 **Michael Kinyon*** (mkinyon@du.edu), 2390 S York St, Denver, CO 80208. *Left braces, automated deduction, and the Yang-Baxter equation.*

A left brace $(B, +, \cdot)$ consists of an abelian group $(B, +)$, a group $(B, \cdot)$, and the identity $x(y + z) + x = xy + xz$ holds. Right braces and two-sided braces are defined in the obvious way. On a left brace $(B, +, \cdot)$, define another operation $x * y = xy - x - y$. Then B is two-sided if and only if $(B, +, *)$ is a (Jacobson) radical ring. Thus one-sided braces can be seen as a generalization of such rings.

Braces were introduced by Rump (2007) to study nondegenerate involutive set-theoretic solutions of the Yang-Baxter equation. To every left brace B, there is a corresponding solution of the YBE on B, while for any solution (X, r) of the YBE, there is a left brace structure on the structure group of (X, r).

Since first introduced, braces have been generalized in various ways: including skew braces ($(B, +)$ is just a group) and semibraces ($(B, +)$ is just a semigroup). Each generalization has brought with it nondegenerate solutions of YBE. In the meantime, two open problems emerged which lent themselves well to automated deduction. I will survey all of the above, and discuss my own contributions:

1) A brace $(B, +, \cdot)$ is two-sided if and only if $*$ is associative,

2) In a semibrace $(B, +, \cdot)$, $(B, +)$ is a completely simple semigroup. (Received September 04, 2018)

1142-20-232 **Petr Vojtěchovský*** (petr@math.du.edu), Department of Mathematics, University of Denver, 2390 S York St, Denver, CO 80208. *A class of latin set-theoretical solutions of the Yang-Baxter equation.* Preliminary report.

We present recent results on quasigroups satisfying the identity $(xy)(xz) = (yx)(yz)$. These form a class of latin set-theoretical solutions of the Yang-Baxter equation, originally introduced by W. Rump. This is joint work with M. Bonatto, M. Kinyon, D. Stanovský and S. Yang. (Received September 04, 2018)

1142-20-237 **Ales Drapal***, drapal@karlin.mff.cuni.cz. *Extremely nonassociative quasigroups.*

Up to recently it was not known whether there exist finite idempotent quasigroups such that every associative triple has to be diagonal. This means that $x(yz) = (xy)z$ always implies $x = y = z$. The existence of such quasigroups will be reported within a framework that will encompass (1) a precise definition of an extremely nonassociative quasigroup (including nonidempotent cases), (2) construction methods of such quasigroups and (3) a report on computer based search. (Received September 04, 2018)

1142-20-242 **Alexander Grishkov**, **Diana Rasskazova**, **Marina Rasskazova** and **Izabella Stuhl*** (ius68@psu.edu). *On some progress in Steiner loops.*

Steiner loops are non-associative algebraic objects originated from Steiner triple systems. In this talk, I will present the classification of finite 3-generated 2-step nilpotent Steiner loops. Furthermore, the universal central extension of Steiner loops will be discussed. (Received September 04, 2018)

1142-20-243 **Ignat Soroko*** (ignatsoroko@lsu.edu), Louisiana State University, 303 Lockett Hall, Baton Rouge, LA 70803. *On intersections and joins in free groups.*

The famous Hanna Neumann Theorem stipulates that for the ranks of arbitrary subgroups H and K of a nonabelian free group we have: $\operatorname{rank} H \cap K - 1 \leq (\operatorname{rank} H - 1)(\operatorname{rank} K - 1)$. It is an interesting open question to quantify this bound with respect to the rank of $H \vee K$, the subgroup generated by H and K. We describe a set of realizable values $(\operatorname{rank} H \vee K, \operatorname{rank} H \cap K)$ for arbitrary H, K, and conjecture that this locus is complete. Using graph-theoretic techniques introduced by Dicks, we show that the region

$$\operatorname{rank} H \vee K \geq \operatorname{rank} H + \operatorname{rank} K - 3 \quad \& \quad \operatorname{rank} H \cap K \geq 4$$

consists of non-realizable values, thus resolving the remaining open case of R. Guzman's conjecture in the affirmative and obtaining applications to 3-dimensional topology. (Received September 04, 2018)

22 ► Topological groups, Lie groups

1142-22-104 **Kathryn Mann*** (mann@math.brown.edu). *Group actions, geometry and rigidity.*

Classical representation theory is concerned with representations of discrete groups into linear groups; in topological or smooth dynamics we study representations of discrete groups into the group of homeomorphisms or diffeomorphisms of a manifold (i.e. group actions) and the stability or flexibility of these representations under perturbation.

This is already a deep and interesting subject when the manifold in question has dimension 1. This is the subject of my talk: I will introduce you to the theory of groups acting on the circle, its connections with geometric topology and dynamics, and some remarkable subtle parallels with the classical case of reps to Lie groups. This will motivate and illustrate a very recent result, joint with Maxime Wolff, that says that rigidity of actions of surface groups always comes from an underlying geometric structure. (Received August 30, 2018)

26 ► Real functions

1142-26-127 **Amalia Culiuc*** (aculiuc@amherst.edu), **Robert Kesler** and **Michael Lacey**. *Sparse bounds for the discrete cubic Hilbert transform.*

For finitely supported functions f on $\mathbb{Z}$, the discrete cubic Hilbert transform is given by

$$H_3 f(n) = \sum_{m \neq 0} \frac{f(n - m^3)}{m}.$$

We prove that there exists $r < 2$ such that H_3 is dominated by an (r, r) sparse form. This result is the first of this type, concerning discrete harmonic analytic operators and immediately implying new weighted inequalities. (Received August 31, 2018)

28 ► Measure and integration

1142-28-14 **Vyron S Vellis*** (vyron.vellis@uconn.edu), Department of Mathematics, University of Connecticut, 341 Mansfield Road U1009, Storrs, CT 06269-1009. *Holder curves and the traveling salesman problem.*

Given a bounded set $E \subset \mathbb{R}^n$, when is it possible to construct a nice map (Holder, Lipschitz) from the unit interval into $\mathbb{R}^n$ so that E is contained in its image? In this talk we approach this question from two different directions. In this talk we discuss an extension of Peter Jones' traveling salesman construction, which provides a sufficient condition for E to be contained in a $(1/s)$-Hölder curve, $s \geq 1$. The original result, corresponding to the case $s = 1$, identified subsets of rectifiable curves. When $s > 1$, $(1/s)$-Hölder curves are more exotic objects than rectifiable curves that include snowflake curves and space-filling curves as basic examples. This talk is based on a joint work with Matthew Badger and a joint work with Matthew Badger and Lisa Naples. (Received July 23, 2018)

1142-28-53 **R M Brown**, **C W Lee** and **K A Ott*** (kott@bates.edu). *Estimates for Brascamp-Lieb forms in L^p-spaces with power weights.*

We establish a set of necessary conditions and a set of sufficient conditions for boundedness of a family of Brascamp-Lieb forms in Lorentz spaces and L^p-spaces with power weights. (Received August 24, 2018)

1142-28-64 **Tim M Wildey*** (tmwilde@sandia.gov), P.O. Box 5800, Albuquerque, NM 87185-1318, and **Troy Butler** and **John Jakeman**. *The Consistent Bayesian Approach for Stochastic Inverse Problems.*

Uncertainty quantification is challenging for large-scale multiphysics applications where the number of uncertain parameters may be large, the number of high-fidelity model evaluations may be limited, and the available data may be corrupted by significant noise. The recently developed consistent Bayesian approach solves a specific stochastic inverse problem based on the measure-theoretic principles. This approach produces a pullback density on the parameters that is consistent in the sense that the push-forward of this density matches the given distribution on the observable data. While the consistent Bayesian approach is theoretically sound and conceptually simple, it does require approximating the push-forward of an initial probability density through the computational model. While this is certainly nontrivial, we can leverage advanced approaches for forward propagation of uncertainty to reduce the online computational burden. In this presentation, we give an overview of the consistent Bayesian approach and discuss some of the challenges in applying this methodology in the context of large-scale multiphysics problems. Numerical results will be presented to highlight various aspects of this consistent Bayesian approach and to compare with the standard Bayesian formulation. (Received August 27, 2018)

30 ► Functions of a complex variable

1142-30-27 **Dima Khavinson*** (dkhavins@usf.edu), Department of Mathematics, University of South Florida, Tampa, FL 33620. *On Interplay between Algebra and PDE.*

I shall discuss O. Hesse's conjecture for homogeneous polynomials and B. I. Korenblum's conjecture on algebras of harmonic functions from the standpoint of nonlinear first-order PDE. Also, a recent theorem of T. McKinley and B. Shekhtman for polynomials is extended to a much wider class of linear PDE with entire coefficients. (Received August 13, 2018)

1142-30-44 **J. E. Pascoe**, **Meredith Sargent*** (sargent@uark.edu) and **Ryan Tully-Doyle**. *Escaping Nontangentiality: Amortization and Auguries.*

A classical Julia-Carathéodory theorem states that if there is a sequence tending to τ in the boundary of a domain D along which the Julia quotient is bounded, then the function φ can be extended to τ such that φ is nontangentially continuous and differentiable at τ and $\varphi(\tau)$ is in the boundary of Ω.

We develop a theory in the case of Pick functions where we consider sequences that approach the boundary in a controlled tangential way, yielding necessary and sufficient conditions for higher order regularity. In this talk, we discuss some of the technical details involved, including amortization of the Julia Quotient, γ-regularity, and γ-auguries. (Received August 21, 2018)

1142-30-110 **Catherine Beneteau*** (cbenetea@usf.edu), 4202 E. Fowler Ave., CMC 342, Tampa, FL 33620. *Limiting Behavior of Optimal Polynomial Approximants in Hardy and Bergman Spaces.* Preliminary report.

In this talk, I will discuss the limiting behavior of certain polynomials that approximate, in some optimal way, inverses of functions in Dirichlet-type function spaces of the unit disk. These polynomials are closely related to classical objects in function theory such as orthogonal polynomials and reproducing kernels in weighted spaces. This work is joint with Myrto Manolaki and Daniel Seco. (Received August 31, 2018)

1142-30-115 **Daniel H Luecking*** (luecking@uark.edu), Dept. of Mathematical Sciences, 1 University of Arkansas, Fayetteville, AR 72701. *Non-uniformly discrete interpolating and sampling sequences for certain weighted Bergman spaces.* Preliminary report.

In previous work I showed that, if the notion of interpolation is suitably generalized, then we can characterize interpolating sequences for Bergman spaces in the unit disk that are not uniformly discrete. In case the sequence is uniformly discrete this notion reduces to the normal notion of interpolation, or to multiple interpolation (interpolation of values plus derivatives). A similar scheme, applied to sampling, was carried out by my student Newton H. Foster V, in his thesis. In this talk, we discuss the extension of these results to weighted Bergman space with weights of the form $e^{-\phi}/(1-|z|^2)$ for certain subharmonic functions ϕ. (Received August 31, 2018)

1142-30-212 **Javad Mashreghi*** (javad.mashreghi@mat.ulaval.ca), 1960 Boul Laurier, Quebec, QC G1S 1M8, Canada. *The last harmonic in Taylor polynomials.*

Taylor polynomials are natural objects for approximation in function spaces. Indeed, it works in several function spaces, e.g., Hardy and Bergman spaces. However, it also fails in some cases and a remedy is needed, e.g., in disc algebra and weighted Dirichlet spaces. We show that in the latter, Taylor polynomials may diverge. However, by properly adjusting the last coefficient we produce a convergent sequence in local Dirichlet spaces. (Received September 04, 2018)

31 ► Potential theory

1142-31-22 **Murat Akman*** (murat.akman@uconn.edu), 341 Mansfield Road, Unit 1009, Department of Mathematics, University of Connecticut, Storrs, CT 06269. *Perturbations of elliptic operators on non-smooth domains.* Preliminary report.

In this talk, we study perturbations of elliptic operators on domains with rough boundaries. In particular, we focus on the following problem: suppose that we have "good estimates" for the Dirichlet problem for a uniformly elliptic operator L_0, under what optimal conditions, are those good estimates transferred to the Dirichlet problem for uniformly elliptic operator L which is a "perturbation" of L_0?

We prove that if discrepancy between L_0 and L satisfies certain smallness assumption then the elliptic measure ω_L corresponding to L is in the reverse Hölder class with exponent 2 with respect to the elliptic measure ω_{L_0} corresponding to L_0 when the domain is 1-sided NTA satisfying the capacity density condition. Our work extends classical results of Fefferman, Kenig, and Pipher in Lipschitz domains, and Milakis, Pipher, and Toro in chord-arc domains to 1-sided NTA domains satisfying the CDC.

This is a joint work in progress with Steve Hofmann, José María Martell, and Tatiana Toro. (Received August 08, 2018)

32 ► Several complex variables and analytic spaces

1142-32-11 **Jiri Lebl***, lebl@okstate.edu, and **Alan Noell** and **Sivaguru Ravisankar**. *Levi-flat Plateau problem.*

The Levi-flat Plateau problem asks for a Levi-flat hypersurface with boundary H given a compact boundary M. The problem has a solution with possible self intersection given that M is an image of a compact hypersurface in $\mathbb{C}^n \times \mathbb{R}$ with elliptic CR singular points. (Received July 06, 2018)

1142-32-16 **Timothy G Clos** and **Mehmet Çelik*** (mehmet.celik@tamuc.edu), Department of Mathematics, P.O. Box 3011, Commerce, TX 75429, and **Sönmez Şahutoğlu**. *Compactness of Hankel operators with symbols continuous on the closure of pseudoconvex domains.*

Let Ω be a bounded pseudoconvex domain in $\mathbb{C}^2$ with Lipschitz boundary or a bounded convex domain in $\mathbb{C}^n$ and $\phi \in C(\overline{\Omega})$ such that the Hankel operator H_ϕ is compact on the Bergman space $A^2(\Omega)$. Then $\phi \circ f$ is holomorphic

for any holomorphic $f : \mathbb{D} \to b\Omega$. (This work is a colaboration with Timothy G. Clos and Sönmez Şahutoğlu, both from University of Toledo, Ohio) (Received July 27, 2018)

1142-32-18 **Debraj Chakrabarti*** (chakr2d@cmich.edu) and **Sonmez Sahutoglu** (sonmez.sahutoglu@utoledo.edu). *The restriction operator on Bergman spaces.*

Let Ω be a domain in $\mathbb{C}^n$, and U an open subset of Ω. We study the analytic properties of the restriction operator from the Bergman space $A^2(\Omega)$ to the Bergman space $A^2(U)$. We are particularly interested in properties such as closed range and compactness. It turns out that the restriction operator is closely related to the Toeplitz operator on $A^2(\Omega)$ whose symbol is the the characteristic function of U, and this allows us to use methods from the theory of Toeplitz operator to answer some of the natural questions about the restriction operator. (Received July 30, 2018)

1142-32-46 **Yunus E Zeytuncu*** (zeytuncu@umich.edu), 2048 Evergreen Road, Dearborn, MI 48128. *Spectra of Kohn Laplacians on Spheres.*

In this talk, we study the spectrum of the Kohn Laplacian on the unit spheres in $\mathbb{C}^n$ and revisit Folland's classical eigenvalue computation. We also look at the growth rate of the eigenvalue counting function in this context. Finally, we compute the eigenvalues of the perturbed Kohn Laplacian on the Rossi sphere in $\mathbb{C}^2$. We present some computational results in *SymPy* that lead to an understanding of spectra of more general second order differential operators on abstract CR manifolds. (Received August 22, 2018)

1142-32-71 **Albert Boggess*** (boggess@asu.edu), School of Math and Statistical Sciences, Arizona State University, Tempe, AZ 85287-1804, and **Andrew Raich**. *Estimates on the Fundamental Solution to the Complex Green Operator in Higher Codimension.* Preliminary report.

The goal of this work (joint with Andy Raich, University of Arkansas) is to discuss recent progress on the estimates of the fundamental solution to the Kohn Laplacian (Box_b) in higher codimension. Unlike the hypersurface case, little is known about these estimates. In this talk, an explicit formula will be presented for the fundamental solution to Box_b for each of three "model" quadrics which have codimension two in C^4 and their estimates will be discussed. The kernel in one of these models is quite a bit more singular than the others and the estimates in this case have no known relationship to familiar metrics in geometry such as the Szego metric or sum of squares metric. Generalizations and conjectures for codimension greater than 2 in C^n will also be mentioned. (Received August 27, 2018)

1142-32-82 **Aaron Peterson*** (aaron.peterson@northwestern.edu). *Diagonal Estimates for the Bergman Kernel in Pseudoconvex Model Domains.* Preliminary report.

Let $\Omega = \{(z_1, \ldots, z_n, z_{n+1}) \in \mathbb{C}^{n+1} \ : \ \mathrm{Im}(z_{n+1}) > P(z_1, \ldots, z_n)\}$, where $P : \mathbb{C}^n \to \mathbb{R}$ is plurisubharmonic. Under some mild non-degeneracy conditions on P, for holomorphic functions defined on Ω we establish a new mean-value theorem over a special class of large sets. As an application we obtain new diagonal estimates for the Bergman kernel in Ω. (Received August 29, 2018)

1142-32-101 **Zhenghui Huo*** (zhenghui.huo@utoledo.edu), Toledo, OH 43606, and **Brett D. Wick**, St. Louis, MO 63130. *A reproducing kernel thesis on the Bergman spaces of some Reinhardt domains.*

In this talk, we will talk about the reproducing kernel thesis for boundedness and compactness for various operators on the Bergman space of the domain $\{(z_1, z_2) \in \mathbb{C}^2 : |z_1|^2 + |z_2|^p < 1\}$. We will discuss several results about Toeplitz operators, Hankel operators, and operators in the Toeplitz algebra. This work is joint with Brett Wick. (Received August 30, 2018)

1142-32-102 **David E Barrett*** (barrett@umich.edu), Dept of Math, 530 Church Street, Ann Arbor, MI 48104, and **Luke D Edholm**. *Use of projective dual coordinates and model domains in analysis of the Leray transform.* Preliminary report.

Projective dual coordinates on a real hypersurface (in complex euclidean or projective space) provide a CR analogue of the Legendre transform from real convexity theory.

With the use of these coordinates, the (Cauchy-)Leray transform (an explicit oblique projection operator mapping L^2 of the hypersurface onto the corresponding Hardy space) may be written in a form resembling the formula for the Szegő projection for the sphere or for the Heisenberg group.

The talk will exhibit how this way of writing things helps with transfer of results for for Leray transform on model hypersurfaces

$$\left\{(z_1, z_2) \colon \ \mathrm{Im}\, z_2 \geq |z_1|^2 + \beta \ \mathrm{Re}(z_1^2)\right\}$$

($0 \leq \beta < 1$) to the setting of general strongly ($\mathbb{C}$-)convex hypersurfaces in complex dimension two. (Received August 30, 2018)

1142-32-109 **Marco M Peloso*** (marco.peloso@unimi.it), Dipartimento di Matematica, Via C. Saldini 50, 20133 Milano, MI, Italy. *Spaces of entire functions in several complex variables.* Preliminary report.

We introduce and study spaces of entire functions in several complex variables whose restriction to a strongly pseudoconvex manifold satisfy some integrability conditions. For these spaces we prove Paley—Wiener type theorems and some other structural properties. These spaces are a natural generalisation of the classical Paley—Wiener space in variable but also define a new class of spaces in the complex plane. We determine some of their structural properties and study the characterisation of sampling, interpolating and complete interpolating sequences. This is report is based on an on-going joint project with A. Monguzzi and S. Salvatori. (Received August 31, 2018)

1142-32-142 **John T. Anderson**, **Purvi Gupta*** (purvi.gupta@rutgers.edu) and **Edgar L. Stout**. *The rational hull of Rudin's Klein bottle.*

In 1981, Rudin constructed an explicit embedding of the Klein bottle into $\mathbb{C}^2$ as an example of a totally real nonorientable surface in $\mathbb{C}^2$. That no totally real Klein bottle can be rationally convex in $\mathbb{C}^2$ was settled much later by Shevchishin. In this talk, we will discuss a technique of computing rational hulls of certain surfaces, which can be applied to Rudin's Klein bottle. This example allows us to answer a natural question regarding the dimension of rational hulls. We will also present a characterization of the rational uniform algebra on Rudin's Klein bottle. (Received September 01, 2018)

1142-32-144 **Kuang-Ru Wu*** (wu739@purdue.edu), Department of Mathematics, Purdue University, 150N University Street, West Lafayette, IN 47906. *A Dirichlet problem for flat hermitian metrics.*

Let $\bar{\Omega}$ be a compact Riemann surface with boundary, and V a Hilbert space . We prove the existence of flat hermitian metrics on $\bar{\Omega} \times V$ with given boundary values. The result generalizes Lempert's theorem that had Ω the unit disc. It also generalizes results of Donaldson and Coifman-Semmes to the case of infinite rank bundles but only on Riemann surfaces. (Received September 01, 2018)

1142-32-145 **Muhenned A. Abdulsahib*** (mabdulsa@uark.edu), AR. *Hartogs Domains and the Diederich Fornaess index*

The Diederich-Fornaess index has played a crucial role in studying regularity of the Bergman projection on pseudoconvex domains in Sobolov spaces as is shown by Kohn, Harrington, and Pinton and Zampieri. In this talk, we will discuss Diederich-Fornaess index on Hartogs domains, and its relation to other properties connected to regularity of the Bergman projection. (Received September 01, 2018)

1142-32-192 **Raymond T. Walter*** (rwalter@email.uark.edu), PO Box 160, Clarkridge, AR 72623. *The Wave Equation for the Kohn Laplacian on Quadrics.* Preliminary report.

In this talk, I consider the formalism of Peloso & Ricci for the analysis of the Kohn Laplacian on quadric CR manifolds, but privilege the Segal-Bargmann or Fock representation of Ogden & Vági rather than the Schrödinger representation that they chose. This model has not been presented in the literature for mixed signatures of the Levi form, to my knowledge. My main application, generalized to these quadrics, is a Laguerre series expansion of the fundamental solution for the wave equation for the Kohn Laplacian, which was obtained by Nachman for the isotropic Heisenberg group. The non-isotropic Heisenberg group turns out to be an easy generalization, and we sketch the case of codimension two CR submanifolds of $\mathbb{C}^4$. My treatment proceeds without reference to the Laguerre calculus of P. Greiner, D.-C. Chang, and other authors. Analogies to mathematical physics are discussed where possible. (Received September 03, 2018)

1142-32-195 **Bingyuan Liu***, 850 W Dickson Street, Fayetteville, AR 72701. *Geometric Analysis on the Diederich-Fornæss index.*

In this talk, we discuss the Diederich–Fornæss index in several complex variables. A domain $\Omega \subset \{C\}^n$ is said to be pseudoconvex if $-\log(-\delta)$ is plurisubharmonic in Ω, where δ is a signed distance function of Ω. The Diederich–Fornæss index has been introduced since 1977 as an index to refine the notion of pseudoconvexity. After a brief review of pseudoconvexity, we discuss this index from the point of view of geometric analysis. We will find an equivalent index associated to the boundary of domains and with it, we are able to obtain accurate values of the Diederich–Fornæss index for many types of domains. (Received September 03, 2018)

1142-32-198 **Martino Fassina*** (fassina2@illinois.edu). *Non-solvability of elliptic operators in the flat category.*

Let $U \subset \mathbb{R}^n$ be an open set. We say that a smooth complex-valued function f on U is flat at $p \in U$ if its k-jet vanishes at p for all k. In this talk we present a class of elliptic operators L on $\mathbb{R}^n, n \geq 2$, with the following property: there exists a function f flat at a point p such that the equation $Lu = f$ has no local solution u that is flat at p. We show some applications of this fact to Several Complex Variables. This talk is based on joint work with Yifei Pan. (Received September 03, 2018)

1142-32-227 **Liz Vivas*** (vivas.3@osu.edu), 231 West 18th Ave, Columbus, OH 43210. *Non-autonomous bifurcation.*

Bifurcation in one complex dynamics concerns the dynamical behavior of a parabolic map and some perturbations of it. I will discuss an specific example and extend the method to several variables. (Received September 04, 2018)

1142-32-234 **Nuray Gul*** (ngul@math.uh.edu), University of Houston, Houston, TX 77204, and **Shanyu Ji** and **Wanke Yin**. *Maps from n-Ball into (3n-2)-Ball are determined by its 3-jets.* Preliminary report.

Abstract: This talk is based on a joint work with Shanyu Ji and Wanke Yin. In 2017, Ji and Yin proved that any map in $Rat(\mathbb{B}^n, \mathbb{B}^{3n-2})$ have degree less than or equal to 3. Also, they found a criterion for maps in $Rat(\mathbb{H}^n, \mathbb{H}^{3n-2})$ with degree 2. Now, we are studying maps in $Rat(\mathbb{H}^n, \mathbb{H}^{3n-2})$ with $\kappa_0 = 2$ and degree 3 to understand maps in $Rat(\mathbb{B}^n, \mathbb{B}^{3n-2})$ well. In this talk, we will discuss any normalized map $F \in Rat(\mathbb{H}^n, \mathbb{H}^{3n-2})$ with $\kappa_0 = 2$ and $deg(F) = 3$ is determined up to jet degree 3. (Received September 04, 2018)

35 ► Partial differential equations

1142-35-10 **Theodore D. Drivas*** (tdrivas@math.princeton.edu) and **Gregory L Eyink**. *An Onsager Singularity Theorem for Turbulent Solutions of Compressible Euler Equations.*

We prove that bounded weak solutions of the compressible Euler equations will conserve thermodynamic entropy unless the solution fields have sufficiently low space-time Besov regularity. A quantity measuring kinetic energy cascade will also vanish for such Euler solutions, unless the same singularity conditions are satisfied. It is shown furthermore that strong limits of solutions of compressible Navier-Stokes equations that are bounded and exhibit anomalous dissipation are weak Euler solutions. These inviscid limit solutions have non-negative anomalous entropy production and kinetic energy dissipation, with both vanishing when solutions are above the critical degree of Besov regularity. Stationary, planar shocks in Euclidean space with an ideal-gas equation of state provide simple examples that satisfy the conditions of our theorems and which demonstrate sharpness of our L3-based conditions. These conditions involve space-time Besov regularity, but we show that they are satisfied by Euler solutions that possess similar space regularity uniformly in time. (Received August 16, 2018)

1142-35-19 **Hongjie Dong**, 182 George Street, Providence, RI 02912, and **Tuoc Phan*** (phan@math.utk.edu), 1403 Circle Drive, Knoxville, TN 37996. *Mixed-norm regularity estimates for non-stationary Stokes systems with singular VMO coefficients and applications.*

We discuss about non-stationary Stokes systems with unbounded measurable coefficients. We prove mixed-norm Sobolev estimates for solutions assuming that the coefficients have small mean oscillations with respect to the spatial variable in small cylinders. As a special case, the results imply Caccioppoli's type estimates for the Stokes systems with variable coefficients. A new ϵ-regularity criterion for Leray-Hopf weak solutions of Navier-Stokes equations is also obtained as a consequence of our regularity results, which in turn implies some borderline cases of the well-known Serrin's regularity criterion. This talk is based on the joint work with H. Dong (Brown University). (Received August 02, 2018)

1142-35-20 **Kazuo Yamazaki***, Department of Mathematics, University of Rochester, Rochester, NY 14627. *Fluid dynamics PDE driven by random noise.* Preliminary report.

The systems of equations to be discussed should include Navier-Stokes equations, magnetohydrodynamics system, Hall-magnetohydrodynamics system, potentially KPZ equations and more. It is worth noting that within this list, only the Hall-magnetohydrodynamics system is quasilinear while others are semilinear and thus naturally analysis on the Hall-magnetohydrodynamics system is in particular difficult.

The directions of research to be discussed should include well-posedness in case the noise is white in time, Markov selections, ergodicity, and the well-posedness in case the noise is white in both space and time. The last

direction of research in particular requires techniques from renormalization and theories of rough path, regularity structures or paraproduct distributions. (Received August 03, 2018)

1142-35-23 **Nathan Glatt-Holtz***, Department of Mathematics, Tulane University, 70118 New Orleans, LA, Laos. *A Bayesian Approach to Quantifying Uncertainty Divergence Free Flows.*

We treat the statistical regularization of the ill-posed inverse problem of estimating a divergence free flow field $\mathbf{u}$ from the partial and noisy observation of a passive scalar θ. Our solution is Bayesian posterior distribution, a probability measure μ which precisely quantifies uncertainties in $\mathbf{u}$ once one specifies models for measurement error and prior knowledge for $\mathbf{u}$. We present some of our recent work which analyzes μ both analytically and numerically. In particular we discuss a posterior contraction (consistency) result as well as some Markov Chain Monte Carlo (MCMC) algorithms which we have developed and refined to effectively sample from μ. This is joint work with Jeff Borggaard and Justin Krometis (Virginia Tech). (Received August 08, 2018)

1142-35-31 **Jiahong Wu*** (jiahong.wu@okstate.edu), 401 Mathematical Sciences, Department of Mathematics, Stillwater, OK 74078. *The magnetohydrodynamic equations with partial or fractional dissipation.*

The magnetohydrodynamic (MHD) equations govern the motion of electrically conducting fluids such as plasmas, liquid metals, and electrolytes. They consist of a coupled system of the Navier-Stokes equations of fluid dynamics and Maxwell's equations of electromagnetism. Besides their wide physical applicability, the MHD equations are also of great interest in mathematics. They share many similar features with the Navier-Stokes and the Euler equations. In the last few years there have been substantial developments on the stability and the global regularity problems concerning the magnetohydrodynamic (MHD) equations, especially when there is only partial or fractional dissipation. The talk presents recent results on the global well-posedness problem as well as on the stability problem for various partially or fractionally dissipated MHD systems. (Received August 15, 2018)

1142-35-32 **Theodore D. Drivas*** (tdrivas@math.princeton.edu) and **Huy Q. Nguyen**. *Remarks on the emergence of weak solutions and anomalous dissipation on domains with boundaries.*

First, we prove that if the local second-order structure function exponents in the inertial range remain positive uniformly in viscosity, then any spacetime L^2 weak limit of Leray–Hopf weak solutions of the Navier-Stokes equations on any bounded domain Ω is a weak solution of the Euler equations. This holds for both no-slip and Navier-friction conditions with viscosity-dependent slip length. Next, we discuss an extension of Onsager's conjecture for these weak solutions. Specifically, we give a localized regularity condition for energy conservation of weak solutions of the Euler equations assuming (local) Besov regularity of the velocity with exponent $\sigma > 1/3$ and, on an arbitrary thin layer around the boundary, boundedness of velocity, pressure and continuity of the wall-normal velocity. We also prove that the global viscous dissipation vanishes in the inviscid limit for Leray-Hopf solutions of the Navier-Stokes equations under the similar assumptions, but holding uniformly in a vanishingly thin viscous boundary layer. (Received August 16, 2018)

1142-35-33 **Phuc Cong Nguyen*** (pcnguyen@math.lsu.edu), Department of Mathematics, Louisiana State University, 303 Lockett Hall, Baton Rouge, LA 70803, and **Cristi Guevara**. *ϵ-regularity and self-similar singularities of the 3D Navier-Stokes system.*

In this talk, the 3D Navier-Stokes system is considered. By viewing the head pressure as weights generally belonging to a Sobolev space of negative order, we obtain some new ϵ-regularity criteria and rule out the existence of Leray's backward self-similar solutions to the Navier-Stokes system with low integrability profiles. This talk is based on joint work with Cristi Guevara. (Received August 16, 2018)

1142-35-43 **Vincent R Martinez*** (vrmartinez@hunter.cuny.edu), CUNY-Hunter College, Department of Mathematics and Statistics, 695 Park Ave, New York, NY 10065. *Unique ergodicity for the damped-driven stochastic KdV equation.* Preliminary report.

In their 1967 seminal paper, Foias and Prodi defined a notion of finitely many degrees of freedom in the context of the two-dimensional incompressible Navier-Stokes equations (NSE). In particular, they proved that if a sufficiently large spectral projection of the difference of two solutions converge to zero asymptotically in time, then the corresponding complementary projection of their difference must also converge to 0 in the infinite-time limit. In other words, the high modes are eventually enslaved by the low modes. One may thus define the number of degrees of freedom of the flow to be the smallest number of modes needed to guarantee this convergence. This property has since led to several developments in the understanding of the long-time behavior of solutions to the NSE, for instance, in the context of turbulence, but also to data assimilation, and the existence of determining forms. In this talk, we will discuss this asymptotic enslavement property as it regards the issue of uniqueness of

invariant measures the damped-driven stochastic KdV equation, of which the undamped, deterministic analog is a classical model for shallow water waves. This is joint work with Nathan Glatt-Holtz (Tulane University) and Geordie Richards (Utah State University). (Received August 20, 2018)

1142-35-61 **Alyssa D. Genschaw*** (adcvd3@mail.missouri.edu), Columbia, MO 65202, and **Steve Hofmann**. *A weak reverse Hölder inequality for parabolic measure.* Preliminary report.

We prove a criterion for nondoubling parabolic measure to satisfy a weak reverse Hölder inequality on a domain with time-backwards ADR boundary, following a result of Bennewitz-Lewis for nondoubling harmonic measure. (Received August 26, 2018)

1142-35-81 **Huy Nguyen*** (hnguyen@math.brown.edu), 151 Thayer Street, PROVIDENCE, RI 02906, and **Benoit Pausader** (benoit.pausader@math.brown.edu), 151 Thayer Street, PROVIDENCE, RI 02906. *On the one-phase Muskat problem.* Preliminary report.

The one-phase Muskat problem models the dynamics of an interface between vacuum and a fluid in porous medium. We will discuss results on well-posedness and maximum principles for this problem in all dimensions and in domains with general geometry. (Received August 29, 2018)

1142-35-87 **Matthew Badger*** (matthew.badger@uconn.edu). *Free boundary regularity for harmonic measure on multi-phase configurations.*

In free boundary regularity problems for harmonic measure, one seeks to determine the extent to which analytic regularity of the harmonic measure of a domain (with respect to surface measure on the boundary or harmonic measure of a complementary domain) controls the geometric regularity of the boundary of the domain. Work over the last twenty years by several authors have revealed a rich landscape of results in both the one-phase and two-phase settings. In this talk, I will pose a multi-phase extension of Kenig and Toro's two-phase free boundary regularity problem and present our initial findings about blowups of harmonic measure on multi-phase NTA configurations. This is joint work with Murat Akman. (Received August 30, 2018)

1142-35-95 **Giusy Mazzone*** (giusy.mazzone@vanderbilt.edu), Department of Mathematics, Vanderbilt University, 1326 Stevenson Center, Nashville, TN 37240, **Jan Prüss**, Martin-Luther-Universität Halle-Wittenberg, Institut für Mathematik, Theodor-Lieser-Strasse 5, D-06120 Halle, Germany, and **Gieri Simonett** (gieri.simonett@vanderbilt.edu), Department of Mathematics, Vanderbilt University, 1326 Stevenson Center, Nashville, TN 37240. *On the inertial motion of a fluid-filled rigid body with Navier boundary conditions.*

In this talk, I will present some new results concerning the inertial motion of a system $\mathcal{S}$ constituted by a rigid body with an interior cavity entirely filled with a viscous incompressible fluid. Navier boundary conditions are imposed on the cavity surface. Under these conditions, the fluid normal velocity is zero, whereas the slip velocity is proportional to the shear stress on the solid boundary. Equilibria of the coupled system are characterized by permanent rotations (rotations with constant angular velocity around the central axes of inertia) of $\mathcal{S}$ with the fluid at a relative rest with respect to the solid. We show that equilibria associated with the largest moment of inertia are asymptotically (exponentially) stable, whereas all other equilibria are unstable in an appropriate topology. For what concerns the time-dependent problem, the existence of (weak and strong) solutions and their long-time behavior will be discussed. We prove that every Leray-Hopf weak solution converges to an equilibrium at an exponential rate for every fluid-solid configuration. The fluid relative velocity, in particular, converges exponentially to zero as time approaches infinity in the topology of $H^{2\alpha}_q$ with $\alpha \in [0, 1)$ and $q \in (1, 6)$. (Received August 30, 2018)

1142-35-106 **Blair Davey*** (bdavey@ccny.cuny.edu). *How to obtain parabolic theorems from their elliptic counterparts.*

Experts have long realized the parallels between elliptic and parabolic theory of partial differential equations. It is well-known that elliptic theory may be considered a static, or steady-state, version of parabolic theory. And in particular, if a parabolic estimate holds, then by eliminating the time parameter, one immediately arrives at the underlying elliptic statement. Producing a parabolic statement from an elliptic statement is not as straightforward. In this talk, we demonstrate a method for producing parabolic theorems from their elliptic analogues. Specifically, we show that an L^2 Carleman estimate for the heat operator may be obtained by taking a high-dimensional limit of L^2 Carleman estimates for the Laplacian. Other applications of this technique will be discussed. (Received August 30, 2018)

1142-35-113 **Ning Ju*** (ning.ju@okstate.edu), 401 Mathematical Sciences, Stillwater, OK 74078.
Some results on existence and uniqueness of weak solutions to the primitive equations for large scale ocean dynamics.

Some recent results obtained by the speaker on existence and uniqueness of weak solutions for primitive equations with dissipation will be presented and discussed. Some related existing results in the literature will also be briefly reviewed. (Received August 31, 2018)

1142-35-120 **Juraj Foldes*** (foldes@virginia.edu) and **Mouhamadou Sy**. *Invariant measures for SQG equation.*

Using a fluctuation dissipation method, we construct an invariant measure for the surface quasi-geostrophic equation (SQG). We also show that the measure is not supported on any finite dimensional manifold. Since the support of the measure contains entire solutions, we obtain an infinite dimensional manifold containing solutions that do not blow-up. This complements results in which a blow-up solutions for SQG are constructed. The method of the proof relies on an addition of a stochastic forcing and a small dissipation to the equation. For such stochastic equation, one can construct an invariant measure and by passing the strength of the forcing and the dissipation to zero, we obtain the desired invariant measure. The estimates on the support of the invariant measure rely on the fact that SQG has infinitely many conservation laws. This is a joint project with Mouhamadou Sy. (Received August 31, 2018)

1142-35-124 **zoran grujic*** (zg7c@virginia.edu). *Restricted Morrey-type classes and 3D Navier-Stokes equations.*

It is well know that boundedness of a solution in certain Morrey scaling-invariant (with respect to the unique scaling transformation leaving the equations invariant) spaces suffices to prevent possible formation of singularities in the 3D NSE. Local versions of this regularity class are also available. The goal of this lecture is to present a regularity class comprised of 'restricted' Morrey-type conditions; in addition to the upper bound on the range of scales in play (as is the case in the local spaces), these conditions also feature a (dynamically determined) lower bound. This explicit lower bound is a manifestation of the diffusion scale. (Received August 31, 2018)

1142-35-141 **Hyunju Kwon*** (hkwon@math.ubc.ca). *Global Navier-Stokes flows for non-decaying initial data with slowly decaying oscillation.*

We consider the Cauchy problem of 3D incompressible Navier-Stokes equations for uniformly locally square integrable initial data. The existence of a time-global weak solution has been known, when the square integral of the initial datum on a ball vanishes as the ball goes to infinity. For non-decaying data, however, the only known global solutions are either for perturbations of constants or when the velocity gradients are in L^p with finite p. In this talk, I will outline how to construct global weak solutions for general non-decaying initial data whose local oscillations slowly decay.

This is a joint work with Tai-Peng Tsai. (Received August 31, 2018)

1142-35-156 **Zihui Zhao***, zhaozh@uw.edu, and **Steve Hofmann**, **José María Martell**, **Svitlana Mayboroda** and **Tatiana Toro**. *Elliptic measures and the geometry of domains.*

Given a bounded domain Ω, the harmonic measure ω is a probability measure on the boundary $\partial\Omega$ and it characterizes where a Brownian traveller in Ω is likely to exit the domain. The elliptic measure is a non-homogenous variant of harmonic measure. Since 1917, there has been much study about the relationship between the elliptic/harmonic measure ω and the boundary surface measure σ. In particular, are ω and σ absolutely continuous with each other? In this talk, I will show how a positive answer to this question implies that the corresponding domain enjoys good geometric property, thus we obtain a sufficient condition for the absolute continuity of ω and σ. (Received September 01, 2018)

1142-35-169 **Jabar Salih Hassan*** (jshm97@mst.edu), 12890 CR 5030 APT 1, Rolla, MO 65401, and **David E Grow**. *Reproducing kernel Hilbert spaces on a semi-infinite domain.*

In this talk we introduce new reproducing kernel Hilbert spaces on a semi-infinite domain and demonstrate existence and uniqueness of solutions to the non-homogeneous telegraph equation in these spaces if the driver is square integrable and sufficiently smooth. These spaces are reasonable for applications and convenient for numerical approximation because the kernels are piecewise polynomial functions. (Received September 02, 2018)

1142-35-175 **Liaosha Xu***, 141 Cabell Dr, Charlottesville, VA 22903. *Local-in-Time Boundedness of Velocity with Oscillatory Types of Initial Data.*

The purpose of this talk is to introduce a method of deriving space analyticity of Navier-Stokes equations, with special emphasis on the local-in-time solvability with rough initial data. Such topics have long research history. However, recent studies indicate such results hold for Besov and BMO type initial values. The first half of the talk will be a general introduction of the idea for proving space analyticity of NSEs, especially the method with complexified extensions. The second half of the talk will discuss some technical issues for the results with oscillatory types of initial values. (Received September 02, 2018)

1142-35-193 **Dorina Mitrea*** (mitread@missouri.edu), University of Missouri, Department of Mathematics, Columbia, MO 65211. *Geometric measure theory, singular integral operators, and integral representation formulas in complex analysis.*

We explore the implications of a new brand of Divergence Theorem formulated with boundary traces taken in a nontangential pointwise sense vis a vis to integral representation formulas in complex analysis in an optimal geometric and analytic setting. (Received September 03, 2018)

1142-35-194 **Dorina Mitrea***, University of Missouri, Department of Mathematics, Columbia, MO 65211. *Boundary Value Problems for Elliptic Systems in the Upper-Half Space.*

In this talk I will survey results obtained in joint work with Jose Maria Martell, Irina Mitrea, and Marius Mitrea, regarding boundary value problems and Fatou type theorems for second-order, constant complex coefficient elliptic systems in $\mathbb{R}^n_+$. Spaces of boundary data I will consider include Lebesgue spaces, Muckenhoupt weighted Lebesgue spaces, spaces of functions with bounded mean oscillations, spaces of functions with vanishing mean oscillations, and spaces of functions exhibiting subcritical growth. (Received September 03, 2018)

1142-35-200 **Marius Mitrea*** (mitream@missouri.edu), University of Missouri, Department of Mathematics, Columbia, MO 65211. *Real analysis techniques in complex analysis.*

I will be discussing techniques developed in the context of harmonic analysis, partial differential equations, and geometric measure theory which have a significant impact in the area of complex analysis. (Received September 03, 2018)

1142-35-201 **Marius Mitrea***, University of Missouri, Department of Mathematics, Columbia, MO 65211. *Norm estimates for singular integral operators on unbounded surfaces.*

The goal is to control the operator norm and certain basic classes of singular integral operators in terms of the mean oscillation of the unit normal to the underlying surface. (Received September 03, 2018)

1142-35-209 **Ramazan Ercan*** (ramazan.ercan@mavs.uta.edu), 703 Bolton Walk Apt 207, Goleta, CA 93117, and **Tuncay Aktosun** (aktosun@uta.edu), The University of Texas at Arlington, Department of Mathematics Box 19408, Arlington, TX 76019. *Direct and inverse scattering problems for a first-order system with energy-dependent potentials.*

The direct and inverse scattering problems on the full line are analyzed for a first-order system of ordinary linear differential equations associated with the derivative nonlinear Schrödinger equations. The system contains a spectral parameter λ and two potentials, and the potentials are functions of the spatial variable x and also linearly contain λ and hence are called energy-dependent potentials. Through a series of transformations the scattering data for the energy-dependent system is related to the scattering data for an energy-independent system. Using such transformations the direct problem is solved, where the goal is to determine the scattering data when the energy-dependent potentials are given. Again with the help of such transformations, the inverse problem is solved, where the goal is to determine the energy-dependent potentials from the corresponding scattering data. A contrast is made with the earlier solution method developed by Kaup and Newell and another method developed by Tsuchida. (Received September 04, 2018)

1142-35-210 **Radu Dascaliuc*** (dascalir@math.oregonstate.edu), OSU Department of Mathematics, Corvallis, OR 97331. *Stochastic explosion and uniqueness of solutions to nonlinear PDE.*

Some evolution equations can be naturally associated with stochastic processes that can be used to generate solutions. An example being heat equation and Brownian motion. In the nonlinear case the stochastic processes take form of a branching random walk. We show how stochastic explosion in these branching processes can be exploited to prove the lack of uniqueness for the associated PDE. We illustrate this approach on the alpha-Riccati equation, which can be viewed as an allegory to the Navier-Stokes system, and discuss possible implications to the the existence and uniqueness problem for the full 3D incompressible Navier-Stokes equations.

Based on the joint work with E. Thomann and E. Waymire. (Received September 04, 2018)

1142-35-213 **Joseph Feneuil*** (joseph.feneuil@temple.edu). *The Dirichlet problem for sets with higher co-dimensional boundaries.*

Let $\Gamma \subset \mathbb{R}^n$ be a set of dimension $d < n-1$ and $\Omega = \mathbb{R}^n \setminus \Gamma$ be its complement. We develop an elliptic theory adapted to Ω, where we introduce a new notion of harmonic measure on Γ. When Γ is a special Lipschitz set with small Lipschitz constant, we solve the Dirichlet problem (D_p) for any $p \in (1, +\infty)$. In particular, we prove that the harmonic measure on Γ is A_∞-absolutely continuous with respect to the d-dimensional Hausdorff measure. This is a joint work with Guy David, Svitlana Mayboroda and Zihui Zhao. (Received September 04, 2018)

1142-35-218 **Simon Bortz**, **Steve Hofmann**, **Jose Luis Luna*** (jlwwc@mail.missouri.edu), **Svitlana Mayboroda** and **Bruno Poggi**. *Sovability of Elliptic Equations with Lower Order Terms.*

The study of boundary value problems for second order elliptic equations of the form

$$-\mathrm{div} A\nabla u = 0 \qquad \text{in } \mathbb{R}^{n+1}_+, \tag{1}$$

for an elliptic matrix A, has a long and celebrated history. In this talk we will focus on generalizing well-posedness of the standard Boundary Value Problems (Dirichlet, Neumann and Regularity) to equations with lower order terms of the form

$$-\mathrm{div}(A\nabla u + B_1 u) + B_2 \cdot \nabla u + Vu = 0, \qquad \text{in } \mathbb{R}^{n+1}_+. \tag{2}$$

Here we will assume the lower order terms lie in the critical spaces

$$B_i \in L^n(\mathbb{R}^n; \mathbb{C}^{n+1}), \quad V \in L^{n/2}(\mathbb{R}^n),$$

with $\|B_i\|_{L^n(\mathbb{R}^n)}$, $\|V\|_{L^{n/2}(\mathbb{R}^n)}$ small. Finally we will require that all the coefficients in (**2**) are independent of the vertical variable.

Our results state roughly that, under the above hypotheses on the lower order terms, the well-posedness (suitably defined) in $L^2(\partial\mathbb{R}^{n+1}_+)$ for (**2**) is inherited from the corresponding property for the equation (**1**).

This is joint work with Simon Bortz, Steve Hofmann, Svitlana Mayboroda and Bruno Poggi. (Received September 04, 2018)

1142-35-221 **Irina Mitrea*** (imitrea@temple.edu), Department of Mathematics, 638 Wachman Hall, Temple University, 1805 N. Broad St., Philadelphia, PA 19122. *Singular Integral Operators of Layer Potential Type.*

One of the most efficient approaches to solving boundary value problems for elliptic partial differential equations is the method of boundary layer potentials. In this talk I will survey some of the recent progress made in understanding the nature of integral operators of boundary layer type in optimal geometrical settings. (Received September 04, 2018)

1142-35-228 **Adam Larios*** (alarios@unl.edu), **Yuan Pei** and **Leo Rebholz**. *An Inviscid Regularization of the Velocity-Vorticity formulation of the 3D Navier-Stokes Equations.*

The Velocity-Vorticity regularization has shown much promise in recent computational studies. However, since it is equivalent to the 3D Navier-Stokes equations, it still suffers from the same issues as 3D Navier-Stokes. In this talk, we apply an inviscid Voigt regularization to only the momentum equation, while leaving the vorticity equation alone. We show that this new 3D system is globally well-posed, and that its solutions converge to solutions of the original equations as the regularization parameters tends to zero, on the interval of existence and uniqueness of the original equations. (Received September 04, 2018)

1142-35-236 **Bruno Giuseppe Poggi*** (poggi008@umn.edu) and **Svitlana Mayboroda** (svitlana@math.umn.edu). *Schrodinger operator: optimal decay of fundamental solutions.*

In this talk we establish sharp exponential decay estimates for operator and integral kernels of the (not necessarily self-adjoint) operators $L = -(\nabla - i\mathbf{a})^T A(\nabla - i\mathbf{a}) + V$. The latter class includes, in particular, the magnetic Schrödinger operator $-(\nabla - i\mathbf{a})^2 + V$ and the generalized electric Schrödinger operator $-\mathrm{div} A\nabla + V$. Our exponential decay bounds rest on a generalization of the Fefferman-Phong uncertainty principle to the present context and are governed by the Agmon distance associated to the corresponding maximal function. In the presence of a scale-invariant Harnack inequality, for instance, for the generalized electric Schrödinger operator with real coefficients, we establish both lower and upper estimates for fundamental solutions, thus demonstrating sharpness of our results. The only previously known estimates of this type pertain to the classical Schrödinger operator $-\Delta + V$. (Received September 04, 2018)

37 ► Dynamical systems and ergodic theory

1142-37-180 **Darlington S. Y. David*** (dsydavid@ieee.org), Department of Mathematics, University of Liberia, Fendall Campus, Louisina, POBox9020 Monrovia, Liberia, **John Soleemulo Fayiah** (jfayiah2005@gmail.com), Department of Biology, University of Liberia, Fendall Campus, Louisina, POBox9020 Monrovia, Liberia, **Jeff Harris** (jh463177@gmail.com), Department of Civil Engineering, University of Liberia, Fendall Campus, Louisina, POBox9020 Monrovia, Liberia, and **Arthur Biomadum Brown, Jr.** (aboimadum@gmail.com), Department of Electrical/Computer Engineering, University of Liberia, Fendall Campus, Louisina, POBox9020 Monrovia, Liberia. *Mathematical Models of Dynamics Transmission and Control of Ebola.* Preliminary report.

Ebola is a deadly disease and it has spread quickly. Previously in West Africa thousands of people have lost their lives due to the disease. The movement of infective individual poses a danger. To understand the effect of those infective immigrants, we have modeled the Ebola Virus Disease (EVD) by using the SEIRS deterministic model. Our analysis suggest that the Ebola epidemiological features and its transmission dynamics may remain constant in the future. Furthermore, we simulated our proposed model to confirm the of the analysis; our simulation result suggests that the disease will remain in the population and it will not completely die out. This result may be consistent with the fact that there is still no specific therapy or vaccine for the EVD. (Received September 03, 2018)

41 ► Approximations and expansions

1142-41-8 **Aaron Michael Yeager***, 913 S. Orchard, Stillwater, OK 74074. *Zeros of random orthogonal polynomials with complex Gaussian coefficients.*

Let $\{f_j\}_{j=0}^n$ be a sequence of orthonormal polynomials where the orthogonality relation is satisfied on either the real line or on the unit circle. We study zero distribution of random linear combinations of the form

$$P_n(z) = \sum_{j=0}^{n} \eta_j f_j(z),$$

where $\eta_0, \ldots, \eta_n$ are complex-valued i.i.d. standard Gaussian random variables. Using the Christoffel-Darboux formula, the density function for the expected number of zeros of P_n in these cases takes a very simple shape. From these expressions, under the mere assumption that the orthogonal polynomials are from the Nevai class, we give the limiting value of the density function away from their respective sets where the orthogonality holds. In the case when $\{f_j\}$ are orthogonal polynomials on the unit circle, the density function shows that the expected number of zeros of P_n are clustering near the unit circle. To quantify this phenomenon, we give a result that estimates the expected number of complex zeros of P_n in shrinking neighborhoods of compact subsets of the unit circle. (Received May 30, 2018)

1142-41-203 **Xiu Yang*** (xiu.yang@pnnl.gov), Pacific Northwest National Laboratory, PO Box 999, MSIN: K7-90, Richland, WA 99352. *A Physics Informed Gaussian Process Regression Method with Application to Subsurface Flow.*

In this talk, we introduce a new Gaussian process regression (GPR) method: physics informed Kriging (PhIK). Different from the standard ordinary Kriging, which approximates quantity of interest using stationary Gaussian process (GP), our method constructs a non-stationary GP from realizations of available stochastic models, e.g., from realizations of governing stochastic partial differential equations solutions. Our approach avoids the costly optimization step in data-driven GPR methods to identify the hyperparameters, and accounts for (partial) physical constraints that are included in the stochastic model. The uncertainty of the prediction is intrinsically incorporated in the GPR framework. Also, we extend the PhIK by using cokriging method and design model selection and verification strategies based on maximum likelihood estimate. The efficiency and accuracy of our method are demonstrated for reconstructing a tracer distribution problem in subsurface flow study. (Received September 03, 2018)

42 ► Fourier analysis

1142-42-9 **Terence L. J. Harris*** (terence2@illinois.edu). *Refined Strichartz inequalities for the wave equation.*

I will present some analogues of the Schrödinger refined Strichartz inequalities (Du, Guth, Li and Zhang) for the wave equation. These can be used to improve the best known L^2 fractal Strichartz inequalities for the wave equation in dimensions $d \geq 4$.

I will spend most of the talk giving an outline of the problem and some of the new ideas in this area. (Received June 01, 2018)

1142-42-131 **Steve Hofmann*** (hofmanns@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Quantitative rectifiability and the Varopolous extension theorem for BMO.*

N. Varopolous proved a remarkable extension property for BMO, namely (to state it in the simplest context), that $f \in BMO(\mathbb{R}^n)$ has a smooth extension F to the half-space $\mathbb{R}^{n+1}_+ := \{(x,t) \in \mathbb{R}^n \times (0,\infty)\}$, such that $|\nabla F(x,t)|dxdt$ is a Carleson measure. It is worth noting that such a result may fail for the harmonic (Poisson) extension $u(\cdot,t) = p_t * f$, which enjoys the more familiar property that $|\nabla u(x,t)|^2 t dxdt$ is a Carleson measure. This result was motivated in part by the fact that it yields an alternative proof of Fefferman's H^1-BMO duality theorem, and in part (via a version for strictly pseudoconvex domains in $\mathbb{C}^n$) by a failed attempt to prove a higher dimensional version of Carleson's Corona theorem.

The extension theorem itself is a consequence of the so-called "ε-approximability" property of bounded harmonic functions, introduced originally by Varopolous and refined by Garnett. In this talk, we present joint work with Olli Tapiola, in which we obtain a version of the Varopolous extension theorem for a domain Ω given by the compliment of a uniformly rectifiable set of co-dimension 1. (Received August 31, 2018)

1142-42-132 **Steve Hofmann*** (hofmanns@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *A geometric characterization of quantitative absolute continuity of harmonic measure.*

Quantitative (scale-invariant) absolute continuity of harmonic measure, with respect to surface measure on the boundary of a domain Ω (more precisely, the weak-A_∞ property), is equivalent to the solvability of the Dirichlet problem with data in some L^p space, $p < \infty$. We discuss a geometric characterization of the domains for which these properties hold, involving quantitative rectifiability of the boundary, along with a certain weak connectivity property. Part of this characterization is joint work with J. M. Martell, and part is due to Azzam, Mourgoglou and Tolsa. (Received August 31, 2018)

43 ► Abstract harmonic analysis

1142-43-103 **Xiumin Du**, **Larry Guth**, **Yumeng Ou**, **Hong Wang**, **Bobby Wilson*** (blwilson@uw.edu) and **Ruixiang Zhang**. *Falconer Distance Set Problem via Weighted Restriction Estimates.*

We will discuss the improvement of the results for the Falconer distance set problem in dimensions three and higher using weighted Fourier restriction estimates. (Received August 30, 2018)

46 ► Functional analysis

1142-46-48 **Flavia Colonna** (fcolonna@gmu.edu) and **Shams Alyusof*** (salyusof@gmu.edu), 2750 Gallows Rd, Apt 636, Vienna, VA 22180. *Essential norms of weighted composition operators from analytic function spaces into Zygmund-type spaces.*

In this work, we characterize the bounded and compact weighted composition operators from a large class of Banach space X of analytic functions on the open unit disk into Zygmund-type spaces. Under more restrictive conditions, we provide an approximation of the essential norm of such operators. We apply our results to the cases when X is the Hardy space H^p and the weighted Bergman space A^p_α for $\alpha > -1$ and $p > 1$. Also, we discuss the case of the space $S^p, p > 1$ where our general results are not applicable. (Received August 22, 2018)

1142-46-130 **Zead Mustafa*** (zead@qu.edu.qa), Department of Mathematics, Statistics and Phy, Doha, 2713, Qatar, and **M.M.M. Jaradat** and **Erdal Karapınar**. *A new fixed point result via property P with an application.*

Abstract

The purpose of this paper is to introduce a new contractive condition. We prove the existence and uniqueness of a fixed point of self-mapping under this new contractive condition. Moreover, we observe analog of these results for the mappings that satisfy the property P. An application on integral equations is presented to illustrate the main result. Our results extend and generalize well-known results in the literature. (Received August 31, 2018)

1142-46-138 **Flavia Colonna** (fcolonna@gmu.edu), George Mason University, fairfax, VA 22030, and **Munirah Aljuaid*** (maljuaid@gmu.edu), George Mason University, fairfax, VA 22030. *Some spaces of harmonic mappings.*

A harmonic mapping is a complex-valued function on a domain in $\mathbb{C}$ whose Laplacian is identically zero. In this talk, we consider several spaces of harmonic mappings that are extensions of familiar analytic function spaces defined on the open unit disk. Specifically, we study the linear structure of the harmonic counterparts of the α-Bloch spaces, the growth spaces, the Besov spaces, and the Zygmund space. We also extend several known properties valid for the analytic case to the harmonic setting. (Received August 31, 2018)

47 ► Operator theory

1142-47-45 **Cheng Chu*** (cheng.chu@vanderbilt.edu), 1326 Stevenson Center, Nashville, TN 37240. *Reducing Subspaces of de Branges-Rovnyak Spaces.*

For $b \in H_1^\infty$, the closed unit ball of H^∞, the de Branges-Rovnyak spaces $\mathcal{H}(b)$ is a Hilbert space contractively contained in the Hardy space H^2 that is invariant by the backward shift operator S^*. We study the reducing subspaces of the operator $S^{*2}|_{\mathcal{H}(b)}$.

When b is an inner function, $S^{*2}|_{\mathcal{H}(b)}$ is a truncated Toepltiz operator and its reducibility was characterized by Douglas and Foias using model theory. We use another approach to extend their result to the case where b is extreme. (Received August 21, 2018)

1142-47-72 **Trieu Le*** (trieu.le2@utoledo.edu). *Inner functions in weighted Hardy spaces over the unit disk.* Preliminary report.

Inner functions play an important role in function theory and operator theory on the Hardy space over the unit disk. Recent works of Bénéteau et al. and of Seco study inner functions in the more general setting of weighted Hardy spaces. Motivated by their results, we discuss several characterizations of such inner functions and investigate a method to construct analogues of finite Blaschke products. (Received August 27, 2018)

1142-47-108 **Carl C Cowen*** (ccowen@iupui.edu), 402 N Blackford St, Indianapolis, IN 46202. *On Spectral Properties of Composition Operators whose Symbol Has a Fixed Point in $\mathbb{D}$.* Preliminary report.

Let φ be an analytic function mapping the unit disk, $\mathbb{D}$, into itself and suppose there is a point a with $|a| < 1$ for which $\varphi(a) = a$. The first general theorem about the spectrum of a composition operator on the Hardy space $H^2(\mathbb{D})$ with such a symbol, proved by H. Kamowitz (1975), says

$$\sigma(C_\varphi) = \{\lambda : |\lambda| \le \rho\} \cup \{\varphi'(z_0)^n : n = 1, 2, \cdots\} \cup \{1\}$$

where ρ is the essential spectral radius of C_φ.

Surprisingly, not much more is known about such operators now than what was proved in 1975. This talk will say more about Kamowitz' result, describe some of the progress that has been made over the years, including recent progress, and try to explain some of the issues in addressing this problem. In particular, we will address the problem of identifying the essential spectrum of C_φ when φ has a fixed point in $\mathbb{D}$. (Received August 31, 2018)

1142-47-111 **Munirah Ajjuaid** and **Flavia Colonna*** (fcolonna@gmu.edu), Dept. of mathematical Sciences, George Mason University, 4400 University Drive, Fairfax, VA 22030. *Composition operators on spaces of harmonic mappings.* Preliminary report.

Let φ be an analytic self-map of the open unit disk in the complex plane. In this talk, we study the composition operator C_φ acting on the harmonic counterparts of the α-Bloch spaces, the growth spaces, the Besov spaces, and the Zygmund space. We characterize boundedness, compactness, and describe the isometries. We also determine the eigenfunctions of C_φ acting on the harmonic Bloch space. (Received August 31, 2018)

1142-47-125 **Sivaram K Narayan*** (sivaram.narayan@cmich.edu), Department of Mathematics, Pearce Hall 218, Central Michigan University, Mount Pleasant, MI 48859. *Complex Symmetric Composition Operators on Weighted Hardy Spaces.*

A bounded operator T on a complex Hilbert space $\mathcal{H}$ is called complex symmetric if $T = CT^*C$, where C is a conjugation (an isometric, antilinear involution of $\mathcal{H}$). We consider the complex symmetry of composition operator $C_\varphi f = f \circ \varphi$ induced on the weighted Hardy spaces $H^2(\beta)$ by holomorphic self-maps φ of the open unit disk $\mathbb{D}$. In this talk, we present necessary conditions for C_φ to be complex symmetric on $H^2(\beta)$. Also, we give a characterization of non-automorphic linear fractional symbols φ such that C_φ is complex symmetric on weighted Bergman spaces $A^2_\alpha(\mathbb{D})$. This is a joint work with Daniel Sievewright and Maria Tjani. (Received August 31, 2018)

1142-47-137 **Eva A. Gallardo-Gutierrez***, Departament of Mathematics, Rawles Hall, 831 East Third St., Indiana University, Bloomington, IN 47405-7106. *C_0-semigroups of 2-isometries and Dirichlet spaces.*

A bounded linear operator T on a separable, infinite dimensional complex Hilbert space $\mathcal{H}$ is called a *2-isometry* if it satisfies

$$T^{*2}T^2 - 2T^*T + I = 0,$$

where I is the identity operator. In addition, such operators are called *analytic* if no nonzero vector is in the range of every power of T. It turns out that M_z, i.e. the multiplication operator by z, acting on the classical Dirichlet space, is a cyclic analytic 2-isometry. But, moreover, Richter proved that any cyclic analytic 2-isometry is unitarily equivalent to M_z acting on a generalized Dirichlet space $D(\mu)$.

In the context of Richter's theorem, we will establish a similarity between C_0-semigroups of analytic 2-isometries acting on $\mathcal{H}$ and the multiplication operator semigroup $\{M_{\phi_t}\}_{t\geq 0}$ induced by $\phi_t(s) = \exp(-st)$ for s in the right-half plane $\mathbb{C}_+$ acting boundedly on weighted Dirichlet spaces on $\mathbb{C}_+$. As a consequence, we derive a connection with the right shift semigroup acting on a weighted Lebesgue space on the half line $\mathbb{R}_+$ and address some applications regarding the study of the invariant subspaces of C_0-semigroups of analytic 2-isometries.

Joint work with J. R. Partington (Leeds). (Received August 31, 2018)

1142-47-140 **Jasbir Singh Manhas**, **Gabriel T Prajitura** and **Ruhan Zhao*** (rzhao@brockport.edu), Department of Mathematics, College at Brockport, State University of New York, Brockport, NY 14420. *Weighted composition operators that preserve frames.* Preliminary report.

We characterize weighted composition operators that preserve frames, tight frames, or normalized tight frames in the general weighted Hilbert Bergman spaces on the unit ball of $\mathbb{C}^n$. (Received August 31, 2018)

1142-47-224 **Joshua Brough Isralowitz*** (jisralowitz@albany.edu), 44 Meadowbrook Drive, Apt. 119, Slingerlands, NY 12159. *Atomic decomposition and duality of weighted Fock spaces.* Preliminary report.

In 1985, D. Luecking proved atomic decomposition and duality results for weighted Bergman spaces on the unit ball with respect to a Bekolle weight. We discuss very similar results, but for the Fock space (where the notion of an appropriate "Muckenhoupt weight" exists.) (Received September 04, 2018)

49 ► Calculus of variations and optimal control; optimization

1142-49-15 **Armin Schikorra*** (armin@pitt.edu), Pittsburgh, PA 15260. *O'Hara's knot energies and $W^{1/p,p}$-harmonic maps into spheres.*

I will report on advances in the regularity theory for minimizers and critical points of a class of knot energies defined by Jun O'Hara. When parametrized by arclength the tangent field of these knots are critical points of a $W^{1/p,p}$ -type energy, and we employ arguments from the regularity theory of $W^{1/p,p}$ -harmonic maps into the sphere. Joint work with S. Blatt, Ph. Reiter. (Received July 24, 2018)

1142-49-39 **Andreas Mang*** (andreas@math.uh.edu), University of Houston, 3551 Cullen Blvd., 641 Philip G. Hoffman Hall, Houston, TX 77204, and **Klaudius Scheufele**, **Shashank Subramanian**, **Miriam Mehl** and **George Biros**. *Optimal control of PDEs: Application to brain tumor modeling.*

We present an optimal control formulation for patient-specific simulation of tumor progression and effective, parallel algorithms for its solution. The inputs to our problem are two sets of probability maps of brain tissue types obtained from magnetic resonance images, one of a brain tumor patient and the other one of a normal brain (no tumor). In the inverse problem, we seek tumor growth parameters and a deformation map from the normal to the abnormal brain so that the tumor predicted by our simulation and the deformed anatomy match the tumor and anatomy seen in the patient image. This problem presents us with numerous mathematical and computational challenges, including non-linearity, non-convexity, and inherent ill-posedness of the inverse problem, an expensive parameter-to-observation map, a strong coupling between mixed-type, multiphysics PDE operators, inhomogeneous material properties with sharp contrasts, a complicated geometry, and uncertainties in the data, model parameters, material properties, and the model itself. We will discuss strategies to tackle these challenges. We will study numerical accuracy, the rate of convergence, quality of the inversion, and scalability of our solver on synthetic and real-world data. (Received August 20, 2018)

51 ► Geometry

1142-51-36 **Malik Obeidin*** (mobeidin@illinois.edu). *Hyperbolicity of Random Link Diagrams.*

One of the most interesting and cryptic of all knot invariants is the hyperbolic structure of the knot complement, whose existence was established for a huge class of 3-manifolds by the work of Thurston. In fact, low dimensional topologists often say that "most" 3-manifolds are hyperbolic. However, this assumption actually fails for many combinatorial descriptions of knots and links: for example, a random link diagram with many crossings is almost surely not hyperbolic, but composite. In this talk, I will give concrete estimates for the probability that a random link diagram is hyperbolic, as well as probabilities for other related properties. (Received August 17, 2018)

1142-51-49 **Tom Needham*** (needham.71@osu.edu) and **Facundo Mémoli**. *Distance Distributions for Curves and Metric Measure Spaces.* Preliminary report.

Given a finite set of points in a Euclidean space, one can consider the histogram of mutual distances between pairs of points as a summary of the geometry of the point cloud. In 2012, Brinkman and Olver extended this idea to define the distance distribution of a plane curve; this is an isometry-invariant function which is more robust to noise than the classical curvature invariant. They conjectured that the distance distribution completely determines a curve up to rigid motions. In this talk, we will demonstrate a counterexample to this conjecture and we show how distance distributions arise in a much more general context: as lower bounds for a metric on the space of all compact metric measure spaces. Using ideas from optimal transport and topological data analysis, we show that distance distributions do have good local injectivity properties for simple classes of metric measure spaces. (Received August 23, 2018)

1142-51-57 **Kathleen Hake*** (khake@carleton.edu). *Knotting Probability of Equilateral Hexagons.* Preliminary report.

For a positive integer $n > 3$, the collection of n-sided polygons embedded in 3-space defines the space of geometric knots. In this talk, we will consider the subspace of equilateral knots, consisting of embedded n-sided polygons with unit length edges. Paths in this space determine isotopies of polygons, so path-components correspond to equilateral knot types. When n is less than 6, the space of equilateral knots is connected. Therefore, we examine the space of equilateral hexagons. Using techniques from symplectic geometry, we can parametrize the space of equilateral hexagons with a set of measure preserving action-angle coordinates. With this coordinate system, we provide new bounds on the knotting probability of equilateral hexagons. (Received August 25, 2018)

1142-51-90 **Thomas D. Eddy*** (eddy@math.colostate.edu). *Upper Bounds for Stick Numbers of Knots Through Random Sampling of Confined Polygons.*

The stick number of a knot is the minimum number of straight edges needed to construct the knot. This invariant is unknown for most knots, although various theoretical and observed bounds are known. Previous research has attempted to improve the observed upper bounds for stick number by generating random polygons and identifying the knots they form. This talk will present a new variation on this method which generates equilateral polygons in tight confinement to increase the incidence of complex knots. Even in tight confinement, the formation of complex knots is rare and thus one must choose a generation algorithm which is capable of

producing large numbers of samples rapidly. This talk will describe such an algorithm, which is based on the toric symplectic structure of equilateral polygon space, and how to use it to generate and identify the knot type of billions of polygons. The talk will conclude with new stick number upper bounds for more than 20 knots, including exact stick numbers for two knots, obtained using this method. (Received August 30, 2018)

1142-51-112 **Kyle Leland Chapman*** (kyle.chapman.topology@gmail.com). *Decomposing Knot Space: a natural simplicial decomposition of equilateral PL-curves.*

The space of equilateral PL-curves is relevant to the study of geometric knot theory. I present a decomposition into simplexes which are all isometric, making the space identifiable with the finite set product a single simplex. This decomposition is indexable in a way that makes the generating of such curves quite rapid, and which cooperates nicely with integer radius constraints and either being open or closed. (Received August 31, 2018)

1142-51-206 **Jonah Gaster***, jbgaster@gmail.com, and **Brice Loustau**. *Computing discrete equivariant harmonic maps.*

Combined work of Eels-Sampson and Hartman asserts the existence of a harmonic diffeomomorphism in any homotopy class of maps between a pair of homeomorphic compact hyperbolic surfaces. After briefly discussing the background, I will present a discretization of the theory, and locate discrete harmonic maps by applying a constant step gradient descent method. Convergence is guaranteed by computations in the hyperbolic plane. In particular, we show that the discrete energy functional is *strongly convex*, a uniform statement not implied by the existing literature. I will also discuss and present a computer implementation that exploits the above viewpoint. This is joint with Brice Loustau. (Received September 04, 2018)

53 ► Differential geometry

1142-53-17 **Hemangi M. Shah***, Chhatnag Road, Jhunsi, Allahabad, UP 211019, India. *Geometry of Asymptotically harmonic manifolds with minimal horospheres.*

(M^n, g) be a complete Riemannian manifold without conjugate points. We show that if M is also simply connected, then M is flat, provided that M is also asymptotically harmonic manifold with minimal horospheres (AHM). The (first order) flatness of M is shown by using the strongest criterion: $\{e_i\}$ be an orthonormal basis of T_pM and $\{b_{e_i}\}$ be the corresponding Busemann functions on M. Then, (1) The vector space $V = span\{b_v | v \in T_pM\}$ is finite dimensional and dim V = dim $M = n$. (2) $\{\nabla b_{e_i}(p)\}$ is a global parallel orthonormal basis of T_pM for any $p \in M$. Thus, M is a parallizable manifold. And (3)$F : M \to R^n$ defined by$F(x) = (b_{e_1}(x), b_{e_2}(x), \cdots, b_{e_n}(x))$, is an isometry and therefore, M is flat. Consequently, AH manifolds can have either polynomial or exponential volume growth, generalizing the corresponding result for harmonic manifolds. In case of harmonic manifold with minimal horospheres (HM), the (second order) flatness was proved by Ranjan and Shah by showing that $span\{b_v^2 | v \in T_pM\}$ is finite dimensional. (Received July 29, 2018)

1142-53-58 **Andrew Cooper***, Box 8205, North Carolina State University, Raleigh, NC 27695. *A Maximum Principle for Circle-Valued Temperatures.*

It is a classical fact that a function $u : M \times [0, T) \to \mathbb{R}$ from a closed Riemannian manifold which satisfies the heat equation $\frac{\partial u}{\partial t} = \Delta u$ must satisfy a maximum principle: its oscillation is nonincreasing in time. This is true even if the Riemannian metric (hence the Laplacian operator Δ) is evolving in time, and even if the metric becomes singular as $t \to T$.

In this talk, I'll describe the corresponding statement when $u : M \times [0, T) \to S^1$ is circle-valued rather than real-valued; the proof is an application of elementary tools from algebraic topology. I'll also give a couple of examples of where such a *circle-valued temperature* arises and explain how the maximum principle is useful there. (Received August 25, 2018)

1142-53-146 **Etienne Vouga*** (evouga@cs.utexas.edu), University of Texas, Austin, TX. *Computational Triaxial Weaving of Curved Surfaces*

Although weaving as a technique for fabricating baskets and other containers is a timeless art, there are geometric and topological obstructions to weaving general 3D shapes out of thin elastic ribbons such as reed or bamboo. The problem of designing a triaxial weave approximating a target surface, that holds its shape in static equilibrium when fabricated, can be couched in terms of optimizing a vector field on a six-fold branched cover of that surface, with the integral curves of the vector field describing the layout of ribbons on the surface. We discuss the relationship between the physics and geometry and topology of woven structures, describe the optimization of fabricable weave patterns in terms of techniques from discrete differential geometry on vector field design

and surface parameterization, and present an algorithmic pipeline for computational design of triaxial weaves on arbitrary curved surfaces using thin ribbons. (Received September 01, 2018)

54 ► General topology

1142-54-187 **Jo Nelson*** (jo.nelson@rice.edu). *Reeb dynamics of the links of simple singularities.*
We discuss Morse-Bott computational methods for computing the contact homology of 3-dimenseional prequantization bundles and applications to quantitative questions in dynamics. Of particular interest will be work in progress establishing a Floer theoretic McKay type correspondence for links of simple singularities via these geometric methods. Along the way, we will see a neat relationship between the Reeb dynamics and the presentation of these links as Seifert fiber spaces. (Received September 05, 2018)

55 ► Algebraic topology

1142-55-139 **Takefumi Nosaka*** (nosaka.t.aa@m.titech.ac.jp), Department of Mathematics Tokyo Institute of, technology, 2-12-1 Ookayama, Meguro-ku, Tokyo, Tokyo 152-8551, Japan. *Quandle homology and relative group homology of degree 3.*
Inoue and Kabaya constructed a chain map from the quandle complex to Hochshild relative group complex, and gave a relation to the complex volume of hyperbolic links. The speaker has studied the chain map of degree 3, and showed the induced map on homology is isomorphic in some cases. In this talk, the speaker give a survey of recent works on the chain map, and some topological interpretation of some topological cocycle invariants in terms of fundamental homology 3-classes. (Received August 31, 2018)

1142-55-196 **Federico Salmoiraghi*** (federico.salmoiraghi@gmail.com) and **Ryan Leigon**. *Equivalence of contact gluing maps in sutured Floer homology.*
The contact invariant is a useful tool for studying contact structures, which arises from Heegaard Floer theory. This invariant is tracked under cut-and-paste operations by contact gluing maps of Honda, Kazez, and Matić. However, these maps are difficult to compute in practice, even in simple cases. Our work reinterprets these maps in terms of Zarev gluing maps, and allows Honda—-Kazez—-Matić maps to be directly computed in interesting cases. This project is joint with Ryan Leigon and realizes unpublished results of Zarev. (Received September 03, 2018)

1142-55-219 **Józef H. Przytycki**, **Petr Vojtěchovský** and **Seung Yeop Yang*** (seungyeop.yang@knu.ac.kr). *Annihilation theorems for rack and quandle homology groups.* Preliminary report.
We investigate known annihilation theorems for torsion subgroups of rack and quandle homology of some finite quandles. We then introduce some new results. (Received September 04, 2018)

57 ► Manifolds and cell complexes

1142-57-24 **Lei Chen*** (chenlei@caltech.edu), chenlei@caltech.edu, and **Nick Salter**. *The Birman exact sequence does not virtually split.* Preliminary report.
This paper answers a basic question about the Birman exact sequence in the theory of mapping class groups. We prove that the Birman exact sequence does not admit a section over any subgroup contained in the Torelli group with finite index. A fortiori this proves that there is no section of the Birman exact sequence for any finite-index subgroup of the full mapping class group. This theorem was announced in a 1990 preprint of G. Mess, but an error was uncovered and described in a recent paper. This is joint work with Nick Salter. (Received August 15, 2018)

1142-57-28 **Sam Nelson*** (sam.nelson@cmc.edu) and **Karina Cho**. *Quandle Coloring Quivers.*
Given a finite quandle X, a set $S \subset \mathrm{Hom}(X, X)$ of quandle endomoprhisms, and an oriented knot or link L, we construct a quiver-valued invariant of oriented knots and links. This quiver categorifies the quandle counting invariant in the most literal sense and can be used to define many enhancements of the counting invariant. This is joint work with Harvey Mudd College student Karina Cho. (Received August 14, 2018)

1142-57-40 **Roger Casals** and **John Etnyre*** (etnyre@math.gatech.edu). *Non-isotopic embeddings of contact manifolds.* Preliminary report.

The study of transverse knots in dimension 3 has been instrumental in the development of 3 dimensional contact geometry. One natural generalization of transverse knots to higher dimensions is contact submanifolds. Embeddings of one contact manifold into another satisfies an h-principle for codimension greater than 2, so we will discuss the case of codimension 2 contact embeddings. We will describe several ways to prove there are non-isotopic contact embeddings in all dimensions. (Received August 20, 2018)

1142-57-41 **Mariano Echeverria*** (me3qr@virginia.edu), 141 cabell drive kerchof hall, charlottesville, VA 22903. *naturality of the contact invariant in monopole floer homology under strong symplectic cobordisms.*

the contact invariant is an element in the monopole floer homology groups of an oriented closed three manifold canonically associated to a given contact structure. a non-vanishing contact invariant implies that the original contact structure is tight, so understanding its behavior under symplectic cobordisms is of interest if one wants to further exploit this property. by extending the gluing argument of mrowka and rollin to the case of a manifold with a cylindrical end, we will show that the contact invariant behaves naturally under a strong symplectic cobordism. as quick applications of the naturality property, we give alternative proofs for the vanishing of the contact invariant in the case of an overtwisted contact structure, its non-vanishing in the case of strongly fillable contact structures and its vanishing in the reduced part of the monopole floer homology group in the case of a planar contact structure. we also prove that a strong filling of a contact manifold which is an l-space must be negative definite. (Received August 20, 2018)

1142-57-50 **Elizabeth Denne***, Washington & Lee University, Robinson Hall, Lexington, VA 24450, and **Corinne Joireman** and **Allison Young**. *The mathematics of tie knots.* Preliminary report.

In 2000, T. Fink and Y. Mao wrote a paper which developed a mathematical model of tie knots. They provided a map between tie knots and certain random walks on a triangular lattice. With added aesthetic constraints, they found 85 tie knots that can be tied with a conventional tie. After joining the two ends of the tie knot together, we viewed the tie knots as mathematical knots. In this talk we will discuss our many discoveries about these knots. For example, we found the knot types of all 85 ties, and we proved that all tie knots are alternating knots. (Received August 23, 2018)

1142-57-52 **John A. Baldwin**, **Tye Lidman** and **C.-M. Michael Wong*** (cmmwong@lsu.edu). *GRID invariants obstruct decomposable Lagrangian cobordisms.* Preliminary report.

Ozsváth, Szabó, and Thurston defined several combinatorial invariants of Legendrian links in the 3-sphere using grid homology, which is a combinatorial version of link Floer homology. These, collectively called the GRID invariants, are known to be effective in distinguishing some Legendrian knots that have the same classical invariants. In this talk, we describe a recent result that the GRID invariants provide an obstruction to the existence of decomposable Lagrangian cobordisms between Legendrian links. This obstruction is stronger than the obstructions from the Thurston–Bennequin and rotation numbers, and is closely related to a recent result by Golla and Juhász. This is joint work with John Baldwin and Tye Lidman. (Received August 23, 2018)

1142-57-62 **Samuel T. Lisi*** (stlisi@olemiss.edu), **Aleksandra Marinković** and **Klaus Niederkrüger**. *On some properties of Bourgeois contact structures.*

In this thesis, Bourgeois introduced a construction of a contact structure on $V \times \mathbb{T}^2$ that takes as input a contact open book decomposition on V. We study to what extent the structure on $V \times \mathbb{T}^2$ remembers the contact structure on V. In particular, we show that $V \times \mathbb{T}^2$ is often weakly fillable, even if V is overtwisted.

We will also consider some questions related to strong fillability of these $V \times \mathbb{T}^2$. (Received August 27, 2018)

1142-57-63 **Yu Pan** and **Dan Rutherford*** (rutherford@bsu.edu). *Augmentations and immersed Lagrangian fillings.*

This is joint work with Y. Pan that applies previous joint work with M. Sullivan. Let $\Lambda \subset \mathbb{R}^3$ be a Legendrian knot with respect to the standard contact structure. The Legendrian contact homology (LCH) DG-algebra, $\mathcal{A}(\Lambda)$, of Λ is functorial for exact Lagrangian cobordisms in the symplectization of $\mathbb{R}^3$, i.e. a cobordism $L \subset Symp(\mathbb{R}^3)$ from Λ_- to Λ_+ induces a DG-algebra map, $f_L : \mathcal{A}(\Lambda_+) \to \mathcal{A}(\Lambda_-)$. In particular, if L is an exact Lagrangian filling, i.e. if $\Lambda_- = \emptyset$, the induced map is an augmentation $\epsilon_L : \mathcal{A}(\Lambda_+) \to \mathbb{Z}/2$.

In this talk, I will discuss an extension of this construction to the case of immersed, exact Lagrangian cobordisms based on considering the Legendrian lift Σ of L. When L is an immersed, exact Lagrangian filling a choice of augmentation α for Σ produces an induced augmentation $\epsilon_{L,\alpha}$ for Λ_+. Using the cellular formulation

of LCH, we are able to show that any augmentation of Λ may be induced by such a filling. (Received August 27, 2018)

1142-57-69 **Christine Ruey Shan Lee*** (crslee@southalabama.edu). *Stability and triviality of Plamenevskaya's transverse invariant from Khovanov homology.*

We prove a stability property of Plamenevskaya's transverse invariant from Khovanov homology, and use it to give families of examples of 3-6 braids for which the invariant may be used to detect non quasi-positivity. We also construct an infinite family of pretzel knots for which Plamenevskaya's invariant vanishes for every transverse link representative. This is joint work with Diana Hubbard. (Received August 27, 2018)

1142-57-73 **Nick Salter*** (nks@math.columbia.edu) and **Lei Chen** (chenlei1991919@gmail.com). *Section problems for configurations of points on the Riemann sphere.*

Given a configuration of n distinct points in $\mathbb{C}$, it is easy to add an additional m distinct points for any $m \geq 1$ that you like: simply add the new points "near infinity". The question of how to add m new points to a configuration of n points becomes substantially more subtle when the ambient space $\mathbb{C}$ is replaced by the Riemann sphere S^2. In work from 2005, Gonçalves and Guaschi found that for any rule for adding m points to n on the sphere, n and m must satisfy some peculiar number-theoretic relations: for instance, they showed that rules for producing 6 new points from 4, or 20 new points from 6, *might* exist, but that no such rules exist for producing 7 from 4 or 21 from 6.

In this talk we will give a complete description of the pairs (n, m) for which an "m from n" rule exists. In the case where the original configuration has at most 4 points, we will use ideas from algebraic geometry to produce a wide variety of rules, including a rule for producing 6 new points from 4 hinted at above. Conversely, by using ideas from the theory of mapping class groups, we will see that there are many fewer rules when $n \geq 6$: e.g. there is no "20 from 6" rule, but there is a "120 from 6" rule. (Received August 28, 2018)

1142-57-75 **Tarik Aougab***, Dept. of Mathematics, Brown University, 151 Thayer St, Providence, RI 02912, and **Shuchi Agrawal**, **Yassin Chandran**, **Marissa Loving**, **Rob Oakley**, **Roberta Shapiro** and **Sunny Yang**. *Automorphisms of curve graph variants: bounded intersection.*

For S a surface of finite type and genus at least 2 and $k \in \mathbb{N}$, let $\mathcal{C}_k(S)$ denote the graph whose vertices are (homotopy classes of) essential simple closed curves on S and whose edges represent pairs of such curves with geometric intersection at most k. When $k = 0$, this is the standard curve graph. We prove that $\mathrm{Aut}(\mathcal{C}_1(S)) \cong \mathrm{Aut}(\mathcal{C}_0(S))$, which when the genus is at least 3, is isomorphic to the extended mapping class group; this resolves a conjecture of Schaller from 2000. More generally, we prove the analogous result for $\mathcal{C}_k(S)$ so long as $|\chi(S)| > k+600$. This represents joint work with Shuchi Agrawal, Yassin Chandran, Marissa Loving, Rob Oakley, Roberta Shapiro, and Sunny Yang. (Received August 28, 2018)

1142-57-98 **Caitlin Leverson*** (leverson@math.gatech.edu) and **Dan Rutherford**. *Satellite ruling polynomials and representations of the Chekanov-Eliashberg algebra.*

Given a pattern braid β in $J^1(S^1)$, to any Legendrian knot K in $\mathbb{R}^3$ with the standard contact structure, we can associate the Legendrian satellite knot $S(K, \beta)$. We will discuss the relationship between augmentations of the Chekanov-Eliashberg differential graded algebra of $S(K, \beta)$ and certain representations of the Chekanov-Eliashberg differential graded algebra of K. For certain patterns, we can then relate a specialization of the ruling polynomial of $S(K, \beta)$ to these representation numbers. (Received August 30, 2018)

1142-57-99 **Radmila Sazdanovic*** (rsazdanovic@math.ncsu.edu), Department of Mathematics, NC State, P.O. Box 8205, Raleigh, NC 27695, and **Michal Adamazsek**, **Henry Adams**, **Ellen Gasparovic**, **Maria Gommel**, **Emilie Purvine**, **Bei Wang**, **Yusu Wang** and **Lori Ziegelmeier**. *Homotopy types and persistence of metric gluings.*

Topological summary, information that one can capture using persistence, of metric wedge sums and gluings of metric spaces is the main topic of this talk. First, we provide a complete characterization of the persistence diagrams in dimension 1 for metric graphs under a particular intrinsic setting. Next we analyze two persistence-based distances defined for metric graphs and discuss progress toward establishing and comparing their discriminative capacities. In particular, we determine that the homotopy type of the Vietoris-Rips (resp., Cech) complex of a wedge sum, equipped with a natural metric, equals that of the wedge sum of the Vietoris-Rips (resp., Cech) complexes and discuss effect gluing metric spaces along a common isometric subset has on persistence. As a corollary, we obtain a complete description of the persistent homology of the Vietoris-Rips complexes for a wide class of metric graphs. (Received August 30, 2018)

1142-57-100 **Allison N. Miller*** (allison.miller@rice.edu), Rice University, Department of Mathematics – MS 136, P.O. Box 1892, Houston, TX 77005. *Satellite operators and knot concordance.*

Abstract: The set of knots modulo (smooth or topological) concordance can be considered with a variety of extra structures, such as the group structure induced by connected sum and the metric induced by the 4-genus function. Since the classical satellite construction behaves nicely with respect to concordance (if K and K' are concordant then $P(K)$ and $P(J)$ are concordant for any pattern P), it is natural to ask about the properties of satellite actions with respect to these extra structures. I will briefly survey known results in this area, and then discuss a recent result which uses winding number to give a complete characterization of when two patterns induce operators which are a bounded distance from each other. (Received August 30, 2018)

1142-57-114 **Irving Dai**, **Jennifer Hom*** (hom@math.gatech.edu), **Matthew Stoffregen** and **Linh Truong**. *Heegaard Floer, homology cobordism, and knot concordance.* Preliminary report.

We discuss applications of Heegaard Floer homology to the homology cobordism group and the knot concordance group. This is joint work with Irving Dai, Matthew Stoffregen, and Linh Truong. (Received August 31, 2018)

1142-57-122 **Eleni Panagiotou*** (panagiotou@math.ucsb.edu). *The effect of topological and geometrical constraints on polymer material properties.*

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 polymer entanglement. More precisely, we develop three dimensional computational models to relate entanglement topology, polymer mechanics, to bulk viscoelastic responses of the material. We study in particular woven polymer configurations having similar polymer densities but die rent topologies. Our approaches provide new mathematical tools for characterizing the origins of the rheological responses of polymeric materials. (Received August 31, 2018)

1142-57-123 **John A Baldwin*** (john.baldwin@bc.edu), Boston, MA 02131, and **Steven Sivek**. *Applications of sutured instanton Floer homology to low-dimensional topology.*

I'll discuss several applications of Kronheimer and Mrowka's sutured instanton Floer homology to problems in low-dimensional topology coming out of my joint work with Steven Sivek. These include a new link between Stein fillings of a 3-manifold and SU(2) representations of the 3-manifold group, and a proof that Khovanov homology detects the trefoil. I'll also discuss other problems that these techniques may solve. (Received August 31, 2018)

1142-57-134 **James Belk**, **Justin Lanier**, **Dan Margalit** and **Rebecca R Winarski*** (winarski@umich.edu). *Twisted rabbit and invariant trees.* Preliminary report.

The twisted rabbit problem is a celebrated problem in complex dynamics. Work of Thurston proves that up to equivalence, there are exactly three branched coverings of the sphere to itself satisfying certain conditions. When one of these branched coverings is modified by a mapping class, a map equivalent to one of the three coverings results. Which one?

After remaining open for 25 years, this problem was solved by Bartholdi–Nekyrashevych using iterated monodromy groups. In joint work with Belk, Lanier and Margalit, we formulate the problem topologically and solve the problem using invariant trees. (Received August 31, 2018)

1142-57-135 **Lvzhou Chen*** (lzchen@math.uchicago.edu). *Stable commutator length in generalized Baumslag–Solitar groups.*

The stable commutator length (scl) is a complexity measurement on loops in a space, and is a characteristic function on the fundamental group. However, it is hard to compute scl in general and thus difficult to study it. By investigating surfaces in spaces, we explain how scl can be computed and why it is rational in Baumslag–Solitar groups, as well as many other graphs of groups. We also exhibit some interesting behaviors not found for scl in free groups. (Received August 31, 2018)

1142-57-151 **Kristen Hendricks*** (hendricks@math.msu.edu), **Jennifer Hom** and **Tye Lidman**. *Connected Heegaard Floer homology and homology cobordism.*

We study applications of Heegaard Floer homology to homology cobordism. In particular, to a homology sphere Y, we define a module $HF_{\mathrm{conn}}(Y)$, called the connected Heegaard Floer homology of Y, and show that this module is invariant under homology cobordism and isomorphic to a summand of $HF_{\mathrm{red}}(Y)$. The definition of this invariant relies on involutive Heegaard Floer homology. We use this to define a new filtration on the homology cobordism group, and to give a reproof of Furuta's theorem. This is joint work with J. Hom and T. Lidman. (Received September 01, 2018)

1142-57-170 **J. Aramayona**, **T. Ghaswala**, **A. E. Kent**, **A. Mcleay**, **J. Tao*** (jing@ou.edu) and **R. R. Winarski**. *Big Torelli Groups.*

I will discuss some joint work with Aramayona, Ghaswala, Kent, McLeay, and Winarski on the Torelli subgroup of big mapping class groups. (Received September 02, 2018)

1142-57-174 **Micah Chrisman*** (chrisman.76@osu.edu). *Virtual Alexander invariants and virtual Seifert surfaces.*

Alexander polynomials and generalized Alexander polynomials of virtual knots can be computed via Alexander biquandles (Crans-Henrich-Nelson) or the extended knot group (Silver-Williams). Here we consider the case of almost classical (AC) knots. These are virtual knots that can be represented by homologically trivial knots in thickened surfaces $\Sigma \times [0,1]$, where Σ is a closed orientable surface. Such knots bound Seifert surfaces $F \subset \Sigma \times [0,1]$. Alexander polynomials of AC knots can be computed from Seifert surfaces in a similar (but not identical) fashion to the classical case (Boden-Gaudreau-Harper-Nicas-White). However, these Seifert surfaces are difficult to draw in practice. We present a generalization of Seifert's algorithm to homologically trivial knots in thickened surfaces. These virtual Seifert surfaces are constructed from Gauss diagrams. In addition to computing Alexander invariants, we show how to use virtual Seifert surfaces to estimate various geometric invariants of knots in thickened surfaces, such as the virtual slice genus and the virtual 3-genus. (Received September 02, 2018)

1142-57-182 **Asaf Hadari*** (hadari@math.hawaii.edu), 3029 Lowrey Ave., Unit P2103, Honolulu, HI 96822. *How good is the representation theory of mapping class groups?*

In recent years, the representation theory of mapping class groups has garnered a lot of attention. Many examples of representations are now known, but a fundamental underlying representation theory has yet to emerge. We pose several fundamental questions that attempt to gauge how descriptive the representations of the mapping class group are, and we will describe several recent results. (Received September 03, 2018)

1142-57-183 **Lisa Piccirillo*** (lpiccirillo@math.utexas.edu). *The Conway knot is not slice.*

Knots in S^3 are considered classically equivalent if they cobound an annulus in S^3 and equivalent in concordance if they cobound an annulus in $S^3 \times I$. Positive mutation is a subtle modification of a knot; pairs of knots related by positive mutation are difficult to distinguish classically and even more so in concordance. The smallest and best studied mutant pair are the 11 crossing Conway and Kinoshita-Teresaka knots. They were distinguished classically by Riley in 1971; in this talk I will distinguish them in concordance. To do so I'll discuss a new concordance obstruction coming from the study of certain 4-manifolds and I will point out several other applications of this study. (Received September 03, 2018)

1142-57-190 **Rhea Palak Bakshi*** (rhea_palak@gwu.edu), Department of Mathematics, Room 725, Phillips Hall, 801 22nd Street NW, Washington, DC 20052, and **Sujoy Mukherjee**, **Marithania Silvero**, **Józef H. Przytycki** and **Xiao Wang**. *On the skein algebra of the thickened four - holed sphere.*

The Kauffman bracket skein module was introduced by J. H. Przytycki as a generalization of the Kauffman bracket polynomial in the 3-sphere to any arbitrary 3-manifold. Since its introduction, the Kauffman bracket skein module has become central to the theory of 3-manifolds. In 1997, C. Frohman and R. Gelca established a compact product-to-sum formula for the Kauffman bracket skein algebra of the torus times the interval. We work on a similar formula for the multiplication of curves in the thickened sphere with four holes and I will present some of our results to this end. This is joint work in progress with Sujoy Mukherjee, Józef H. Przytycki, Marithania Silvero and Xiao Wang. (Received September 03, 2018)

1142-57-207 **Jozef H. Przytycki*** (przytyck@gwu.edu), George Washington University, Washington, DC 20052, and **Xiao Wang**. *The second Yang-Baxter homology of the Homflypt polynomial of links.*

We consider the homology of a column unital Yang-Baxter operator. In particular, we prove that the second homology is given by the following theorem:

Let R_m be a unital Yang-Baxter operator giving Homflypt polynomial on level m, then for $k = Z[y]$:

$$H_2(R_m) = k^{1+\binom{m}{2}} \oplus \left(k/(1-y^2)\right)^{\binom{m}{2}} \oplus \left(k/(1-y^4)\right)^{m-1}.$$

(Received September 04, 2018)

1142-57-215 **Sujoy Mukherjee*** (sujoymukherjee@gwu.edu) and **Józef H. Przytycki** (przytyck@gwu.edu). *On the rack homology of graphic quandles.*

The graphic axiom $a * b = (a * b) * a$ was introduced by F. W. Lawvere in 1987. Quandles are self-distributive algebraic structures with axioms motivated by the three Reidemeister moves in knot theory. Spindles are obtained by weakening the axioms of a quandle. It was discovered by M. Niebrzydowski and J. H. Przytycki that there are quandles and spindles satisfying the graphic axiom. One such family of quandles satisfying the graphic axiom consist of $f_{i,j}-$quandles. We will answer the question whether or not there are quandles outside this family satisfying the graphic axiom. In the second half of the talk, we will discuss the rack homology of these quandles. (Received September 04, 2018)

1142-57-226 **Amey Kaloti*** (askaloti@uark.edu), SCEN, 850 W Dickson St #309, Apartment 107, Fayetteville, AR 72701, and **Jeremy Van Horn-Morris**. *Embeddings of Wenstein manifolds.*

We describe a method to embed Weinstein 4 manifolds into Weinstein 6 manifolds. We give examples of Weinstein 6 manifolds which contain all Weinstein 4 manifolds as properly embedded submanifolds. This is joint work with Jeremy Van Horn-Morris. (Received September 04, 2018)

1142-57-233 **Christopher R Cornwell*** (ccornwell@towson.edu). *Full twists and augmentations in knot contact homology.* Preliminary report.

We will discuss augmentations in the context of knot contact homology. Our focus is the existence of a special augmentation – one which has large *rank* – which forces some numerical invariants of the knot to be well-behaved. In particular, we consider the situation when there are many full twists in a closed braid representative of the knot. (Received September 04, 2018)

1142-57-238 **Juanita Pinzon-Caicedo*** (jpinzon@ncsu.edu). *Relative trisections and HF contact invariants.* Preliminary report.

A relative trisection of a 4–manifold W with connected boundary ∂W is a decomposition of W into three 4–dimensional 1–handlebodies that induces an open book decomposition on the boundary ∂W. Thus, relative trisections can be regarded as fillings of open book decompositions and the latter are known to carry geometric information. This talk explores the connection between the topology of the trisection and the geometry of the contact structure via Heegaard 4-tuples and the contact invariant(s) in Heegaard Floer homology. (Received September 04, 2018)

1142-57-239 **M K Dabkowski*** (mdab@utdallas.edu) and **J H Przytycki** (przytyck@gwu.edu). *Coefficients of Catalan states obtained from lattice crossing.*

For a Catalan state C of a lattice crossing $L(m, n)$ with no returns on one side, we find its coefficient $C(A)$ in the Relative Kauffman Bracket Skein Module expansion of $L(m, n)$. We show, in particular, that $C(A)$ can be found using the plucking polynomial of a rooted tree with a delay function associated to C. For C with returns on one side only, we prove that $C(A)$ is a product of Gaussian polynomials. Furthermore, for an arbitrary Catalan state C obtained from $L(m, 3)$, we give a method to compute $C(A)$. (Received September 04, 2018)

1142-57-240 **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. *Unified Khovanov homology of homologically thin knots.* Preliminary report.

Unified Khovanov homology combines even and odd Khovanov homology theories into a single algebraic object that carries the structure of a module over the group ring $\mathbb{Z}\mathbb{Z}_2$. In this talk, we prove that the unified homology of homologically thin knots over $\mathbb{Z}_2$ is completely determined by their Jones polynomial and signature. The proof is based on the algorithm for computing the unified homology developed by the authors. (Received September 04, 2018)

1142-57-247 **Adam Saltz*** (adam.saltz@uga.edu), Boyd Hall, University of Georgia, Athens, GA 30602. *Link homology, bridge trisections, and invariants of knotted surfaces.*

I will describe an invariant of knotted surfaces in S^4 obtained by applying link homology to Meier and Zupan's bridge trisections. This invariant takes values in Z/2Z and distinguishes the unknotted sphere from the spun (2,3)-torus knot. I'll finish with some more speculative connections to transverse links and links in other three-manifolds. (Received September 05, 2018)

58 ► Global analysis, analysis on manifolds

1142-58-235 **Sherry Gong*** (ggyiran@gmail.com). *Some results regarding the computation of singular instanton homology for links.* Preliminary report.

We discuss some computations arising from the spectral sequence constructed by Kronheimer and Mrowka relating the Khovanov homology of a link to its singular instanton homology. (Received September 04, 2018)

60 ► Probability theory and stochastic processes

1142-60-6 **Brad Marvin** (tanbui@ices.utexas.edu) and **Tan Bui-Thanh***, 210 East 24th street, Austin, TX 78712. *Fast Methods for Bayesian Optimal Experimental Design.*

We cast data assimilation problem into a model inadequacy problem which is then solved by a Bayesian approach. The Bayesian posterior is then used for Bayesian Optimal Experimental Design (OED). Our focus is on the A- and D-optimal OED problems for which we construct scalable approximations that involve: 1) randomized trace estimators; 2) Gaussian quadratures; and 3) trace upper bounds. Unlike most of contemporary approaches, our methods work directly with the inverse of the posterior covariance, i.e. the Hessian of the regularized misfit for linear data assimilation problems, and hence avoiding inverting large matrices. We show that the efficiency of our methods can be further enhanced with randomized SVD. Various numerical results for linear inverse convection-diffusion data assimilation problems will be presented to validate our approaches. (Received May 07, 2018)

62 ► Statistics

1142-62-241 **Avishek Chakraborty*** (ac032@uark.edu), Department of Mathematical Sciences, SCEN 309, University of Arkansas, Fayetteville, AR 72701. *Bayesian Modeling Ideas for Data Assimilation and Uncertainty Quantification.*

Deterministic computer models (simulators), common in many scientific disciplines to explore the dynamics of physical events, are usually resource and time expensive and they may not adequately capture the real-world system. An emulator, a stochastic surrogate for the computer code, is used within a hierarchical framework to combine realizations from the computer model and field observations for estimation of parameters governing the system and prediction at new input combinations. In this talk, we are going to look at two different choices for emulators based on over-specified set of functions- splines and polynomial chaos expansions. Notably, the number of such functions, and their inclusion probabilities, are treated as unknown quantities. This approach is found to have smaller predictive uncertainty and computational efficiency than the standard Gaussian process approach to emulation and calibration. We will also look at associated inverse problem for retrieval of the unknown experimental input from the observed output. Another aspect of this talk will be to explore options for measurement error modeling in physical experiments when it is known to be non-Gaussian. We will use an example from Astrophysics to illustrate the concepts we discuss. (Received September 04, 2018)

65 ► Numerical analysis

1142-65-30 **Xiaoming He*** (hex@mst.edu), 400 W. 12th St., Department of Mathematics and Statistics, Missouri University of Science and Technology, Rolla, MO 65401. *Multi-grid and multi-level Monte Carlo method for Stokes-Darcy model with random permeability.* Preliminary report.

Stokes-Darcy type models have attracted significant attention since it arises in many applications such as surface and subsurface flow interaction, groundwater flows in karst aquifers, petroleum extraction and industrial filtration. In the natural world, a lot of porous media has random permeability, especially in the subsurface flow system. We present multi-grid and multi-level Monte Carlo method for solving a stochastic Stokes-Darcy model with random permeability. Compared with the traditional Monte Carlo method, this method can significantly reduce the number of samples, hence improve the efficiency. Both theoretical and numerical results are presented to illustrate this method. (Received August 15, 2018)

1142-65-54 **Remi Abgrall*** (remi.abgrall@math.uzh.ch), University of Zurich, Winterthurerstrasse 190, 8057 Zurich, Switzerland, **Roxana Crisovan**, Winterthurerstrasse 190, 8057 Zurich, Switzerland, **Davide Torlo**, Winterthurerstrasse 190, 8057 Zurich, Switzerland, and **Svetlana Tokareva**, Winterthurerstrasse 190, 8057 Zurich, Switzerland. *Model order reduction for parametrized nonlinear hyperbolic problems as an application to Uncertainty Quantification.*

In this work, we focus on reduced order modeling (ROM) techniques for hyperbolic conservation laws with application in uncertainty quantification (UQ) and in conjunction with the well-known Monte Carlo sampling method. The aim is to reduce drasticaly the computational cost of CFD algorithms. Because we are interested in model order reduction (MOR) techniques for unsteady non-linear hyperbolic systems of conservation laws, which involve moving waves and discontinuities, we explore the parameter-time framework and in the same time we deal with nonlinearities using a POD-EIM-Greedy algorithm (M. Drohmann et al. SIAM SISC, 34 (2012), pp. A937–A969.) We provide under some hypothesis an error indicator, which is also an error upper bound for the difference between the high fidelity solution and the reduced one (Received August 24, 2018)

1142-65-68 **Jonathan D. Hauenstein*** (hauenstein@nd.edu). *Numerical Algebraic Geometry and Optimization.*

The field of numerical algebraic geometry aims to compute and manipulate solution sets to systems of nonlinear polynomial equations. One fundamental computational tool of numerical algebraic geometry is homotopy continuation which computes solution paths as the system of equations are deformed. Standard interior point methods for solving optimization problems can be viewed as a special case of homotopy continuation. This talk will explore this natural link via interior point methods between numerical algebraic geometry and optimization along with several other recent interactions. (Received August 27, 2018)

1142-65-105 **Carley R Walker*** (carley.walker@usm.edu), The University of Southern Mississippi, 118 College Drive, Hattiesburg, MS 39402. *Removal of Multiplicative Poisson Noise Using Variance Based Joint Sparsity Recovery.*

There has been much effort put into the use of multi-measurement vectors (MMV) and $\ell_{2,1}$ regularization to recover signals. Specifically, recent research has suggested that the effects of bad data on a signal may be lessened by using the variance based joint sparsity recovery method (VBJS), which weights the original jointly sparse (JS) signal recovery method, making signal recovery more accurate and cost efficient. This method, however, only accounts for additive noise supplement to the deblurring model for reconstruction of the true signal. Realistically, there is automatically inconsistency in the deblurring model, as well as other factors, that will also create multiplicative noise in the model. In this talk, this multiplicative noise in the model will be addressed, specifically multiplicative Poisson error distribution noise. Understanding the effects of this noise on the deblurring model as well as how to reduce its effects on the reconstruction of the true signal are essential for using the VBJS method in data fusion problems, where measurements may be obtained through multiple techniques and must be combined for an accurate reconstruction. This proposal is considered in 1-dimension, but through future work may also be applied to 2- and 3-dimensional scenes. (Received August 30, 2018)

1142-65-128 **Kit C Newton*** (kcnewton@math.wisc.edu), **Qin Li** and **Andrew Stuart**. *Diffusive Optical Tomography in the Bayesian Framework.*

Optical tomography, mostly used in medical imaging, is a technique for constructing optical properties in tested tissues via measurements of the incoming and outgoing light intensity. Mathematically, light propagation is modeled by the radiative transfer equation (RTE), and optical tomography amounts to reconstructing the scattering and absorption coefficients in the RTE using the boundary measurements. We study this problem in the Bayesian framework, and pay special attention to the strong scattering regime. Asymptotically, when this happens, the RTE is equivalent to the diffusion equation (DE), whose inverse problem is severely ill. We study the stability deterioration as the equation changes regimes and prove the convergence of the inverse RTE to the inverse DE in both nonlinear and linear settings. (Received August 31, 2018)

1142-65-167 **Simon J Tavener*** (simon.tavener@colostate.edu), 117 Statistics Building, Colorado State University, Fort Collins, CO 80523-1801, and **Varis Carey**, **Donald Estep**, **Victor Ginting** and **David Kay**. *Estimating and controlling "communication" errors in multiphysics problems.*

Multiphysics problems by their very nature involve the communication or transfer of information between distinct physical processes, domains or time scales. This communication necessarily results in the transfer of numerical (and modeling) error between different physical processes, domains or time scales, which must be estimated and controlled as part of a successful computation. We develop adjoint-based *a posteriori* error techniques to estimate

the error in a quantity of interest and implement refinement strategies to reduce these three very different types of "communication" error. (Received September 02, 2018)

1142-65-189 **James V Lambers*** (james.lambers@usm.edu), 118 College Dr #5043, Hattiesburg, MS 39406. *Matrices, Moments, Quadrature and PDEs.*

Krylov subspace spectral (KSS) methods are high-order accurate, explicit time-stepping methods with stability characteristic of implicit methods. This "best-of-both-worlds" compromise is achieved by computing each Fourier coefficient of the solution using an individualized approximation, based on techniques from "matrices, moments and quadrature' due to Golub and Meurant for computing bilinear forms involving matrix functions. This talk will present an overview of their derivation and essential properties, and also highlight ongoing projects aimed at enhancing their performance and applicability. (Received September 03, 2018)

1142-65-223 **Nathan Bliss**, **Timothy Duff*** (tduff3@gatech.edu), **Cvetelina Hill**, **Kisun Lee**, **Anton Leykin**, **Anders Jensen** and **Jeff Sommars**. *Monodromy solver: sequential and parallel.*

Monodromy provides a powerful but largely heuristic set of tools for studying algebraic equations via numerical homotopy continuation. We consider the application of monodromy to "generic solving" for families of zero-dimensional polynomial systems. We establish a language describing the implementation of such solvers in terms of decorated graphs and showcase some successes of a basic implementation in the Macaulay2 system. We also consider potential avenues for improvement—while naive statistical analysis provides insight into the successes, the fine-tuning of better solvers may require experimentation outside the scope of theory. In pursuit of this goal, we have also developed a simulator that allows us to run a large number of experiments without recomputing the outcomes of the continuation subroutine. (Received September 04, 2018)

1142-65-231 **Tianran Chen***, P.O. Box 244023, Montgomery, AL 36124. *Direct acyclic decomposition for Kuramoto networks.*

Synchronization in networks of interconnected oscillators is a fascinating phenomenon that appears naturally in many independent fields of science and engineering. The Kuramoto model, being extremely simple yet surprisingly powerful, is one of most widely used model for studying such behavior. A substantial amount of work has been devoted to understanding all possible frequency synchronization configurations on a given network modeled the Kuramoto model. These configurations are defined by a system of rational equations that has rich structures. Taking an approach from toric geometry and numerical algebraic geometry, in this talk, we propose a decomposition scheme that can reduce a complex network into smaller direct acyclic networks while preserving frequency synchronization configurations. (Received September 04, 2018)

68 ► Computer science

1142-68-245 **Junseok Kang***, CRG, Cresskill, NJ, Cresskill, and **Richard Kyung**. *Study on the Resolution of Digital Image Using Computational and Mathematical Analysis.*

Classifying the similar small particles can be possible by using image processing. Also processing a lot of particle images using computational and mathematical analysis is possible. In image processing, a Gaussian blur is the result of blurring an image by a Gaussian function. It is used to reduce image noise and reduce detail. Changing different variables in low pass filters can change the function produced over the image domain. Originally, square functions are used during Fourier Transformations. Also, various filters were tested in creating images to find an efficient proper filter. The proposed function filters were different from the rectangular function and Gaussian function, but trial and errors were done on the new filter to have all the advantages or properties of the LPF functions. (Received September 05, 2018)

76 ► Fluid mechanics

1142-76-5 **James Glimm*** (james.glimm@stonybrook.edu), 121 Thompson Street, Port Jefferson, NY 11777. *K41, K62 and all that.*

Recent progress and understanding of fractal and multifractal theories of fully developed turbulence will be discussed. Such theories yield the two point correlation function as the expectation value of correlations defined by a statistical model. Computational models of physics coupled nonlinearly to turbulent flow should be improved from such developments. (Received May 04, 2018)

1142-76-7 **Eleftherios Gkioulekas*** (drlf@hushmail.com), 1201 West University Drive, University of Texas Rio Grande Valley, School of Mathematical and Statistical Scienc, Edinburg, TX 78539. *The role of the asymmetric Ekman dissipation term on the energetics of the two-layer quasi-geostrophic model at large length scales.* Preliminary report.

In the two-layer quasi-geostrophic model, the friction between the flow at the bottom layer and the surface layer beneath it is modeled by the Ekman term, which is a linear dissipation term with respect to the horizontal velocity at the bottom layer. The Ekman term appears in the governing equations asymmetrically; it is placed at the bottom layer but does not appear at the top layer. A variation proposed by Salmon uses extrapolation to place the Ekman term between the bottom and surface layer or at the surface layer. In this presentation we present theoretical results that show that in either the standard or the extrapolated configurations, the Ekman term dissipates energy at large scales, but does not dissipate potential enstrophy. It also creates a stable almost symmetric distribution of potential enstrophy between the two layers. The behavior of the term changes fundamentally at large wavenumbers. (Received May 23, 2018)

1142-76-21 **John C Bowman*** (bowman@ualberta.ca), Department of Mathematical Sciences, University of Alberta, Edmonton, Alberta T6G 2G1, Canada, and **Pedram Emami**. *On the Global Attractor of 2D Incompressible Turbulence with Random Forcing and Friction.*

We revisit bounds on the projection of the global attractor in the energy–enstrophy plane obtained by Dascaliuc, Foias, and Jolly [2005, 2010]. In addition to providing more elegant proofs of some of the required nonlinear identities, the treatment is extended from the case of constant forcing to the more realistic case of random forcing. Numerical simulations in particular often use a stochastic white-noise forcing to achieve a prescribed mean energy injection rate. The analytical bounds are illustrated numerically for the case of white-noise forcing. In most numerical studies of 2D turbulence, an artificial friction term is added to drain energy from the inverse cascade. We investigate the effect of this additional term on the projection of the global attractor. (Received August 07, 2018)

1142-76-65 **Jared P Whitehead*** (whitehead@mathematics.byu.edu), 275 TMCB, Brigham Young University, Provo, UT 84602. *Prepare to be assimilated: Data Assimilation between two similar, but distinct systems.*

We consider a classical data assimilation algorithm for large Prandtl number convection, but when the assimilated system satisfies the simplified infinite Prandtl number equations. Comparing numerical simulations of this scheme to a more traditional assimilation algorithm wherein the observations and assimilating model are both at either large Prandtl or infinite Prandtl numbers we see that the assimilation itself is not the restriction on the accuracy of the scheme, but rather that the 'closeness' of the large Prandtl number system to the infinite Prandtl system throttle the accuracy of the assimilation scheme. Implications for realistic data assimilation schemes in other settings are discussed at length. (Received August 27, 2018)

1142-76-80 **Andrew D Bragg*** (andrew.bragg@duke.edu) and **Josin Tom**. *On the multiscale mechanism generating enhanced particle settling speeds in turbulence.*

According to Maxey (J. Fluid Mech., 174:441–465, 1987), enhanced particle settling speeds in turbulence occur because of the way that inertial particles preferentially sample the fluid velocity gradient field ∇u. However, recent Direct Numerical Simulation (DNS) results in Ireland et al. (J. Fluid Mech., 796:659–711, 2016) show that the settling enhancement is strongest in a portion of the parameter space where preferential sampling of ∇u is very weak. The results also show that the settling can be strongly enhanced with increasing Reynolds number. The analysis of Maxey does not account for these findings, partly since it was restricted to particle Stokes numbers $St \ll 1$. To explain the findings, we have developed a new theoretical analysis, valid for arbitrary St, that employs Probability Density Function (PDF) methods, particle velocity fields constructed using averaging decompositions, and coarse-graining for the fields to reveal which scales of the turbulence contribute to the enhanced settling speeds. This analysis is complemented by results from DNS where we examine how the particle settling speeds vary when the fluid velocity field is subject to different levels of coarse-graining. (Received August 29, 2018)

1142-76-116 **Animikh Biswas*** (abiswas@umbc.edu), **Ciprian Foias**, **Cecilia F Mondaini** and **Edriss S Titi**. *Determining Quantities for Statistical Solutions of the Navier-Stokes Equations.* Preliminary report.

In turbulent flows, physical properties are universally recognized as randomly varying and characterized by some suitable probability distribution functions. Theoretical considerations are often couched in terms of ensemble averages with respect to some probability distribution on the phase space.The evolution of these probability distributions are determined by the underlying governing equation, namely the Navier-Stokes equations. On

the other hand, measurements of various aspects of turbulent flows are actually measurements of time-averaged quantities. The notion of statistical solutions, first introduced in a seminal work by Foias, provide the requisite rigorous mathematical framework connecting these two notions. In this joint work with Foias, Mondaini and Titi, we explore various notions of determining quantities for statistical solutions, which in turn is related to finite degrees of freedom for turbulent flows. One of our main tool is a recently introduced data assimilation algorithm by Azouni, Olson and Titi, applicable to a wide class of dissipative system. (Received August 31, 2018)

1142-76-119 **Animikh Biswas*** (abiswas@umbc.edu). *Navier-Stokes equations in Gevrey classes.* Preliminary report.

We discuss existence time for the 3D Navier-Stokes equations (NSE) in a new functional class which is a subclass of smooth functions. This class appeared recently in the work of Foias, Jolly, Yong and Zhang in the study of the attractors for the 2D NSE. We show that for the 3D case, the differential inequality that one obtains in this class is very nearly linear. This leads to an existence time which is better than the reciprocal of any power of the norm of the initial data. Subsequently, we discuss blow up rates for solutions in analytic Gevrey classes. (Received August 31, 2018)

1142-76-136 **Elaine Cozzi*** (cozzie@math.oregonstate.edu) and **James P. Kelliher**. *Solutions to the 2D Euler equations with velocity growing at infinity.*

In this talk, we discuss existence of solutions to the 2D Euler equations with vorticity bounded and velocity growing at infinity. If time permits, we will also mention recent results and open questions related to uniqueness and continuous dependence on the initial data for these solutions. (Received August 31, 2018)

1142-76-158 **Michael S Jolly*** (msjolly@indiana.edu) and **Djoko Wirosoetisno**. *Effect of energy spectra on tracer cascade.*

We first consider the effect the inverse cascade in 2D can have on the tracer cascade. In this case, we assume two spectra for the tracer which are consistent with the energy spectra according to Obukhov and Corrsin. We show that the tracer cascade range extends to a power of 5/6 of the dissipation wave number of the fluid under certain reasonable constraints on the Grashof number of the fluid, and the gap between the injection of the tracer and the energy. For moderate Schmidt numbers the diffusive wave number is comparable to the dissipation wave number, so this provides a tracer cascade range which is close to optimal. It is shown that in both 2D and 3D, taking the Schmidt number sufficiently large in terms of the Grashof number, the tracer cascade range extends to a power arbitrarily close to unity of the diffusion wave number, up to a logarithm. These results are mainly due to the prefactors in the spectra, as opposed to the precise decay rate of energy as a function of wave number. (Received September 01, 2018)

1142-76-191 **Michael S. Jolly*** (msjolly@indiana.edu). *Bounds on the attractor for the 2D Rayleigh-Bénard problem.* Preliminary report.

We find regions that bound the global attractor of the Rayleigh-Bénard problem in the EZ-plane, where E is a sum of squared L^2 norms of velocity and temperature and Z is a similar sum, but for gradient norms. This is done for both no-slip and free-slip boundary conditions, with modest improvement for the overall gradient norm bounds on the global attractor. We then find invariant regions in the 3-space spanned by enstrophy, palinstrophy and the gradient norm of temperature in the free-slip case. (Received September 03, 2018)

1142-76-197 **Ethan T. Vishniac*** (evishni1@jhu.edu), Dept of Physics and Astronomy, Johns Hopkins University, Baltimore, MD 21218. *Topology and the Large Scale Turbulent Dynamo.*

Astrophysical objects, such stars, planets, galaxies, and accretion disks, all show evidence for magnetic fields with a significant amount of power on the scale of the object. These fields seem to arise from a combination of rotation and turbulence in highly conducting fluids. I will discuss how the generation of these fields can be understood from the conservation of magnetic helicity in ideal magnetohydrodynamics. Magnetic helicity is the only classical example of a Chern-Simons symmetry and has the rare trait of being robustly conserved in systems that are not exactly ideal. I will show how scaling arguments derived from these arguments can explain the dependence of stellar magnetic fields on rotation rates. Finally, I note that these same arguments can be used to show that kinematic dynamo theory does not play a significant role in the generation of large scale magnetic fields. (Received September 03, 2018)

1142-76-204 **Tulin Kaman*** (tkaman@uark.edu), University of Arkansas, Department of Mathematical Sciences, SCEN 218, Fayetteville, AR 72701. *Numerical challenges in turbulent mixing simulations.*

In this talk, we address the issue to characterize and quantify the effects of uncertainties in model parameters in the numerical simulations of turbulent mixing of miscible fluids. We compare new simulations and their analysis with experiments of Rayleigh-Taylor instabilities, using the front-tracking based software code and study the statistical convergence properties. (Received September 04, 2018)

1142-76-214 **Adam Larios*** (alarios@unl.edu), Department of Mathematics, University of Nebraska-Lincoln, Lincoln, NE 68588-0130. *Variations on the Azouani-Olson-Titi Algorithm for Data Assimilation in PDEs.*

A major difficulty in accurately simulating turbulent flows is the problem of determining the initial state of the flow. For example, weather prediction models typically require the present state of the weather as input. However, the state of the weather is only measured at certain points, such as at the locations of weather stations or weather satellites. Data assimilation eliminates the need for complete knowledge of the initial state. It incorporates incoming data into the equations, driving the simulation to the correct solution. The objective of this talk is to discuss new computational and mathematical methods to test, improve, and extend a promising new class of algorithms for data assimilation in turbulent flows and related PDEs, stemming from the pioneering work of Azouani, Olson, and Titi. (Received September 04, 2018)

1142-76-216 **Hussein Aluie***, hussein@rochester.edu, and **Mahmoud Sadek**, **Matthew Hecht** and **Geoffrey Vallis**. *Multi-Scale Dynamics of Flows on the 2-Sphere: Applications to the Ocean.*

Large-scale currents and eddies pervade the ocean and play a prime role in the general circulation and climate. The coupling between scales ranging from $O(10^4)$ km down to $O(1)$ mm presents a major difficulty in understanding, modeling, and predicting oceanic circulation and mixing, where our constraints on the energy budget suffer from large uncertainties. Identifying the energy sources and sinks at various scales and geographic locations can reduce such uncertainty and yield insight into new parameterizations of nonlinear physical processes. To this end, we have developed a coarse-graining (or filtering) framework for analyzing the multi-scale dynamics on the 2-sphere. This is made possible by generalizing the convolution to ensure that our filtering operators commute with spatial derivatives on the 2-sphere, thereby allowing us to derive the PDEs governing any sets of scales. I will demonstrate the application of this framework to satellite altimetry data and to strongly eddying high-resolution simulations using General Circulation Models. (Received September 04, 2018)

83 ► Relativity and gravitational theory

1142-83-161 **Hatim Kareem Khudhair*** (hkkz89@mst.edu), 1706 N Elm St #12, Rolla, MO 65401, and **Zhang**. *Numerical simulation of pattern formation of the spatial-fractional Gray-Scott equation.*

In this talk, we introduce numerical simulation of pattern formation of the spatial-fractional Gray-Scott equation to understand the nonlocal effects of the fractional Laplacian. The linear stability analysis will be examined to predict the conditions of the Turing pattern. Furthermore, we discretize the fractional Gray-Scott equation by the Fourier pseudo-spectral method in space and the 4th order Runge-Kutta method in time, and then we numerically investigate the effects of the fractional exponent on the spatiotemporal patterns formation and pattern selection in Gray-Scott system. The pattern formations in the standard and fractional Gray-Scott models will be compared in this study to give more insights of the nonlocal effects (Received September 02, 2018)

1142-83-249 **Mihalis Dafermos***, Fine Hall, Washington Road, Princeton, NJ 08544. *On falling into black holes.*

The celebrated "black hole" spacetimes of Schwarzschild and Kerr play a central role in our current understanding of Einstein's general theory of relativity. Are these spacetimes stable, however, as solutions to the Einstein vacuum equations, in their exterior region? And what fate awaits physical observers who enter inside a "generic" black hole? It turns out that these two questions are intimately related and the answer to the second may be more disturbing than previously thought. This talk will try to explain how so. (Received September 05, 2018)

90 ► Operations research, mathematical programming

1142-90-186 **Timo de Wolff*** (dewolff@math.tu-berlin.de), Institut für Mathematik der TU Berlin, Sekr. MA 6-2, Str. des 17. Juni 136, Berlin, Germany, and **Henning Seidler**. *Polynomial Optimization via SONC Certificates.*

Deciding nonnegativity of real polynomials is a fundamental problem in real algebraic geometry and polynomial optimization. Since the 19th century, sums of squares (SOS) are a standard certificates for nonnegativity, which can be detected via semidefinite programming (SDP) in practice.

In 2014, Sadik Iliman and I introduced a new nonnegativity certificate based on *sums of nonnegative circuit polynomials (SONC)*. These certificates are *independent* of sums of squares. In the same year, we applied SONCs to global nonnegativity problems using geometric programming (GP) for the first time.

In this talk, I will present recent work with my graduate student Henning Seidler: In early 2018, we released a first version of our software POEM for polynomial optimization especially using SONC certificates. Recently, we finished a first experimental, large-scale comparison of SONC and SOS certificates for unconstrained optimization. Though both the SDPs corresponding to SOS and the GPs corresponding to SONC are convex optimization problems, which are solved numerically via interior point methods, their performance differs dramatically in practice. (Received September 03, 2018)

91 ► Game theory, economics, social and behavioral sciences

1142-91-248 **Remy Wu***, CRG, Cresskill, NJ, and **Richard Kyung**, CRG, Cresskill, NJ. *Study on Stock Market Patterns with Economic Fluctuations Using Statistical and Computational Simulations.*

While both the casual investor and large hedge funds thrive off booms in the stock market, the effect that a crash has on society as a whole is much more extreme. Recently, there have been many historic stock market crashes, such as those in 2002 and 2008. These stock market crashes create wide scale unemployment and send waves of fear through the world of business.

Although depressions have many different causes, they can be predicted through certain patterns in P/E Ratio, Nasdaq, and VIX. We used many different types of statistical and computational theories to find patterns in these data. Time series analysis allows us to account for the dynamic fluctuations in the stock market and analyze the sequential data. If trends from the time series analysis are too noisy, smoothing is used to distinguish the signal and the noise. Curve fitting allows for the extrapolation of data points, therefore calculating return periods that can be used to predict stock market crashes.

This research identifies different return periods for stock market crashes based on their size. These patterns can be used to estimate how often a crash of a certain magnitude occurs, helping mitigate its effect on society. (Received September 05, 2018)

92 ► Biology and other natural sciences

1142-92-12 **Md Mondal Hasan Zahid*** (mdmondal.zahid@mavs.uta.edu) and **Christopher M Kribs** (kribs@mathed.uta.edu). *Ebola: Impact of hospital's admission policy in an overwhelmed scenario.*

Infectious disease outbreaks sometimes overwhelm healthcare facilities with patients. A recent case occurred in West Africa in 2014 when an outbreak of Ebola virus overwhelmed healthcare facilities. In this type of scenario, how many patients can hospitals admit to minimize the burden of the epidemic? Here, we considered what type of admission policy by a hospital during a hypothetical Ebola outbreak can better serve the community. Our result shows that which policy minimizes loss to the community depends on the initial estimation of the basic reproduction number,R_0. When the outbreak grows extremely fast ($R_0 \gg 1$) it is better(in terms of total disease burden) to stop admitting patients after reaching the carrying capacity because overcrowding in the hospital makes the hospital setting ineffective at containing infection, but when the outbreak grows only a little faster than the system's ability to contain it ($R_0 \gtrsim 1$), it is better to continue admitting patients beyond the carrying capacity because limited overcrowding still reduces infection more in the community. However, when R_0 is no more than a little greater than 1(for our parameter values, 1.012), both policies result the same because the number of patients will never go beyond the maximum capacity. (Received July 19, 2018)

1142-92-177 **Md Rafiul Islam*** (rafiul.islam@ttu.edu), 1612 avenue Y 205A, Lubbock, TX 79401, and **Patrick J. Cusaac**, **Matthew J. Gray** and **Angela Peace**. *Mathematical modeling of Batrachochytrium salamandrivorans on the Eastern Newt with environmental transmission.* Preliminary report.

The recently discovered fungal pathogen, Batrachochytrium salamandrivorans (Bsal) is believed to be from Asia and was likely introduced into Europe through international trade that caused rapid die-offs of naïve salamanders in Europe and Gray et al. (2015) predicts North America will soon experience similar devastation if no policy actions are taken and the pathogen emerges. In order to better understand Bsal pathogen dynamics, we develop nonlinear Susceptible-Infected-Recovered-Susceptible (SIRS) model for this emerging fungal pathogen. Our models included two routes of pathogen transmission: direct transmission via contact between infected and susceptible individuals and environmental transmission via shed zoospores in the water. Unlike previous models, we categorized individuals into multiple stages of infection. We found the invasion probability for Bsal into a population of the Eastern Newt adults. We performed numerical simulations and parameter sensitivity analysis using latin hypercube sampling with PRCC. We identified the dominant transmission pathway and suggested control strategies.

References

Gray, Matthew J., et al. "Batrachochytrium salamandrivorans: the North American response and a call for action." PLoS pathogens (Received September 02, 2018)

1142-92-205 **Binod Regmi*** (binodregmi30@gmail.com), 1551 N Leverett Ave 52, FAYETTEVILLE, AR 72703, and **Marlis Douglas** and **Michael Douglas**. *Machine learning on morphometry, an evaluation of classifiers' performance on closely related species delimitation.*

Learning algorithms have been implemented to investigate communities of different fish species in natural habitats; however, the potentiality of the algorithms to discriminate closely related species has not been examined yet. In this study, we digitized 18 anatomical landmarks from 564 images captured from museum specimens of five fish species collected in the Central Himalayas. Landmarks co-ordinates (2D) were transformed using Generalized Procrustes Alignment (GPA). Principal component analysis with logistic regression, linear discriminant analysis, support vector machine learning, and random forest approaches were evaluated for their performance to discriminate putative endemic species of snowtrout in Lake Rara and two other common species of snowtrout found in major rivers in the Central Himalayas. To get an insight on model performance, we implemented multistage error estimation and cross-validation from data extraction through analysis. We compared MNOVA, accuracy estimates, and area under ROC for evaluating the machine learning algorithms. Both support vector machine and linear discriminant analysis as performing well for distinguishing species. This study demonstrates the prospect of developing automatized species recognition systems using popular statistical algorithms. (Received September 04, 2018)

00 ► General

1143-00-85 **Gabi Pragier*** (gabipragier@post.tau.ac.il) and **Yoel Shkolnisky**. *A (self) common lines approach for ab-initio modeling of cyclic symmetric molecules in cryo-electron microscopy.*

One of the main goals in cryo-electron microscopy is to recover the rotations matrices $R_i \in SO(3),\ i = 1, \ldots, N$ that correspond to the viewing directions of a given set of projection-images $P_{R_1}, \ldots, P_{R_N}$ of some molecule. In many cases, this is achieved using the projection-slice theorem, which states that the two-dimensional Fourier transform of any projection-image is equal to the restriction of the three-dimensional Fourier transform of the molecule ϕ to the central plane whose normal coincides with the beaming direction of the image, and thus each pair of projection-images share a common-line. In this work, we focus on C_n molecules; that is molecules that have an n-fold cyclic symmetry for which existing common-lines-based methods are not applicable. Our method utilizes self-common-lines which induce identical lines within the same image. We show that the location of self-common-lines is related to the underlying image's viewing-direction polar angle, and that it admits quite a few favorable geometrical constraints, thus enabling a high detection rate even in a noisy setting. (Received July 31, 2018)

1143-00-114 **Anna Maria Spagnuolo***, spagnuol@oakland.edu, **Victor DiRita**, diritavi@msu.edu, and **Denise Kirschner**, kirschne@umich.edu. *A mathematical model for vibrio cholerae colonization in the human intestine.*

Vibrio cholerae is a strict human pathogen that causes the disease cholera. It is an old-world pathogen that has re-emerged as a new threat since the early 1990s. V. cholerae colonizes the upper, small intestine where it produces a toxin that leads to watery diarrhea, characterizing the disease. The dynamics of colonization by the bacteria of the intestines are largely unknown. Although a large initial infectious dose is required for infection, data suggests that only a smaller sub-population colonizes a portion of the small bowel leading to disease. There are many barriers to colonization in the intestines including peristalsis, fluid wash-out, viscosity of the mucus layer, and pH. In this talk, I will describe a mathematical model that will help identify the mechanisms that allow this sub-population of bacteria to survive and colonize the intestines when faced with these barriers. Numerical simulations will also be presented. (Received August 04, 2018)

1143-00-321 **S. Verma*** (sadanand.verma@unlv.edu), University of Nevada Las Vegas, 4505 Mariland Parkway, Las Vegas, NV 89152. *Mjnimization via double dip Maximization.* Preliminary report.

The purpose of this paper is to extend the domain of Standard form problems in Simplex Method for Maximization and apply the method of maximization to minimization problems by double dipping. In Simplex method for Maximization for problems in standard form, the condition of requiring that the linear constraint inequality be more than or equal to a positive number is very restrictive and eliminates many problems that can be done by using the standard form algorithm. The condition of requiring a positive number can easily be changed to requiring a non-negative number. Furthermore a Minimization problem can also be done by using a maximization algorithm by what is called a double dipping. A more efficient general Algorithm for Optimization in general is also discussed in this paper. (Received August 17, 2018)

1143-00-400 **Giovanni Di Crescenzo*** (gdicrescenzo@perspectalabs.com) and **Kelsey G Horan** (khoran@gradcenter.cuny.edu). *Securing Inner-Product-based Classifiers using Cryptographic Program Obfuscation.* Preliminary report.

It has been recently observed that Machine Learning classifiers can be subject to a variety of attacks, with undesirable consequences in their practical applications. Among possible remedy approaches, researchers are considering cryptographic program obfuscation, the area of cryptographic methods that studies ways to allow execution of a program while provably preserving the privacy of the program's secret data. In this talk, we discuss work in progress on cryptographic program obfuscation of a class of programs, related to inner product based functions, as these are a frequent building block of machine learning classifiers. Our preliminary solutions, similarly to previous work in the area, are based on functions over cyclic groups with homomorphic properties. (Received August 19, 2018)

1143-00-517 **Robert M. Strain** and **Maja Taskovic*** (taskovic@math.upenn.edu). *Entropy dissipation estimates for the relativistic Landau equation, and applications.*

The Landau equation, derived by Landau in 1936, models a dilute hot plasma where fast moving particles interact via Coulomb interactions. This model does not include the effects of Einstein's theory of special relativity. When particle velocities are close to the speed of light, which happens frequently in a hot plasma, then relativistic effects become important. A model that captures these effects, the relativistic Landau equation, was derived by Budker and Beliaev in 1956.

We study the Cauchy problem for the spatially homogeneous relativistic Landau equation with Coulomb interactions. The difficulty of the problem lies in the extreme complexity of the kernel of the collision operator. We present a new decomposition of such kernel. This is used to prove the global Entropy dissipation estimate, the propagation of any polynomial moment for a weak solution, and the existence of a true weak solution for a large class of initial data. (Received August 21, 2018)

1143-00-536 **Reza Soroushmehr*** (ssoroush@umich.edu). *Analyzing characteristics of image watermarking methods.*

Nowadays due to widespread internet usage, digital contents are easily distributed throughout the world. Digital media products are subjects of piracy and plagiarism. Therefore, protecting them against illegal copyright is a major concern for many digital forensic experts. Digital watermarking can be employed as a reliable way to embed a message into multimedia documents to resolve copyright ownership concerns. Robustness, invisibility, and capacity are three major characteristics of a watermarking algorithm. A watermarking system is considered invisible if original cover image and watermarked image are not perceptually distinguishable. A robust watermarking system is able to withstand against attacks such as filtering, compression, and so on. The capacity of a watermarking system is the maximum amount of message can be inserted in a cover image without noticeable loss in the quality of the image. In this paper we analyze these characteristics by investigating a number of watermarking approaches. (Received August 21, 2018)

01 ► History and biography

1143-01-344 **Donald A. Sokol*** (3471das@gmail.com), 11S047 Palisades RD., bURR rIDGE, IL 60527. *Plimpton 322.3 Rosetta Stone: Part Drei/Some Loose Ends.*

Earlier in the 2nd decade of the 21st century,it was shown that there exists several algorithms in addition to the one provided by Euclid in his treatise ""the Elements"(circa 300 B.C.)to construct integer triples (a, cand b) of the P.T.,from given values identified as x and y. Also during this period it was further shown how the square root and negative values in x and y affected the scale and orientation of the resultant integer triple. It is the purpose of this presentation to clear up some loose ends ,notably by addressing the ability of these algorithms to transform conic wave forms into right trangles that meet the rigors of the P,T.; and why a=b is a boundary condition. (Received August 18, 2018)

03 ► Mathematical logic and foundations

1143-03-4 **M Malliaris***, Department of Mathematics, University of Chicago, 5734 S University Avenue, Chicago, IL 60637. *Regular ultrafilters.*

Recent progress on understanding Keisler's order, a classification program in model theory which compares theories using regular ultrafilters, has required advances in ultrafilter construction and also brought to light some limitations of our current understanding of regular ultrafilters. The talk will explain some of these frontiers. (Received February 13, 2018)

1143-03-175 **Daniel J Hathaway*** (daniel.hathaway@uvm.edu) and **Natasha Dobrinen**. *The Halpern-Läuchli Theorem and Forcing.*

We will show the various effects that forcing has on several forms of the Halpern-Läuchli Theorem. We will show that the the theorems at an inaccessible κ are preserved by forcings of size $< \kappa$. Combining this with work of Zhang, we have that a certain partition relation on the κ-rationals can be made to be preserved by all forcings of size $< \kappa$. We also show that the various Halpern-Läuchli Theorems are preserved by $<\kappa$-closed forcings assuming κ is measurable. (Received August 09, 2018)

1143-03-196 **Haim Horowitz*** (haim@math.toronto.edu). *New results and open problems on the definability of mad families.*

The study of the definability of mad families and their relatives has seen rapid progress in the last few years. I'll discuss some recent results and work in progress, as well as some recent open problems in this area. (Received August 13, 2018)

1143-03-203 **Brent Cody*** (bmcody@vcu.edu), 1015 Floyd Avenue, Richmond, VA 23220. *Characterizations of the weakly compact ideal on $P_\kappa\lambda$.*

Baumgartner used a natural two-cardinal version of the cumulative hierarchy to define a notion of Π^1_1-indescribable subset of $P_\kappa\lambda$, which gives rise to the normal ideal of non-Π^1_1-indescribable subsets of $P_\kappa\lambda$. We generalize two of the most useful characterizations of Π^1_1-indescribable subsets of a cardinal to subsets of $P_\kappa\lambda$. Wen Zhi Sun proved that, assuming κ is Π^1_1-indescribable, a set $W \subseteq \kappa$ is Π^1_1-indescribable if and only if $W \cap C \neq \emptyset$ for every 1-club $C \subseteq \kappa$. Using the minimal *strongly* normal ideal on $P_\kappa\lambda$, we formulate an appropriate notion of 1-club subset of $P_\kappa\lambda$ such that Sun's characterization generalizes to Baumgartner's two-cardinal indescribability. We also give an elementary embedding characterization of Baumgartner's two-cardinal indescribability using embeddings resembling those considered by Jason Schanker witnessing *near supercompactness*. We will discuss applications including an answer to a question of Cox-Lücke and prove several partial results involving shooting 1-clubs through weakly compact subsets of $P_\kappa\lambda$. (Received August 13, 2018)

1143-03-248 **Hossein Lamei Ramandi** and **Justin Tatch Moore***, Department of Mathematics, Malott Hall, Cornell University, Ithaca, NY 14850. *There may be no minimal non σ-scattered linear orders.*

Laver proved in 1971 that the class of σ-scattered linear orders is well quasi ordered by embeddability, confirming a conjecture of Fraïssé. Here a linear order is scattered if it does not contain a copy of the rational line and σ-scattered if it is a countable union of scattered suborders. It is natural to ask whether Laver's result can be extended to a broader class of linear orders. This is the same as asking whether there is a linear order which is minimal with respect to being non σ-scattered. Around the time of Laver's result, Baumgartner showed that consistently any set of reals of cardinality $\aleph_1$ is a minimal non σ-scattered linear order. We prove that, assuming the consistency of a supercompact cardinal, that it is consistent that there are no minimal non σ-scattered linear orders. (Received August 15, 2018)

1143-03-259 **Trevor M. Wilson*** (twilson@miamioh.edu). *Weakly remarkable cardinals, Erdős cardinals, and the generic Vopěnka principle.*

We consider a weak version of Schindler's remarkable cardinals that may fail to be Σ_2-reflecting. We show that the Σ_2-reflecting weakly remarkable cardinals are exactly the remarkable cardinals, and we show that the existence of a non-Σ_2-reflecting weakly remarkable cardinal has higher consistency strength: it is equiconsistent with the existence of an ω-Erdős cardinal. We give an application involving gVP, the generic Vopěnka principle defined by Bagaria, Gitman, and Schindler. Namely, we show that gVP + "Ord is not Δ_2-Mahlo" and gVP($\mathbf{\Pi}_1$) + "there is no proper class of remarkable cardinals" are both equiconsistent with the existence of a proper class of ω-Erdős cardinals, extending results of Bagaria, Gitman, Hamkins, and Schindler. (Received August 15, 2018)

1143-03-287 **Sean D Cox*** (scox9@vcu.edu), 1015 Floyd Ave, Richmond, VA 23284. *Forcing axioms, approachability, and stationary reflection.*

Foreman and Todorcevic considered several subclasses of $\{W : |W| = \omega_1 \subset W\}$: the internally approachable (IA), internally club (IC), internally stationary (IS), and internally unbounded (IU) sets. ZFC proves that IA $\subseteq$ IC $\subseteq$ IS $\subseteq$ IU. Under the CH, these classes are essentially the same; and (assuming $2^{\omega_1} = \omega_2$) the assertion that *at least one* of the 3 containments is strict (in H_{ω_2}) is equivalent to the failure of the Approachability Property at ω_2. In a series of papers Krueger proved that, under various strong forcing axioms, each of the 3 inclusions is (globally) strict, and also proved that the principle $\mathrm{RP}_{\mathrm{IS}}$ (stationary reflection to internally stationary sets) does not imply $\mathrm{RP}_{\mathrm{IC}}$ (stationary reflection to internally club sets). We will discuss some strengthenings and simplifications of Krueger's theorems, and some "no-go" theorems regarding a question of Krueger (whether $\mathrm{RP}_{\mathrm{IS}}$ is equivalent to $\mathrm{RP}_{\mathrm{IU}}$). (Received August 16, 2018)

1143-03-338 **Konstantinos A. Beros*** (berosk@miamioh.edu), Department of Mathematics, 123 Bachelor Hall, 301 S. Patterson Ave., Oxford, OH 45056, and **Paul B. Larson**. *P-ideals and the weak Rudin-Keisler order.*

In a 1991 paper, David Fremlin proved that the summable ideal ℓ_1 has maximal Tukey type among analytic P-ideals (equivalently, among Polishable ideals). We prove an analogous result for the *weak Rudin-Keisler order*, a pre-order which is stronger than the Tukey order, but weaker than the usual Rudin-Keisler order.

Time permitting, we will discuss additional results related to the Tukey order and the weak Rudin-Keisler order. (Received August 18, 2018)

1143-03-369 **Jin Du***, jdu8@uic.edu. *Strong Tree Property and Failure of SCH.*

Assuming the consistency of infinitely many supercompacts, I show that the singular cardinal hypothesis can fail at a strong limit singular together with the strong tree property holding at its successor. (Received August 19, 2018)

1143-03-370 **Dima Sinapova*** (sinapova@uic.edu). *ITP.*

Recall that for an inaccessible cardinal weak compactness is equivalent to having the tree property. In his thesis Magidor defined a strengthening called ITP and showed that for an inaccessible cardinal, ITP is equivalent to supercompactness. As such, ITP captures the combinatorial nature of a supercompact cardinal. And just like in the case of the tree property, it can hold at successor cardinals. For example, back in the 70ies Magidor showed that ITP can be Mitchell-forced at $\aleph_2$. Also, in 2010 Christoph Weiss proved that PFA implies ITP at $\aleph_2$. Since then there has been a number of results about this principle, but the situation at the successor of a singular had remained open.

We will show that ITP holds at the successor of the limit of ω many supercompact cardinals, and also that it can be forced at $\aleph_{\omega+1}$. This is joint work with Sherwood Hachtman. (Received August 19, 2018)

1143-03-378 **James Cummings*** (jcumming@andrew.cmu.edu) and **Arthur W. Apter**. *Easton's theorem with preservation of strong and supercompact cardinals.*

We show that if F is a locally definable Easton function and GCH holds then there is a generic extension in which:

- Cardinals and cofinalities are preserved.
- $2^\kappa = F(\kappa)$ for every regular κ.
- All strong cardinals and all supercompact cardinals are preserved.

This extends earlier results of Menas and of Friedman and Honzik. (Received August 19, 2018)

1143-03-410 **Hossein Lamei Ramandi*** (hlramandi@gmail.com). *Baumgartner's isomorphism theorem for Kurepa lines.*

Baumgartner proved that ZFC is consistent with the statement that all $\aleph_1$-dense subsets of the reals are isomorphic. We will prove ZFC is consistent with the statement that there is a Kurepa line which is isomorphic to all of its $\aleph_2$-dense suborders which do not have any element with countable cofinality or coinitiality. (Received August 20, 2018)

1143-03-414 **Shehzad Ahmed*** (sa066513@ohio.edu), Ohio University, Department of Mathematics 321 Morton Hall, Athens, OH 45701. *The Weak pcf Conjecture.*

Recall that, for a set A of regular cardinals, we define

$$\mathrm{pcf}(A) := \{\mathrm{cf}(\prod A/D) : D \text{ is an ultrafilter on A}\}.$$

In the case that A is an interval of regular cardinals satisfying $|A| < \min(A)$, we know that $|\mathrm{pcf}(A)| < |A|^{+4}$. This bound allows us to show that, for example, if $\aleph_\omega$ is a strong limit singular cardinal, then $2^{\aleph_\omega} < \aleph_{\omega_4}$. In the event that A is not an interval of regular cardinals, we know of no such bound on $|\mathrm{pcf}(A)|$. A conjecture of Shelah's is that, if A is a set of regular cardinals with $|A| < \min(A)$, then $\mathrm{pcf}(A)$ has no inaccessible accumulation point. In this talk, I will discuss why this is an important conjecture, and discuss some of its consequences. (Received August 20, 2018)

1143-03-436 **Iian B Smythe*** (i.smythe@rutgers.edu). *Equivalence of generic reals.* Preliminary report.

Given a countable transitive model of set theory and a notion of forcing in it, there is a natural countable Borel equivalence relation on generic objects over the model; two generics are equivalent if they yield the same generic extension. We study generic reals arising from familiar notions of forcing, e.g., Cohen and random forcing, under this equivalence relation and describe their relative complexity using the techniques of invariant descriptive set theory. (Received August 20, 2018)

1143-03-457 **Andreas R. Blass*** (ablass@umich.edu), Mathematics Dept., Univ. of Michigan, 530 Church St., Ann Arbor, MI 48109. *Partitions and Ultrafilters.* Preliminary report.

I plan to discuss connections between partition properties that arise in the study of certain ultrafilters on countable sets. (Received August 20, 2018)

1143-03-462 **E. Todd Eisworth*** (eisworth@ohio.edu). *Sticks above the continuum.*

Suppose λ is a regular cardinal greater than $2^{\aleph_0}$. We use pcf theory to obtain a bound on the minimal cardinality of a collection X of countable subsets of λ such that for any $A \subseteq \lambda$ of cardinality $\aleph_1$, there is a $B \in X$ with $B \subseteq A$. (Received August 20, 2018)

1143-03-465 **Paul McKenney*** (mckennp2@miamioh.edu), 501 E. High St., 224 Bachelor Hall, Oxford, OH 45056, and **Alessandro Vignati** (ale.vignati@gmail.com), 4 Place Jussieu, Paris, France. *Forcing axioms and rigidity of corona algebras.*

It has become clear over the last two decades or so that forcing axioms like PFA often have strong consequences in the rigidity of structures of size continuum. One such line of results, going back to the 80's, describes explicitly all possible isomorphisms between certain quotient Boolean algebras in the presence of PFA (or more accurately a couple of its combinatorial consequences). The techniques involved were used more recently by Farah to solve a long-outstanding problem on the automorphisms of the Calkin algebra. We will describe a strong generalization of all of these results, which takes place in the setting of C*-algebras. No prior knowledge of C*-algebras will be assumed. This talk represents joint work with Alessandro Vignati. (Received August 20, 2018)

1143-03-483 **Gabriel T Goldberg*** (goldberg@college.harvard.edu), 2 Arrow St, Cambridge, MA 02138. *Ultrafilters and inner models.*

The simplest objects associated to large cardinal axioms are countably complete ultrafilters, but the combinatorics of countably complete ultrafilters in general is largely obscured by independence results. A good example is Magidor's result that it is consistent with ZFC that the least measurable cardinal is strongly compact. The Ultrapower Axiom (UA) is a combinatorial principle motivated by inner model theory under which the general theory of countably complete ultrafilters can be developed satisfactorily. We discuss some consequences of UA, focusing on the result that under UA, the least strongly compact cardinal is supercompact. The main open question is whether UA is consistent with a strongly compact cardinal. (Received August 20, 2018)

1143-03-486 **Jeffrey Bergfalk*** (jeffrey@matmor.unam.mx), Centro de Ciencias Matemáticas, UNAM, Campus Morelia, 42656 Morelia, Michoacan, Mexico. *Large cardinals and the cohomology of the ordinals.*

The collection of height-κ coherent families of integer-valued functions has a natural group structure. Its quotient by the group of height-κ trivial families of such functions is more handily and suggestively denoted as $\check{\mathrm{H}}^1(\kappa, \underline{\mathbb{Z}})$. (Here $\underline{\mathbb{Z}}$ denotes the constant sheaf of integers.) Hence $\check{\mathrm{H}}^1(\omega, \underline{\mathbb{Z}}) = 0$, while Todorcevic's rho functions canonically witness that $\check{\mathrm{H}}^1(\omega_1, \underline{\mathbb{Z}}) \neq 0$, and for κ of higher cofinality, $\check{\mathrm{H}}^1(\kappa, \underline{\mathbb{Z}}) \neq 0$ is (modulo large cardinals) an assertion independent of the ZFC axioms. These recognitions cue the more general study of the Čech cohomology of the ordinals: each $\check{\mathrm{H}}^n(\kappa, \underline{\mathbb{Z}}) \neq 0$ denotes an incompactness principle tending to hold on regular cardinals $\kappa \geq \omega_n$, but in tension with large cardinals — a tension we'll illustrate with several sample theorems. We'll close with the largely open question of where these principles can fail, a question evidently requiring large cardinal assumptions and a better understanding of higher coherence for its general solution. (Received August 20, 2018)

1143-03-507 **Will Brian*** (wbrian.math@gmail.com) and **Neil Hindman**. *Factoring a minimal ultrafilter into a thick part and a syndetic part.*

$\beta\mathbb{N}$ is at once a topological space, a dynamical system, and a semigroup. The *minimal ultrafilters* are special points of $\beta\mathbb{N}$ defined in terms of its dynamical and algebraic structure. In this talk I will explain what minimal ultrafilters are, and how their dynamical/algebraic properties can be used to reveal their set-theoretic and topological properties. The main result is that every minimal ultrafilter $\mathcal{U}$ can be "factored" into a thick part and a syndetic part, meaning that there is a filter $\mathcal{F}$ containing only thick sets and a filter $\mathcal{G}$ containing only

syndetic sets such that $\mathcal{U}$ is generated by $\mathcal{F} \cup \mathcal{G}$. One consequence of this is that $\beta\mathbb{N} \setminus \{\mathcal{U}\}$ and $\mathbb{N}^* \setminus \{\mathcal{U}\}$ are both non-normal spaces. (Received August 21, 2018)

1143-03-553 **Zach Norwood*** (zbnorwood@math.cornell.edu). *Coding along trees and remarkable cardinals.*

One goal of modern set theory is to understand the connection between large cardinals and generic-absoluteness principles, which assert that forcing notions from a certain class cannot change the truth value of certain statements about the real numbers (e.g. projective statements). For example, in the 1980s Kunen and Harrington–Shelah showed that absoluteness to ccc forcing extensions is equiconsistent with a weakly compact cardinal. More recently, Schindler showed that absoluteness to proper forcing extensions is equiconsistent with a remarkable cardinal. (Remarkable cardinals will be defined in the talk.) Schindler's proof does not resemble Kunen's, however, using almost-disjoint coding instead of Kunen's innovative method of coding along branchless trees. We will show how to reconcile this gap, improving Schindler's theorem to apply to the class of σ-closed $*$ ccc posets. Our proof bears more resemblance to Kunen's than to Schindler's.

The proof depends crucially on a method to code a real using trees of height ω_1 with uncountable levels. If time allows, we will discuss questions related to this coding method. This work is joint with Itay Neeman. (Received August 21, 2018)

05 ► Combinatorics

1143-05-17 **Elizabeth Drellich*** (edrelli1@swarthmore.edu). *Posets of Hessenberg Varieties.*

Hessenberg varieties have become a powerful tool for tackling combinatorial problems, but Hessenberg varieties themselves are also intriguing combinatorial objects. A Hessenberg variety is a collection of full flags determined by an element X in the Lie algebra $\mathfrak{g}$ and a Hessenberg space H which is an upper order ideal in the root decomposition of $\mathfrak{g}$. By fixing X but varying H, the Hessenberg varieties form a poset of algebraic varieties, ordered by containment. The analogous poset for Schubert varieties is isomorphic to the Bruhat order, but for Hessenberg varieties, the containment poset is a coarsening of the poset of upper order ideals. This talk will discuss recent results about the structure of these posets of Hessenberg varieties. (Received May 29, 2018)

1143-05-38 **Wiktor J Mogilski*** (wmogilsk@iu.edu). *The e-vector of a simplicial complex.*

We introduce the coarsely graded exponential Hilbert series of the Stanley-Reisner ring of an abstract simplicial complex Δ and the e-vector of Δ, which relates to the coefficients of the exponential Hilbert series. We explore the relationship of the e-vector with the classical f-vector and h-vector of Δ while simultaneously investigating the geometric information that the e-vector encodes about Δ. We then prove a simple combinatorial identity for the e-vector in the case where Δ is a Eulerian manifold. This is joint work with Wayne Johnson. (Received July 06, 2018)

1143-05-40 **Eric G Ramos*** (eramos@uoregon.edu), **David Speyer** and **Graham White**. *Changing behaviors in the spectra of highly symmetric graphs.*

For each n, let K_n denote the complete graph on n vertices. The spectrum of the adjacency matrix of K_n is easily computed as follows: $n-1$ is an eigenvalue appearing with mulitplicity one, while -1 is an eigenvalue appearing with multiplicity $n-1$. One observes the following three interesting consequences of this computation: The total number of distinct eigenvalues is eventually independent of n, each of these finitely many eigenvalues agrees with a polynomial in n, and the multiplicities of these eigenvalues agrees with a polynomial in n. In this talk we will discuss the fundamental algebra underlying these behaviors, and exhibit how they appear in a wealth of other examples. To accomplish this we use the new theory of FI-modules and representation stability recently established by Church, Ellenberg, and Farb. This is joint work with David Speyer and Graham White. (Received July 06, 2018)

1143-05-46 **Melissa U. Sherman-Bennett*** (m_shermanbennett@berkeley.edu). *Combinatorics of $\mathcal{X}$-variables in finite type cluster algebras.*

We compute the number of $\mathcal{X}$-variables (also called coefficients) of a cluster algebra of finite type when the underlying semifield is the universal semifield. In general, there is a bijection between $\mathcal{X}$-variables and certain ordered pairs of almost positive roots in the root system of the same type. For classical types, this follows from a bijection between $\mathcal{X}$-variables and quadrilaterals (with a choice of diagonal) appearing in triangulations of certain marked surfaces. We conjecture that a similar bijection holds for cluster algebras from arbitrary

marked surfaces, and obtain corollaries regarding the structure of finite type cluster algebras of geometric type. (Received July 11, 2018)

1143-05-76 **Zoltan Füredi**, **Alexandr Kostochka*** (kostochk@math.uiuc.edu) and **Ruth Luo**.
Long Berge cycles and paths in dense uniform hypergraphs. Preliminary report.

Classical bounds on the number of edges in n-vertex graphs that have no long paths or no long cycles were proved by Erdős and Gallai in 1959. An analog of the Erdős–Gallai Path Theorem for Berge paths of length k in n-vertex r-uniform hypergraphs for $k \neq r+1$ was recently proved by Győri, Katona and Lemons. Then Davoodi, Győri, Methuku and Tompkins settled the remaining case $k = r+1$. Their bounds are exact for every k and r for infinitely many n. They also proved a better bound for connected hypergraphs in the case $n >> k >> r$.

We prove an analog of the Erdős–Gallai Cycle Theorem for Berge cycles of length at least k in n-vertex r-uniform hypergaphs for $k \notin \{r+1, r+2\}$. We also describe the hypergraphs for which our bounds are exact. Our results imply somewhat refined versions of the above mentioned theorems for Berge paths when $k \notin \{r+1, r+2\}$. We also give a better bound for 2-connected hypergraphs in the case $n >> k > 8r$.

This is joint work with Z. Füredi and R. Luo. (Received July 30, 2018)

1143-05-84 **Gerald J. Janusz*** (janusz@math.uiuc.edu), 5181 Doral Ct, Ann Arbor, MI 48108.
Solution of the existence problem for a binary, self-dual, doubly- even code with parameters [72,36,16].

We use enumerator polynomials, covering polynomials, design properties, and transvections to show that there is no self-dual, doubly-even, binary code with parameters [72,36,16], [96,48,20] [120,60,24] and [144,72, 28].

This solves the 45-year-old problem (for the length 72 case) and gives evidence for the **conjecture**: If there is a binary, self-dual, doubly even code with parameters [24k,12k,4k+4], then k = 1 or 2. (Received July 31, 2018)

1143-05-102 **Christopher Eur*** (chrisweur@gmail.com). *Divisors on matroids and their volumes.*

The classical volume polynomial in algebraic geometry measures the degrees of ample (and nef) divisors on a smooth projective variety. We introduce an analogous volume polynomial for matroids, and give a complete combinatorial formula. For a realizable matroid, we thus obtain an explicit formula for the classical volume polynomial of the associated wonderful compactification. We then introduce a new invariant called the volume of a matroid as a particular specialization of its volume polynomial, and discuss its algebro-geometric and combinatorial properties in connection to graded linear series on blow-ups of projective spaces. (Received August 03, 2018)

1143-05-116 **Jeff Kahn** and **Jinyoung Park*** (jp1324@math.rutgers.edu), Department of Mathematics, Rutgers University, Hill Center for the Mathematical Sciences, 110 Frelinghuysen Rd., Piscataway, NJ 08854. *The number of 4-colorings of the Hamming cube.*

Let Q_d be the d-dimensional Hamming cube (hypercube) and $N = 2^d$. We discuss the number of proper (vertex) colorings of Q_d given q colors. It is easy to see that there are exactly 2 of 2-colorings, but for $q > 2$, the number of q-colorings of Q_d is highly nontrivial. Since Galvin (2002) proved that the number of 3-colorings is asymptotically $6e2^{N/2}$, the other cases remained open so far. In this talk, we prove that the number of 4-colorings of Q_d is asymptotically $6e2^N$, as was conjectured by Engbers and Galvin in 2012. The proof uses a combination of information theory (entropy) and isoperimetric ideas originating in work of Sapozhenko in the 1980's. (Received August 04, 2018)

1143-05-123 **Matthew Jenssen**, **Felix Joos** and **Will Perkins*** (william.perkins@gmail.com).
Sphere packings and kissing numbers in high dimensions via hard core models.

We improve the classic Chabauty-Shannon-Wyner lower bound on the kissing number of Euclidean space by a factor linear in the dimension. The proof is based on analyzing a hard cap model related to the hard-core lattice gas from statistical physics. The proof technique also applies to sphere packings and to independent sets in triangle-free graphs. I will use the connection with independent sets in graphs to describe some plausible scenarios for the densest sphere packings and kissing configurations in high dimensions. (Received August 05, 2018)

1143-05-148 **Jon Cutler**, **JD Nir** and **Jamie Radcliffe*** (jamie.radcliffe@unl.edu).
Supersaturation for subgraph counts.

Turán's theorem states that the maximum number of edges in a K_{r+1}-free graph on n vertices is attained by the complete r-partite graph with part sizes as equal as possible. We write the number of edges in this graph as $\mathrm{ex}(n, K_{r+1})$ (often called the extremal number of K_{r+1}).

Supersaturation questions consider what happens if G has more than $\mathrm{ex}(n, K_{r+1})$ edges: how many copies of K_{r+1} must G contain? Recently, Alon and Shikhelman introduced a generalization of the extremal number. Given graphs H and T, let $\mathrm{ex}_T(n, H)$ be the maximum number of copies of T an H-free graph on n vertices can contain. It is natural to ask supersaturation questions in this context as well. We present some results in this area. (Received August 07, 2018)

1143-05-155 **Deborah Oliveros**, **Christopher ONeill** and **Shira Zerbib*** (zerbib@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *The geometry and combinatorics of discrete line segment hypergraphs.*

An r-segment hypergraph H is a hypergraph whose edges consist of r consecutive integer points on line segments in R^2. We bound the chromatic number $\chi(H)$ and covering number $\tau(H)$ of hypergraphs in this family, uncovering several interesting geometric properties in the process. For $r \geq 3$ we conjecture that $\tau(H) \leq (r-1)\nu(H)$, where $\nu(H)$ denotes the matching number of H. We prove our conjecture in the case where $\nu(H) = 1$, and provide improved optimal bounds on $\tau(H)$ for $r \leq 5$. We also provide sharp bounds on the chromatic number $\chi(H)$ in terms of r, and use them to prove two fractional versions of our conjecture. (Received August 08, 2018)

1143-05-173 **Jie Han** and **Yi Zhao*** (yzhao6@gsu.edu). *Hamiltonicity in randomly perturbed hypergraphs.*

For integers $k \geq 3$ and $1 \leq \ell \leq k-1$, we prove that for any $\alpha > 0$, there exist $\epsilon > 0$ and $C > 0$ such that for sufficiently large $n \in (k-\ell)\mathbb{N}$, the union of a k-uniform hypergraph with minimum vertex degree αn^{k-1} and a binomial random k-uniform hypergraph $\mathbb{G}^{(k)}(n,p)$ with $p \geq n^{-(k-\ell)-\epsilon}$ for $\ell \geq 2$ and $p \geq Cn^{-(k-1)}$ for $\ell = 1$ on the same vertex set contains a Hamiltonian ℓ-cycle with high probability. Our result is best possible up to the values of ϵ and C and completely answers a question of Krivelevich, Kwan and Sudakov. (Received August 09, 2018)

1143-05-177 **Cédric Lecouvey**, Faculté des Sciences et Techniques, Université François Rabelais, 37200 Tours, France, and **Cristian Lenart*** (clenart@albany.edu), Department of Mathematics and Statistics, State University of New York at Albany, 1400 Washington Avenue, Albany, NY 12222. *Atomic decomposition of characters and crystals.*

Lusztig defined the Kostka-Foulkes polynomial $K_{\lambda,\mu}(t)$ as a t-analogue of the multiplicity of a dominant weight μ in the irreducible representation of highest weight λ of a semisimple Lie algebra. Lascoux stated that the type A Kostka-Foulkes polynomials expand positively in terms of so-called atomic polynomials. We define a combinatorial version of the atomic decomposition in arbitrary type, as a decomposition of a modified crystal graph; this property can also be viewed as a strengthening of the monotonicity of $K_{\lambda,\mu}(t)$. We prove that the combinatorial atomic decomposition holds in types A, C, and D, as well as in some other cases, while we conjecture that it holds more generally. We also give a geometric interpretation. (Received August 10, 2018)

1143-05-186 **Jozsef Balogh*** (jobal@math.uiuc.edu), Math Dept UIUC, Urbana, IL. *An improved lower bound for Folkman's theorem.*

Ramsey type of results in additive combinatorics could be originated to Hilbert. In this talk a brief history of the topics and some recent developments will be explained.

Folkman's Theorem asserts that for each k in N, there exists a natural number $n = F(k)$ such that whenever the elements of $[n]$ are two-coloured, there exists a subset A of $[n]$ of size k with the property that all the sums of the form $\sum_{x \in B} x$, where B is a nonempty subset of A, are contained in $[n]$ and have the same colour. In 1989, Erdős and Spencer showed that $F(k) \geq 2^{ck^2/logk}$, where $c > 0$ is an absolute constant; here, we improve this bound. Additional related results are discussed. Joint work with Sean Eberhard, Misha Lavrov, Bhargav Narayanan, George Shakan, Andrew Treglown, Adam Zsolt Wagner. (Received August 11, 2018)

1143-05-190 **Ilkyoo Choi**, **Daniel Cranston*** (dcranston@vcu.edu) and **Théo Pierron**. *Coloring Squares of Planar Graphs.*

The *square*, G^2, of a graph G is formed from G by adding an edge joining each pair of vertices at distance 2 in G. If $\Delta(G) = k$ then $\Delta(G^2)$ can be as big as k^2, and $\chi(G^2)$ can be as big as $k^2 + 1$. In general these bounds cannot be improved much. If G is the incidence graph of a projective plane and $\Delta(G) = k$, then $\Delta(G^2) = k^2$ and $\chi(G^2) \approx k^2 - k$. However, for planar graphs, we can do much better.

Trivially, $\Delta(G) = k$ implies $\chi(G^2) \geq k + 1$. We survey various classes of planar graphs where this trivial lower bound holds with equality or nearly so. We seek a class $\mathcal{H}$ of planar graphs and a constant C such that every graph $G \in \mathcal{H}$ with $\Delta(G) = k$ satisfies $\chi(G^2) \leq k^2 + C$. First, we prove that if $\mathcal{H}$ is defined by forbidding a finite set of cycle lengths, then $\mathcal{H}$ has this property if and only if we forbid 4-cycles. For such graphs G we

prove $\chi(G^2) \leq \Delta(G) + 73$. Second, we prove that when $\Delta(G)$ is sufficiently large we have $\chi(G^2) \leq \Delta(G) + 2$. This bound is sharp. Our bounds also hold for list chromatic number and even for correspondence chromatic number.

This is joint work with Ilkyoo Choi and Théo Pierron. (Received August 11, 2018)

1143-05-199 **Michael Tait***, 5000 Forbes Ave, Pittsburgh, PA 15213. *Using random polynomials in extremal graph theory.*

For a fixed integer k we consider the problem of how many edges may be in an n-vertex graph where no pair of vertices have t internally disjoint paths of length k between them. When $t = 2$ this is the notorious even cycle problem. We show that such a graph has at most $c_k t^{1-1/k} n^{1+1/k}$ edges, and we use graphs constructed via random polynomials to show that the dependence on t is correct when k is odd.

This is joint work with Boris Bukh and Sunny He. (Received August 13, 2018)

1143-05-200 **Louis DeBiasio*** (debiasld@miamioh.edu), **András Gyárfás**, **Robert A. Krueger**, **Miklós Ruszinkó** and **Gábor N. Sárközy**. *Monochromatic structures in edge-colored bipartite graphs.*

Given a (not necessarily complete) bipartite graph and an arbitrary edge-coloring, how large is the largest monochromatic component/balanced-component/connected-matching/path/cycle? We obtain asymptotically best possible results for two colors and provide new bounds in the case of three or more colors. (Received August 13, 2018)

1143-05-210 **Curtis Bennett**, **Juan Carrillo** and **John Machacek** (sagan@math.msu.edu), Ann Arbor, MI 48105, and **Bruce Sagan*** (sagan@math.msu.edu). *Combinatorial interpretations of Lucas analogues.* Preliminary report.

The Lucas sequence is a sequence of polynomials in s, t defined recursively by $\{0\} = 0$, $\{1\} = 1$, and $\{n\} = s\{n-1\} + t\{n-2\}$ for $n \geq 2$. On specialization of s and t one can recover the Fibonacci numbers, the nonnegative integers, and the q-integers $[n]_q$. Given a quantity which is expressed in terms of products and quotients of nonnegative integers, one obtains a Lucas analogue by replacing each factor of n in the expression with $\{n\}$. It is then natural to ask if the resulting rational function is actually a polynomial in s and t and, if so, what it counts. Using lattice paths, we give combinatorial models for Lucas analogues of binomial coefficients as well as Catalan numbers and their relatives, such as those for finite Coxeter groups. (Received August 13, 2018)

1143-05-212 **Alan Frieze*** (alan@random.math.cmu.edu), Pittsburgh, PA 15213. *Coloring (random) hypergraphs.* Preliminary report.

We sketch some results related to coloring hypergraphs. 1. An MCMC algorithm for the case where the maximum degree is $\Omega(\log n)$. 2. Connectivity of the set of random colorings of a random hypergraph.

Joint work with Michael Anastos (Received August 13, 2018)

1143-05-216 **Dieter Mitsche**, **Mike Molloy** and **Pawel Pralat*** (pralat@ryerson.ca), Department of Mathematics, Ryerson University, 350 Victoria St., Toronto, ON M5B 2K3, Canada. *k-regular subgraphs near the k-core threshold of a random graph.*

We prove that the binomial random graph $G_{n,p=c/n}$ with high probability has a k-regular subgraph if c is at least $e^{-\Theta(k)}$ above the threshold for the appearance of a subgraph with minimum degree at least k; i.e. an non-empty k-core. In particular, this pins down the threshold for the appearance of a k-regular subgraph to a window of size $e^{-\Theta(k)}$. (Joint work with Dieter Mitsche and Mike Molloy.) (Received August 14, 2018)

1143-05-227 **Karin Baur**, **Eleonore Faber**, **Sira Gratz**, **Khrystyna Serhiyenko*** (khrystyna.serhiyenko@berkeley.edu) and **Gordana Todorov**. *Friezes and Grassmannian cluster algebras.* Preliminary report.

An sl_k frieze is a lattice of positive integers where the determinant of any k by k diamond is 1. We show how these friezes are related to cluster algebras A associated to the Grassmannian $Gr(k, n)$. In particular, we determine a finite collection of cluster variables in A that can be arranged to produce a frieze. We also discuss relationships between sl_k friezes and mesh friezes of the corresponding cluster categories. (Received August 14, 2018)

1143-05-241 **Paul B. Larson*** (larsonpb@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056, and **Nicholas Matteo** and **Saharon Shelah**. *Majority decisions when abstention is possible.*

Suppose that we are given a family of choice functions (with repetition) on pairs from a given finite set. The set is considered as a set of alternatives, or candidates for an office, and the functions as the preferences of individual voters. What choice functions agree, on every pair, with the majority of some finite subfamily of the voters? For the problem as stated, a complete characterization was given in a 2009 paper of Shelah, but here we allow voters to abstain, i.e., we allow the choice functions to be non-total. Aside from the trivial cases, the possible families of partial choice functions break into three cases in terms of the functions that can be generated by majority decision. In one of these, the partisan case, cycles along the lines of Condorcet's paradox are avoided. In another, all partial choice functions can be represented. (Received August 15, 2018)

1143-05-242 **Alexander Garver**, **Rebecca Patrias*** (patriasr@lacim.ca) and **Hugh Thomas**. *Reverse plane partitions via representations of quivers I.*

We start with a brief introduction to quiver representations. We then take a type A Dynkin quiver with a choice of minuscule vertex and define a bijection from a subcategory of the representations of the quiver to reverse plane partitions of a rectangular shape determined by the minuscule vertex. We discuss the connection to the classical Robinson–Schensted–Knuth correspondence. The next talk of this two-part series will generalize this to other cominuscule types. (Received August 15, 2018)

1143-05-252 **Jessica McDonald***, mcdonald@auburn.edu. *Non-monochromatic triangles in 2-edge-coloured graphs.*

Given an edge-coloured graph G, when can we guarantee that there exists a non-monochromatic triangle? We provide a best possible answer for 2-edge-colourings. Joint work with Matt DeVos and Amanda Montejano. (Received August 15, 2018)

1143-05-255 **Lauren Keough***, keoulaur@gvsu.edu, and **David Shane**. *Toward A Nordhaus-Gaddum Inequality for the Number of Dominating Sets.*

A dominating set in a graph G is a set S of vertices such that every vertex of G is either in S or is adjacent to a vertex in S. Nordhaus-Gaddum inequailties relate a graph G to its complement $\bar{G}$. For example, the original Nordhaus-Gaddum inequalities were about the sum and product of the chromatic number of a graph and the chromatic number of its complement. In this spirit Wagner proved that any graph G on n vertices satisfies $\partial(G) + \partial(\bar{G}) \geq 2^n$ where $\partial(G)$ is the number of dominating sets in a graph G. In the same paper he comments that an upper bound for $\partial(G) + \partial(\bar{G})$ among all graphs on n vertices seems to be much more difficult. We conjecture that the complete balanced bipartite graph maximizes $\partial(G) + \partial(\bar{G})$ and have verified this computationally for all graphs on at most 10 vertices. We'll prove an upper bound on $\partial(G) + \partial(\bar{G})$, provide a maximum and minimum degree condition on the extremal graphs, and discuss some of the other techniques we tried to shed some light on why this problem seems difficult. (Received August 15, 2018)

1143-05-257 **Pu Gao** and **Xavier Pérez-Giménez***, (xperez@unl.edu), and **Cristiane Sato**. *Packing Edge-disjoint Spanning Trees in Random Geometric Graphs.* Preliminary report.

We consider the problem of packing edge-disjoint spanning trees in the random geometric graph $G(n, r)$. This was inspired by some earlier work on the $G(n, p)$ model, in which we proved that (with high probability) $G(n, p)$ contains exactly $\min(\delta, \lfloor m/(n-1) \rfloor)$ edge-disjoint spanning trees, where m is the number of edges and δ is the minimum degree. This result has been recently extended to the random geometric setting for all r such that $\delta < \epsilon \log n$. In particular we show that, for r in that range, $G(n, r)$ contains (with high probability) δ edge-disjoint spanning trees, and obtain the corresponding hitting-time result for the random graph process in which edges are added one by one in increasing order of length. (Received August 15, 2018)

1143-05-262 **Sarah D Brauner***, braun622@umn.edu, and **Tamar Friedmann**. *One Garnir to Rule them All: On Specht Modules and the CataLAnKe Theorem.*

Specht modules are irreducible representations of the symmetric group indexed by partitions which (in characteristic 0) make up a complete set of irreducible representations of the symmetric group. One standard presentation of Specht modules, introduced by Kraskiewicz and later Fulton, is realized by quotienting the space of column tabloids by a subspace generated with certain relations called dual Garnir relations. In this talk, I will give a simplification of this presentation that significantly reduces the number of generators required.

I will then explain how this result gives rise to an alternative proof of a recent theorem by Friedmann, Hanlon, Staney and Wachs, which studies a generalization of the representations of the symmetric group on the

multilinear component of the free Lie algebra. I will discuss the proof, which provides an explicit isomorphism and elegant basis for the representation of interest. (Received August 15, 2018)

1143-05-275 **Jeff Kahn** and **Abigail Raz*** (ajr224@math.rutgers.edu). *What do the largest subgraphs of $G_{n,p}$ with a given matching number look like?* Preliminary report.

In 1959 Erdős and Gallai showed that every largest (in number of edges) subgraph of K_n with matching number k must have one of two basic forms. The Erdős matching conjecture extends this notion to uniform hypergraphs. We instead look at the extension to the Erdős-Renyi random graph, $G_{n,p}$. We show that for p sufficiently large or sufficiently small, with high probability, Erdős and Gallai's result extends (though for two very different reasons); however, there are intermediate values of p where, with high probability, the theorem does not extend. (Received August 16, 2018)

1143-05-278 **Steven N. Karp*** (snkarp@umich.edu), **Lauren K. Williams** and **Yan X Zhang**. *Geometry of the amplituhedron.*

The tree amplituhedron is a geometric object which was introduced by Arkani-Hamed and Trnka in 2013. It may be viewed as a generalization of a cyclic polytope into the Grassmannian. It comes with a canonical differential form which is of interest in physics. I will survey what is known about amplituhedra and discuss some open problems, including a tantalizing conjecture relating triangulations of amplituhedra to plane partitions inside a box. This talk is based on arXiv:1608.08288 (joint with Lauren Williams) and arXiv:1708:09525 (joint with Lauren Williams and Yan Zhang). (Received August 19, 2018)

1143-05-303 **Laura Escobar*** (laurae@wustl.edu) and **Megumi Harada**. *Wall-crossing phenomena for Newton-Okounkov bodies.* Preliminary report.

A Newton-Okounkov body is a convex set associated to a projective variety, equipped with a valuation. These bodies generalize the theory of Newton polytopes. Work of Kaveh-Manon gives an explicit link between tropical geometry and Newton-Okounkov bodies. We use this link to describe a wall-crossing phenomenon for Newton-Okounkov bodies. As an application we show how the wall-crossing formula for the tropicalization of Gr(2, n) is an instance of our phenomenon for Newton-Okounkov bodies. (Received August 17, 2018)

1143-05-306 **Laura Escobar*** (laurae@wustl.edu). *Moment polytopes of desingularizations of Schubert and symmetric orbit closures.*

Schubert varieties have a natural action by an algebraic torus from which one can construct their moment polytopes. This is also true for the Bott-Samelson varieties, which are desingularizations of Schubert varieties, and Barbasch-Evens-Magyar varieties, which are desingularizations of symmetric orbit closures in the flag manifold. In this talk we will discuss these moment polytopes and relate them to some classical polytopes. (Received August 17, 2018)

1143-05-353 **Tao Jiang*** (jiangt@miamioh.edu), Department of Mathematics, Miami University, Oxford, OH 45056, and **Jie Ma** (jiema@ustc.edu.cn) and **Liana Yepremyan** (liana.yepremyan@maths.ox.ac.uk). *On Turán exponents of bipartite graphs.*

Given a family $\mathcal{F}$ of graphs, the Turan number $ex(n, \mathcal{F})$ is the maximum number of edges in an n-vertex graph that does not contain any member of $\mathcal{F}$ as a subgraph. Verifying an old conjecture of Erdos and Simonovits (and reiterated by Frankl and Furedi and Simonovits), Bukh and Conlon showed that for each rational number r with $1 < r < 2$ there exists a family $\mathcal{F}$ of bipartite graphs such that $ex(n, \mathcal{F}) = \Theta(n^r)$.

A related conjecture of Erdős and Simonovits asks if for each rational number r with $1 < r < 2$ there exists a single bipartite graph H such that $ex(n, H) = \Theta(n^r)$. This conjecture is still wide open. Until recently the conjecture was only verified for $r = 1 + 1/k$ and $r = 2 - 1/k$ where k is an integer at least 2, achieved by so-called theta graphs and complete bipartite graphs, respectively. In this talk, we show that the answer to the Erdős-Simonovits question is affirmative for all rational numbers r of the form $4k/(2k+1)$, where k is a positive integer, and for $r = 7/5$. Our first theorem also answers a question of Pinchasi and Sharir on graphs related to the cubes. This provides infinitely many new bipartite graphs H for which the order of magnitude of $ex(n, H)$ is determined. (Received August 18, 2018)

1143-05-360 **Graham Hawkes***, Department of Mathematics, UC Davis, 1 Shields Ave., Davis, CA 95616, and **Anne Schilling**, **Maria Monks Gillespie** and **Wencin Poh**. *Properties of Queer Supercrystals.*

We analyze the crystal bases for the quantum queer superalgebra recently introduced by Grantcharov et al.. Like crystals of type A, this crystal can be described by explicit operators on words in the alphabet $\{1, 2, \ldots, n\}$. Like crystals of type A, each connected component of a queer supercrystal has a unique highest (and lowest)

weight. In the type A case, if one is given a certain highest weight, one can reconstruct the connected component containing it using simple axioms introduced by Stembridge. However, given a highest weight, it is much more difficult to reconstruct the queer connected component containing it in this way.

Nevertheless, a set of axioms has been conjectured by Assaf and Oguz to do just this. Unfortunately these axioms are not sufficient, in fact they already fail to uniquely characterize the queer connected component containing highest weight $(4, 2, 0)$. In this talk, we provide the additional information which is needed to reconstruct the connected queer crystal which contains a given highest weight. (Received August 19, 2018)

1143-05-364 **Marie Meyer*** (mmeyer2@lewisu.edu), **Gabriele Balletti**, **Akiyoshi Tsuchiya** and **Takayuki Hibi**. *Laplacian Simplices Associated to Digraphs.*

We associate to a finite digraph D a lattice polytope P_D whose vertices are the rows of the Laplacian matrix of D. This generalizes a construction introduced by Braun and Meyer. In this talk, we relate properties of P_D to graphical properties of D. We establish interesting connections with other families of simplices and use them to describe reflexivity, the h-polynomial, and the integer decomposition property of P_D in these cases. (Received August 19, 2018)

1143-05-365 **Tefjol Pllaha*** (tefjol.pllaha@uky.edu) and **Marie Meyer**. *Laplacian Simplices II: A Coding Theoretic Approach.*

This talk will be about Laplacian simplices, that is, simplices whose vertices are rows of the Laplacian matrix of a simple connected graph. We will focus on graphs and graph operations that yield reflexive Laplacian simplices. We spot such graphs by showing that the h^*-vector of the simplex is symmetric. We use the same approach as Batyrev and Hofscheier by considering the fundamental parallelepiped lattice points as a finite abelian group. This is joint work with Marie Meyer. (Received August 19, 2018)

1143-05-375 **Pavel Galashin**, **Steven Karp** and **Thomas Lam*** (tfylam@umich.edu). *On the topology of totally positive spaces.*

Total positivity is classically the study of real matrices all of whose minors are positive. I will discuss the topology of certain totally positive spaces, including the totally nonnegative Grassmannian and totally nonnegative partial flag varieties. Our work is motivated by parallels (some recently discovered, and others known for some time) between these spaces and convex polytopes. (Received August 19, 2018)

1143-05-381 **Cameron Stuart Marcott*** (cam.marcott@gmail.com). *Basis shape loci and the positive Grassmannian.* Preliminary report.

We study the set of k dimensional planes in $\mathbb{R}^n$ admitting a basis of vectors of prescribed supports. We describe conditions on the prescribed support shape for when this set of planes has the expected dimension in the Grassmannian, and for when this set of planes intersects the positive Grassmannian in its full dimension. (Received August 19, 2018)

1143-05-409 **Eric Bucher*** (buchere1@xavier.edu), Eric Bucher, Xavier University, 3800 Victory Parkway, Cincinnati, OH 45207, and **John Machacek**, **Evan Runburg**, **Abe Yeck** and **Ethan Zewde**. *Utilizing component preserving mutations for computing maximal green sequences of cluster algebras.* Preliminary report.

Cluster algebras were first discovered by Fomin and Zelevinsky in the early 2000's. Since their inception they have shown to be an integral part of a variety of mathematical areas: including mathematical physics, algebraic geometry, and integrable systems. In this talk we look at the question of finding reddening and maximal green sequences for given cluster algebras.

We will present a method which we have called "component preserving mutation". This method allows one to tether mutation sequences of induced subquivers together to form maximal green sequences for the larger quiver. The talk is intended to be example driven and will be a bit of a survey on the types of phenomenon where this methodology is useful. (Received August 20, 2018)

1143-05-412 **Sunita Chepuri*** (chepu003@umn.edu). *Plabic R-Matrices.*

We discuss the inverse boundary problem for planar directed networks on a cylinder. In particular, we introduce a family of graphs on a cylinder and examine a semi-local transformation on weights for these graphs that preserves boundary measurements. If time allows, we will discuss an underlying cluster algebra structure for this transformation. (Received August 20, 2018)

1143-05-413 **Daniel Král'**, **Bernard Lidický*** (lidicky@iastate.edu), **Taísa L. Martins** and **Yanitsa Pehova**. *Decomposing graphs into edges and triangles.*

We prove the following 30-year old conjecture of Győri and Tuza: the edges of every n-vertex graph G can be decomposed into complete graphs $C_1, \ldots, C_\ell$ of orders two and three such that $|C_1| + \cdots + |C_\ell| \leq (1/2 + o(1))n^2$. This result implies the asymptotic version of the old result of Erdős, Goodman and Pósa that asserts the existence of such a decomposition with $\ell \leq n^2/4$. (Received August 20, 2018)

1143-05-420 **Zoltan Furedi*** (z-furedi@math.uiuc.edu) and **Imre Ruzsa**. *Nearly-subadditive sequences.*

The sequence $a(1), a(2), a(3), \ldots$ of reals is called *subadditive* if $a(n+m) \leq a(n) + a(m)$ holds for all integers $n, m \geq 1$. Fekete's lemma (1923) states that the sequence $\{a(n)/n\}$ has a limit (possible negative infinity). Let $f(n)$ be a non-negative, non-decreasing sequence. deBruijn and Erdős (1952) called the sequence $\{a(n)\}$ *nearly* f-subadditive if

$$a(n+m) \leq a(n) + a(m) + f(n+m) \tag{1}$$

holds for all $n \leq m \leq 2n$. They showed that if the error term f is small,

$$\sum_{n=1}^{\infty} f(n)/n^2 \quad \text{is finite,} \tag{2}$$

then the limit $\{a(n)/n\}$ still exists. We show that the deBruijn-Erdős condition (2) for the error term is not only sufficient but also necessary in the following strong sense. If $\sum_{n=1}^{\infty} f(n)/n^2 = \infty$, then there exists a nearly f-subadditive sequence $\{b(n)\}$ such that the sequence of slopes $\{b(n)/n\}$ takes every rational number. On the other hand, we show that their condition can be weakened such that the limit exists if (1) holds only for the pairs $n \leq m \leq cn$ for some fixed $c > 1$. (Received August 20, 2018)

1143-05-427 **Hemanshu Kaul***, Department of Applied Math, Illinois Institute of Technology, Chicago, IL 60616. *Proportional Choosability: A New List Analogue of Equitable Coloring.*

The study of equitable coloring began with a conjecture of Erdos in 1964, and a formal introduction by Meyer in 1973. An equitable k-coloring of a graph G is a proper k-coloring of G such that the sizes of the color classes differ by at most 1. In 2003 Kostochka, Pelsmajer, and West introduced a list analogue of equitable coloring, called equitable choosability, in which the size of the color classes is required only to be appropriately bounded from above.

Here we introduce proportional choosability, a new list analogue of equitable coloring s.t. the number of times a color is used must be proportional to the number of lists in which the color appears. Proportional k-choosability implies both equitable k-choosability and equitable k-colorability. We show that if a graph G is proportionally k-choosable, then every subgraph of G is also proportionally k-choosable and also G is proportionally $(k+1)$-choosable, unlike equitable choosability for which analogous claims would be false. We will discuss proportional choosability of graphs with small order, completely characterize proportionally 2-choosable graphs, and illustrate some of the techniques we have used here. This is joint work with Jeffrey Mudrock, Michael Pelsmajer, and Benjamin Reiniger. (Received August 20, 2018)

1143-05-435 **Joshua N Cooper***, Department of Mathematics, 1523 Greene St, Columbia, SC 29208, and **Gregory J Clark**. *A Generalization of the Harary-Sachs Theorem to Hypergraphs.*

We give a complete description of the coefficients of the characteristic polynomial $\chi_H(\lambda)$ of a (k-uniform) hypergraph H, defined by the hyperdeterminant $\det(\mathcal{A} - \lambda\mathcal{I})$, where $\mathcal{A}$ is of the adjacency tensor/hypermatrix of H, and the hyperdeterminant is defined in terms of resultants of homogeneous systems associated to its argument. The co-degree k coefficients can be obtained by an explicit formula yielding a linear combination of subgraph counts in H of certain "Veblen hypergraphs". This generalizes the Harary-Sachs Theorem for graphs, provides hints of a Leibniz-type formula for symmetric hyperdeterminants, and can be used in concert with computational algebraic methods to obtain the full characteristic polynomial of many new hypergraphs, even when the degrees of these polynomials is enormous. (Received August 20, 2018)

1143-05-441 **William Graham** (wag@math.uga.edu) and **Victor Kreiman*** (kreiman@uwp.edu). *Combinatorics of cominuscule points.* Preliminary report.

In the past, methods involving equivariant K-theory and equivariant cohomology were used to produce formulas for the Hilbert series and multiplicity at points of Schubert varieties in cominuscule flag varieties. More recently, these methods and formulas have been extended to a broader class of points, called cominuscule points. I will briefly describe the methods for obtaining the formulas, and then discuss combinatorial characterizations of cominuscule points and tools for evaluating the formulas. (Received August 20, 2018)

1143-05-442 **Keith Frankston*** (keith.frankston@rutgers.edu), **Jeff Kahn** and **Bhargav Narayanan**. *On regular 3-wise intersecting families.*

Ellis and Narayanan showed, verifying a conjecture of Frankl, that any 3-wise intersecting family of subsets of $\{1, 2, \ldots, n\}$ admitting a transitive automorphism group has cardinality $o(2^n)$, while a construction of Frankl demonstrates that the same conclusion need not hold under the weaker constraint of being regular. Answering a question of Cameron, Frankl and Kantor from 1989, we show that the restriction of admitting a transitive automorphism group may be relaxed significantly: we prove that any 3-wise intersecting family of subsets of $\{1, 2, \ldots, n\}$ that is regular and increasing has cardinality $o(2^n)$. (Received August 20, 2018)

1143-05-469 **Eric Ramos**, **David Speyer** and **Graham White*** (grrwhite@iu.edu). *Families of nested graphs with compatible symmetric-group actions: classification and properties.*

Kneser graphs are a well-studied family. For any fixed k, the graph G_n has vertices indexed by k–tuples of elements of $[n]$, and edges between disjoint tuples. As n increases, each of these graphs is included in the next. There is an action of the symmetric group S_n on G_n, acting directly on the labels, and these actions are compatible with the graph inclusions via the natural inclusions of each symmetric group into the next.

We study FI–graphs, which are families of nested graphs with such compatible symmetric group actions. It turns out that any FI–graph eventually is of a fairly simple form, which could be considered as a kind of generalised Kneser graph.

Using techniques from the theory of FI–modules, we extend known results about Kneser graphs to these more general objects — for example, that they eventually have a fixed number of distinct eigenvalues, independent of n, and that the multiplicities of these eigenvalues are eventually equal to polynomials in n. (Received August 20, 2018)

1143-05-475 **Christin Bibby*** (bibby@umich.edu). *Supersolvable posets.* Preliminary report.

The structure of a supersolvable geometric lattice has proven to be fruitful in the theory of hyperplane arrangements, where it arises as the intersection poset of a fiber-type arrangement. A nice partition of the atoms in the poset determines the roots of the characteristic polynomial, thus giving a factorization of the Poincaré polynomial of the arrangement complement. The Orlik-Solomon algebra is a Koszul algebra, which allows one to extract information about the rational homotopy theory of the complement. We explore these ideas for toric and elliptic arrangements, where the analogue of the intersection poset is not even a semilattice but a notion of supersolvability can still be applied. The main motivating example is an analogue of reflection arrangements, where the complement is an orbit configuration space and the poset is a generalization of partition and Dowling lattices. Based on joint work with Emanuele Delucchi. (Received August 20, 2018)

1143-05-484 **Abdul Basit*** (abasit@nd.edu), Department of Mathematics, University of Notre Dame, 255 Hurley Hall, Notre Dame, IN 46556. *Sum-product bounds for quaternions.*

For a finite non-empty set A in a ring R, the sum and product sets are defined to be $A + A = \{a + b : a, b \in A\}$ and $A \cdot A = \{a \cdot b : a, b \in A\}$, respectively. The sum-product conjecture of Erdős and Szemerédi asserts that when $R = \mathbb{Z}$, then $|A + A| + |A \cdot A| \gg_\epsilon |A|^{2-\epsilon}$ for every finite $A \subset \mathbb{Z}$ and every $\epsilon > 0$.

I will discuss this problem and known results. I will also present recent work with Bend Lund, in which we study the problem in the more general setting when $R = \mathbb{H}$. Expanding upon results of Konyagin, Rudnev and Shkredov, we show that there exists a constant $c > 0$ such that for any finite subset A of the quaternions,

$$|A + A| + |A \cdot A| \gg |A|^{4/3+c}.$$

(Received August 20, 2018)

1143-05-498 **Kevin G Milans*** (milans@math.wvu.edu) and **Michael C Wigal**. *A Dichotomy Theorem for Greedy Chain Partitions.*

First-Fit is a simple greedy algorithm for partitioning the elements of a poset into chains. Let $\mathrm{FF}(w, Q)$ be the maximum number of chains that First-Fit uses on a Q-free poset of width w. Although $\mathrm{FF}(w, Q)$ is infinite when $w = 2$ and Q has width at least 3, Bosek, Krawczyk, and Matecki proved that $\mathrm{FF}(w, Q)$ is bounded by a function of w when Q has width at most 2.

We present the following dichotomy theorem. There exists a poset family $\mathcal{Q}$ such that if $Q \in \mathcal{Q}$, then $\mathrm{FF}(w, Q) \leq 2^{c(\log w)^2}$ for some constant c, and if $Q \notin \mathcal{Q}$, then $\mathrm{FF}(w, Q) \geq 2^w - 1$. The family $\mathcal{Q}$ is explicitly described, giving a characterization of the posets Q for which $\mathrm{FF}(w, Q)$ is at least exponential in w. (Received August 21, 2018)

1143-05-509 **Amanda E Redlich*** (amanda_redlich@uml.edu). *Missed connections: Finding similar vertices using random walks.*

Community detection, or clustering "similar" vertices in naturally-occurring networks, is a highly active area of research. For many applications, neighboring vertices are assumed to have something in common; more closely-connected vertices are more similar. However, many natural networks do not have this trait. For example, edges in some biological networks simply indicate interaction. Measuring similarity in this type of graph requires a different method than clustering algorithms. In this talk I discuss several similarity metrics appropriate for this type of graph that use random walks. (Received August 21, 2018)

1143-05-511 **John Engbers** (john.engbers@marquette.edu), **David Galvin** (david.galvin.12@nd.edu) and **Clifford Smyth*** (cdsmyth@uncg.edu). *Combinatorial formulas for restricted Stirling and Lah number matrices and their inverses.*

Given a set R of natural numbers let S(n,k,R) be the restricted Stirling number of the second kind: the number of ways of partitioning a set of size n into k non-empty subsets with the sizes of these subsets restricted to lie in R. Let S(R) be the matrix with S(n,k,R) in its (n,k) entry. If R contains 1, S(R) has an inverse T(R) with integer entries. We find that for many R the entries T(n,k,R) of T(R) are expressible (up to sign) as the cardinalities of explicitly defined sets of trees and forests. For example this is the case when R has no exposed odds, i.e. R contains 1 and 2 and R never contains an odd number n greater than 1 without also containing n+1 and n-1. We have similar results for restricted Stirling numbers of the first kind (partitions into cycles) and Lah numbers (partitions into ordered lists). Our proofs depend in part on a combinatorial formula for the coefficients of the compositional inverse of a power series that expresses each coefficient as a sum of weighted trees. (Received August 21, 2018)

1143-05-529 **Jacques A Verstraete*** (jacques@ucsd.edu), 9500 Gilman Drive, La Jolla, CA 92093-0112. *Extremal problems for independent sets in hypergraphs.*

In this talk I will survey some extremal problems involving independent sets in hypergraphs, connected to Ramsey theory, finite geometry, discrete geometry and clique covering and packing problems.

Partly joint work with D. Mubayi and A. Kostochka (Received August 21, 2018)

1143-05-530 **Brendan Pawlowski***, br.pawlowski@gmail.com. *Chromatic symmetric functions via the group algebra of S_n.*

The chromatic symmetric function of a (hyper)forest (or any chordal graph) can be expressed as the Frobenius characteristic of an element of the group algebra of S_n with a simple factorization. We deduce Schur positivity of some chromatic symmetric functions from linear algebraic properties of these group algebra elements. In particular, we resolve a conjecture of Taylor which implies the Schur positivity of the formal group law $f^{-1}(f(x_1) + f(x_2) + ...)$ associated to some generating functions $f(x)$. (Received August 21, 2018)

1143-05-531 **Tom Bohman*** (tbohman@math.cmu.edu), Department of Mathematical Sciences, Carnegie Mellon University, Pittsburgh, PA 15213, and **Lutz Warnke**. *Large girth approximate Steiner triple systems.*

One can define the girth of a graph to be the minimum k such that there is a set of k vertices that spans at least k edges. This definition can be extended to the setting of Steiner triple systems by defining the girth to be the smallest $k \geq 4$ for which there is a set of k vertices that spans at least $k - 2$ triples. In the 1970s Erdős conjectured the existence of Steiner triple systems with arbitrarily large girth. In this talk we discuss a randomized algorithm that produces an approximate triple Steiner system of arbitrarily large girth. (Received August 21, 2018)

1143-05-544 **Adam Logan** (adam.m.logan@gmail.com), **Michael Molloy*** (molloy@cs.toronto.edu) and **Pawel Pralat** (pralat@ryerson.ca). *A random graph process.*

We introduce a new variation on the Erdos-Renyi random graph process. We begin with n vertices and label k of them as special. We will construct a graph in which no component contains two special vertices. We repeatedly select a uniformly random edge, without replacement, and add it to the graph iff it does not join two components that each contain a special vertex. We run the process until there are exactly k components.

The main question we consider is whether one of the components will contain almost all of the vertices. It turns out that if k is smaller than roughly $n^{1/3}$ then w.h.p. the largest component will have $n - o(n)$ vertices, while if k is larger than roughly $n^{1/3}$ then the largest component will have $o(n)$ vertices. (Received August 21, 2018)

1143-05-550 **James Rudzinski*** (jerudzin@uncg.edu). *Efficient Generation of Unlabeled Graphs.* Preliminary report.

We will discuss two algorithms of McKay related to graph isomorphism. The first algorithm, known as nauty, is widely used to find canonical graph isomorphs along with graph automorphisms. The second is an algorithm for generating a complete set of unique representatives of isomorphism classes of objects. We examine the second algorithm in particular with respect to graph generation and will discuss an efficient variation of this algorithm that can generate distinct representatives for each unlabeled graph on a fixed number of vertices. (Received August 21, 2018)

06 ► Order, lattices, ordered algebraic structures

1143-06-179 **Emily Barnard** (e.barnard@northeastern.edu), 360 Huntinton Ave, 567 Lake Hall, Math department of Northeastern Univeristy, Boston, MA 02115, **Gordana Todorov** (g.todorov@northeastern.edu), 360 Huntington Avenue, 567 Lake Hall, Math department of Northeastern Univeristy, Boston, MA 02115, and **Shijie Zhu*** (shijiezhu0011@gmail.com), 14 Maclean Hall, Math. Department of The University of Iowa, Iowa City, IA 52242. *An automorphism of the poset of functorially finite torsion classes.*

There are two methods in the study of (functorially finite) torsion classes: the tilting theory and the minimal extending theory. While the tilting theory has been intensively studied, the minimal extending theory is developed much recently. Using the minimal extending theory, we construct an automorphism $\bar{\kappa}$ of the poset of functorially finite torsion classes over hereditary algebras. Combinatorially, over the path algebra of a Dynkin quiver, $\bar{\kappa}$ represents the Kreweras complement of the corresponding non-crossing partition. (Received August 11, 2018)

1143-06-391 **Harry J Altman*** (haltman@umich.edu). *Choosing and multichoosing with ordinals.* Preliminary report.

It's clear what choose and multichoose mean for cardinals, but what about for ordinals? We'll discuss several ways to generalize the idea of choose and multichoose to ordinal numbers using the theory of well partial orders (or in one case a generalization to surreal numbers), and make some notes as to what properties these satisfy and how they may be computed. (Received August 19, 2018)

08 ► General algebraic systems

1143-08-339 **Gilbert Baumslag** and **Benjamin Fine*** (fine@fairfield.edu), Fairfield University, Department of Mathematics, Fairfield, CT 06840, and **Martin Kreuzer** and **Gerhard Rosenberger**. *Speculation on Further Uses of Group Theory in Cryptographic Settings.* Preliminary report.

Group theory, specifically the combinatorial group theory of finitely presented groups has been utilized effectively cryptology. Several new public key cryptosystems have been devloped and this has ushered a new area in cryptogrpahy called braid group cryptography. The basic idea is that a finitely presented group can be described by a finite amount of data. This provides techniques to enormously compress and hide information. This suggests that we have only barely scraped the surface of using finitely presented groups for data control, security and storage. In this talk which is speculative we suggest additional uses of group theory, some complicated and some simple, For example, we describe a far-reaching extension for controlling access to files which could be relevant in medical records. (Received August 18, 2018)

11 ► Number theory

1143-11-26 **Edward F Schaefer*** (eschaefer@scu.edu), Department of Mathematics and, Computer Science, 500 El Camino Real, Santa Clara, CA 95050. *Explicit descent for Jacobians of prime power cyclic covers of the projective line.*

Abstract: Let K be a field and X/K be the curve given by $y^n = f(x)$ for some $f(x) \in K[x]$. The Jacobian J of X is isogenous to the product of abelian subvarieties, one for each positive divisor of n. Such a subabelian variety is the image of a certain endomorphism of J, as described by Lorenzini and Tucker. Now assume that K is a number field. In an article with Poonen, we showed how to compute certain Selmer groups for the subabelian

varieties associated to prime divisors of n. These subabelian varieties are themselves Jacobians. In this talk, we discuss how to compute certain Selmer groups for subabelian varieties associated to non-trivial prime-power divisors of n. Such subabelian varieties are not expected to be Jacobians themselves. If the Chabauty condition holds for the subabelian variety associated to any divisor of n, then there is hope of determining the set of rational points on X. (Received June 21, 2018)

1143-11-55 **Vishal Arul**, **Alex Best**, **Edgar Costa**, **Richard Magner** and **Nicholas Triantafillou*** (ngtriant@mit.edu). *Zeta Functions of Superelliptic Curves in Large Characteristic.*

We describe an algorithm to compute the zeta function of a cyclic cover of the projective line over a finite field of characteristic p that runs in time $p^{1/2+o(1)}$. The algorithm extends both Gonçalves's generalization of Kedlaya's algorithm for cyclic covers, and Harvey's work on Kedlaya's algorithm for large characteristic. We confirm its practicality and effectiveness by reporting on the performance of our SageMath implementation on a range of examples.

Our work provides a valuable tool for the study of superelliptic curves over local and global fields by providing data which, among other things, helps to understand their Galois representations, the torsion subgroups of their Jacobians, and analogues of the Lang-Trotter conjecture. (Received August 14, 2018)

1143-11-96 **Melissa Emory*** (m.emory@utoronto.ca). *On the global Gan-Gross-Prasad conjecture for general spin groups.*

In the 1990s, Benedict Gross and Dipendra Prasad formulated an intriguing conjecture connected with restriction laws for automorphic representations of a particular group. More recently, Gan, Gross, and Prasad extended this conjecture, now known as the *Gan-Gross-Prasad Conjecture*, to the remaining classical groups. Roughly speaking, they conjectured the non-vanishing of a certain period integral is equivalent to the non-vanishing of the central value of a certain L- function. Ichino and Ikeda refined the conjecture to give an explicit relationship between this central value of a L-function and the period integral. An analogous conjecture was formulated for unitary groups by R.N. Harris. We propose a similar conjecture for a non-classical group, the general spin group, and prove several cases. (Received August 02, 2018)

1143-11-117 **Daniel Rayor Hast*** (drh@rice.edu). *Rational points and unipotent fundamental groups.*

Given a curve of genus at least 2 over a number field, what can we say about its set of rational points? Faltings' theorem tells us that this set is finite, but many questions remain about how to obtain good bounds on the number of rational points and how to provably list all rational points. We will survey some recent progress and ongoing work on these questions using Kim's non-abelian Chabauty method, which uses the fundamental group to construct p-adic analytic functions that vanish on the set of rational points.

In particular, we present a new proof of Faltings' theorem for superelliptic curves over $\mathbb{Q}$, due to joint work with Jordan Ellenberg. We will also discuss a conditional generalization of this strategy from $\mathbb{Q}$-points to points in any real number field. (Received August 04, 2018)

1143-11-165 **Tony Feng*** (tonyfeng@stanford.edu), 450 Serra Mall, Stanford, CA 94035. *A base change fundamental lemma via the geometry of shtukas.*

We will present a geometric proof of a base change fundamental lemma for parahoric Hecke algebras over local function fields. The argument, which is based on ideas of Ngo Bao Chau, works by comparing the cohomology of various moduli spaces of shtukas, which have played a fundamental role in recent breakthroughs on the Langlands correspondence over function fields. (Received August 08, 2018)

1143-11-266 **Giacomo Micheli*** (giacomo.micheli@maths.ox.ac.uk). *Fractional Jumps.*

Constructing pseudorandom number generators (PRNG) has always been a task of great interest in applied areas and in particular in Cryptography. In this talk we produce PRNGs using Fractional Jumps of transitive projective maps. The concept of Fractional Jump intertwines the theory of projective automorphisms with the theory of polynomials over finite fields and analytic number theory. In turn this leads to competitive pseudorandom number generation. Furthermore, our theory covers entirely the theory of Inversive Congruential Generator (ICG) sequences. The sequences produced using our generators have the same discrepancy bound but improved computational complexity with respect to the classical ICG sequences. (Received August 16, 2018)

1143-11-289 **Rahul Krishna*** (krishna@math.northwestern.edu). *On the global Gross-Prasad conjecture for orthogonal groups.* Preliminary report.

Let F be a number field, $\mathbb{A}$ its ring of adeles, and $W \subset V$ non-degenerate quadratic spaces of rank n and $n+1$ respectively. Let $\mathrm{G} = \mathrm{SO}_W \times \mathrm{SO}_V$; let $\mathrm{H} = \mathrm{SO}_W$, embedded diagonally in G. Let π be an automorphic cuspidal

representation of $\mathrm{G}(\mathbb{A})$. The global Gross-Prasad conjecture, formulated some twenty years ago, postulates a striking relationship between a period integral of an automorphic form $\varphi \in \pi$ over $\mathrm{H}(F)\backslash\mathrm{H}(\mathbb{A})$ and the central value $L(1/2, \pi)$ of the standard L-function of π. Despite motivating much progress in the theory of automorphic periods and special values of L-functions, this conjecture has remained largely open.

In this talk, I will present a possible approach to this conjecture via a bizarre comparison of relative trace formulas. This comparison relies on two local conjectures of smooth transfer and fundamental lemma. I will explain the evidence for these local identities in cases of small n, and comment on what remains to be done. (Received August 16, 2018)

1143-11-332 **Shuichiro Takeda*** (takedas@missouri.edu). *On local theta correspondences.*
I will give a survey of local theta correspondences and describe the main theorems on theta correspondence including the Howe duality conjecture. (Received August 18, 2018)

1143-11-386 **Jonathan Cohen*** (jonathan.s.cohen-1@ou.edu). *Local Newforms for Odd Unitary Groups.* Preliminary report.
We construct a sequence K_n of compact open subgroups inside an odd, unramified unitary group G over a p-adic field. We then study the spaces of K_n-fixed vectors in irreducible representations of G, focusing on generic representations. In particular, we show that any generic representation contains a K_n-fixed vector for sufficiently large n. Our setup is analogous to the classical theory of newforms for GL_n, which was more recently developed by Tsai for split odd orthogonal groups. In the case of $G = U(2, 1)$, our results were previously proven by Miyauchi. (Received August 19, 2018)

1143-11-421 **Niccolò Ronchetti*** (niccronc@math.ucla.edu). *Structure and applications of the p-torsion derived spherical Hecke algebras of a p-adic group.*
We introduce the derived spherical Hecke algebra of a reductive p-adic group with general p-torsion coefficients, and describe its structure as a graded algebra, as well as with some worked examples.

Time permitting, we will discuss both global applications to the theory of automorphic forms as well as local applications to the mod p representation theory of a p-adic group. (Received August 20, 2018)

1143-11-504 **Karol Koziol***, University of Alberta, Department of Mathematics, Edmonton, AB T6G 2G1, Canada, and **Stefano Morra**. *Serre weight conjectures for unitary groups.*
In the 1970s, Serre formulated his remarkable conjecture that every two-dimensional mod-p Galois representation of the absolute Galois group of $\mathbb{Q}$, which is odd and irreducible, should come from a modular form. He later refined his conjecture, giving a precise recipe for the weight and level of the modular form. Both the "weak form" and "strong form" of Serre's conjecture are now theorems, due to the work of many mathematicians (Khare-Wintenberger, Kisin, Edixhoven, Ribet, and others). In this talk, we will discuss how to generalize Serre's weight recipe when the Galois representation is replaced by a homomorphism from an absolute Galois group to the Langlands dual of a rank 2 unitary group. This is joint work with Stefano Morra. (Received August 21, 2018)

1143-11-505 **Daniel L Johnstone*** (johnstod@umn.edu), 127 Vincent Hall, Minneapolis, MN 55455. *Stable Transfer Factors for the Symmetric Square Lifting from GL_2 to GL_3.*
I will discuss work in progress towards an explicit computation of the stable transfer factor in the sense of Langlands' paper Singularit{e} et Transfert for the symmetric square lifting from GL_2 to GL_3 for padic fields. (Received August 21, 2018)

1143-11-506 **Dubravka Ban**, **Kwangho Choiy** and **David Goldberg*** (goldberg@math.purdue.edu), Department of Mathematics, 150 N. University Street, Purdue Universiy, West Lafayette, IN 47907. *Recent progress in R-groups in the non-quasi-split case.*
The Knapp-Stein R-group gives a description of parabolically induced from discrete series representations, and is constructed from the theory of intertwining operators, as studied by Knapp-Stein, and Harish-Chandra, among others. The Arthur R-group is constructed from the conjectural Langlands parameter, and is predicted to be equivalent to the Knapp- Stein R—group. When G is quasi-split and G' is an inner form, then a Levi subgroup, M' of G' will be an inner form of some Levi subgroup, M of G. So, these two Levi subgroups share an L–group, i.e. ${}^LM = {}^LM'$ and hence there is a correspondence, $\{\sigma\} \leftrightarrow \{\sigma'\}$, between L–packets of M and those of M'. Thus, one can hope to determine the Arthur R-group attached to σ' in terms of the one for *sigma*, and thus, conjecturally, determine the Knapp-Stein R–group attached to σ' in terms of that for σ. In this talk we discuss the progress the authors have made in recent years to expand the catalogue of known R-groups by using

standard approaches to the Knapp-Stein R-group for the quasi-split case, proving the isomorphic with the Arthur R–group, and transferring data to the non-quasi-split inner form. (Received August 21, 2018)

1143-11-554 **Elena Fuchs*** (efuchs@math.ucdavis.edu), 420 Heron Place, DAVIS, CA 95616. *Primes and local to global in circle packings.*

Circle packings in which all circles have integer curvature, particularly Apollonian circle packings, have in the last several years become objects of great interest in number theory. In this talk, we explore some of their most fascinating arithmetic features, from local to global properties to primes in the packings, going from theorems, to widely believed conjectures, to wild guesses as to what might be true. (Received August 21, 2018)

12 ► Field theory and polynomials

1143-12-555 **Paul Baginski*** (pbaginski@fairfield.edu), Department of Mathematics, Fairfield University, 1073 North Benson Rd., Fairfield, CT 06824. *Nonunique factorization in the ring of integer-valued polynomials.*

The ring of integer-valued polynomials $\mathrm{Int}(\mathbb{Z})$ is the set of polynomials with rational coefficients which produce integer values for integer inputs. Specifically,

$$\mathrm{Int}(\mathbb{Z}) = \{f(x) \in \mathbb{Q}[x] \,|\, \forall n \in \mathbb{Z}\, f(n) \in \mathbb{Z}\}.$$

$\mathrm{Int}(\mathbb{Z})$ constitutes an interesting example in algebra from many perspectives; for example, it is a natural example of a non-Noetherian ring. It is also a ring with nonunique factorization. Every element has only finitely many factorizations, yet the number of irreducibles involved grows without bound. Frisch recently demonstrated that in $\mathrm{Int}(\mathbb{Z})$, you can find an element $f(x)$ that has any factorization lengths you desire and you can even prescribe the number of factorizations of each length. The polynomials constructed in this way have high degree. We give a graded analysis, determining all the possible elasticities and catenary degrees for a polynomial as a function of the degree of the polynomial.

Joint work with: Greg Knapp, Jad Salem, and Gabrielle Scullard. (Received August 21, 2018)

13 ► Commutative rings and algebras

1143-13-6 **Steven Dale Cutkosky*** (cutkoskys@missouri.edu), University of Missouri, Dept. Math., Columbia, MO 65211. *Mixed Multiplicities of Filtrations.*

We extend the definition of mixed multiplicities of ideals to mixed multiplicities of (not necessarily Noetherian) filtrations. We prove that classical results for ideals (by Tessier, Rees and Sharp) extend to the case of filtrations. For instance, the Minkowski inequalities hold for filtrations and the associativity formula holds. This theory works on local rings R of dimension d such the dimension of the nil radical of the completion of R is less than d. This includes the case of analytically unramified local rings. The theory does not hold outside of this situation. (Received March 31, 2018)

1143-13-74 **Giulio Caviglia**, **Marc Chardin**, **Jason McCullough**, **Matteo Varbaro** and **Irena Peeva***, Mathematics Department, Cornell University, Ithaca, NY 14853. *Castelnuovo-Mumford Regularity.*

Regularity is a numerical invariant that measures the complexity of the structure of homogeneous ideals in a polynomial ring. Papers of Bayer-Mumford and others give examples of families of ideals attaining doubly exponential regularity. In contrast, Bertram-Ein-Lazarsfeld, Chardin-Ulrich, and Mumford have proven that there are nice bounds on the regularity of the ideals of smooth (or nearly smooth) projective varieties. As discussed in an influential paper by Bayer and Mumford (1993), the biggest missing link between the general case and the smooth case is to obtain a decent bound on the regularity of all prime ideals. The long standing Eisenbud-Goto Regularity Conjecture (1984) predicts an elegant linear bound, in terms of the degree of the variety. The conjecture was proven for curves by Gruson-Lazarsfeld-Peskine, for smooth surfaces by Lazarsfeld and Pinkham, and in other special cases. Recently, McCullough and I introduced two new techniques and used them to provide counterexamples to the Eisenbud-Goto conjecture. We show that the regularity of prime ideals is not bounded by any polynomial function of the degree. Furthermore, in a joint work with Caviglia, Chardin, McCullough, and Varbaro, we answer several natural questions which arise from the counterexamples. (Received July 29, 2018)

1143-13-75 **Visu Makam*** (visu@umich.edu) and **Harm Derksen**. *Degree lower bounds for* SL_n *invariants.*

The ring of invariants for a rational representation of a reductive group is finitely generated and graded. We will exhibit a technique that can be used to show that an invariant ring is not generated by invariants of small degree. The main ingredients are Grosshans principle and the moment map. We will use this technique to show exponential lower bounds for the invariant ring for the action of $\mathrm{SL}(V)$ on $\mathrm{Sym}^3(V)^{\oplus 4}$. (Received July 30, 2018)

1143-13-77 **Nicholas J Werner*** (wernern@oldwestbury.edu). *Integer-valued Skew Polynomials.*

For an integral domain D with field of fractions K, the ring over integer-valued polynomials on D is $\mathrm{Int}(D) = \{f \in K[x] \mid f(D) \subseteq D\}$. In this talk, we will discuss how to construct generalizations of $\mathrm{Int}(D)$ by using skew polynomials. Given an automorphism σ of K, the skew polynomial ring $K[x;\sigma]$ consists of polynomials with coefficients from K, and with multiplication given by $xa = \sigma(a)x$ for all $a \in K$. We define

$$\mathrm{Int}(D;\sigma) = \{f \in K[x;\sigma] \mid f(D) \subseteq D\},$$

which is the set of integer-valued skew polynomials on D. When σ is not the identity, $K[x;\sigma]$ is noncommutative and evaluation behaves differently than it does for ordinary polynomials. Despite these difficulties, we will show that $\mathrm{Int}(D;\sigma)$ has a ring structure in many cases. While multiplication in these rings is manifestly noncommutative, we can construct interesting commutative rings of polynomials by considering only those polynomials in $\mathrm{Int}(D;\sigma)$ whose coefficients are fixed by σ. Properties of the above rings that may be discussed in this talk include elements, prime and maximal ideals, chain conditions, and behavior under localization. (Received July 30, 2018)

1143-13-113 **Linhui Shen*** (linhui@math.msu.edu). *Grassmannians and cyclic sieving.*

The Grassmannian $Gr(k,n)$ parametrizes k-dimensional subspaces in $\mathbb{C}^n$. Due to work of Scott, its homogenous coordinate ring $\mathbb{C}[Gr(k,n)]$ is a cluster algebra of geometric type. We introduce a periodic configuration space $X(k,n)$ equipped with a natural potential function W. We prove that the tropicalization of $(X(k,n),W)$ canonically parametrizes a linear basis of $\mathbb{C}[Gr(k,n)]$, as expected by the Duality Conjecture of Fock-Goncharov. We identify the tropical set of $(X(k,n),W)$ with the set of plane partitions. As an application, we show a cyclic sieving phenomenon involving the latter. This talk is based on joint work with Daping Weng. (Received August 04, 2018)

1143-13-120 **Mats Boij** and **Zach Teitler*** (zteitler@boisestate.edu), 1910 University Drive, Department of Mathematics, Boise State University, Boise, ID 83725-1555. *A bound for the Waring rank of the determinant via syzygies.*

The Waring rank of the 3×3 generic determinant is known to be greater than or equal to 14, and less than or equal to 20. Proofs of the lower bound of 14 were given in terms of geometric singularities or the Hilbert function of the apolar ideal. We improve the lower bound to 15 by considering higher syzygies in the minimal graded free resolution of the apolar ideal of the determinant. This is joint work with Mats Boij. (Received August 04, 2018)

1143-13-144 **Marco Fontana** (fontana@mat.uniroma3.it), **Evan Houston*** (eghousto@uncc.edu) and **Mi Hee Park** (mypark@cau.ac.kr). *Idempotence and divisoriality in Prüfer-like domains.*

Let D be a Prüfer $\star$-multiplication domain, where $\star$ is a semistar operation on D. We show that certain ideal-theoretic properties related to idempotence and divisoriality hold in Prüfer domains, and we use the associated semistar Nagata ring of D to show that the natural counterparts of these properties also hold in D. (Received August 07, 2018)

1143-13-160 **Nicholas R Baeth*** (nbaeth@fandm.edu), Department of Mathematics, Franklin & Marshall College, Lancaster, PA 17604, and **Matthew Enlow**. *The multiplicative structure of numerical semigroups.* Preliminary report.

Numerical semigroups are finite-complement additive subsemigroups of the nonnegative integers. Their additive structure, including factorization-theoretic properties, has been well studied. Surprisingly, their multiplicative structure has yet to be investigated. In this preliminary report we describe multiplicative behavior in numerical semigroups, show that they belong to a larger class of C-monoids, and give some first results indicating how unique or nonunique factorization can be in these multiplicative numerical semigroups. (Received August 08, 2018)

1143-13-161 **Adam L Boocher*** (aboocher@gmail.com). *How Big Are the Betti Numbers of Finite Length Modules?* Preliminary report.

If M is a graded module of finite length over a polynomial ring, there are many conjectured lower bounds for the betti numbers of M. One of the most tantalizing is the total rank conjecture, which was recently proven by Walker. In this talk I'll survey these conjectures and offer some new results that suggest how one might strengthen these bounds in many cases of interest. (Received August 08, 2018)

1143-13-164 **Nicholas Switala*** (nswitala@uic.edu) and **Wenliang Zhang**. *The stable part of the Matlis dual of an F-finite F-module.* Preliminary report.

Let k be an algebraically closed field of characteristic $p > 0$, and let R be a formal power series ring over k. If M is an F-finite F-module over R, we prove that the $\mathbb{F}_p$-dimension of the space of F-module homomorphisms $M \to E$ (where E is the Matlis dualizing module over R) is the same as the k-dimension of the Frobenius stable part of the Matlis dual $D(M)$. With "stable part" in place of "0th de Rham cohomology", this is a positive-characteristic analogue of a recent result of Hartshorne and Polini on holonomic D-modules. This is work in progress with Wenliang Zhang. (Received August 08, 2018)

1143-13-170 **Hailong Dao**, **Joseph Doolittle**, **Ken Duna**, **Bennet Goeckner**, **Brent J Holmes*** (brentholmes@ku.edu) and **Justin Lyle**. *Higher Nerves, Depth, and Serre Condition.*

In this talk, I will present generalized notions of the nerve complex for the facets of a simplicial complex. The homologies of these higher nerve complexes determine the depth of the Stanley-Reisner ring $k[\Delta]$ as well as the f-vector and h-vector of Δ. I will present relationships between simplicial complexes satisfying Serre's condition (S_ℓ) and the vanishing of reduced homologies of their higher nerve complexes. (Received August 09, 2018)

1143-13-181 **H. E. A. Campbell** and **David L. Wehlau*** (wehlau@rmc.ca). *Distinguishing finite planes, ZZ-topes and Fibonacci Numbers.* Preliminary report.

Let $\mathbb{F}_p$ denote the finite field of order p and $\mathbb{F}$ its algebraic closure. Classifying the $\mathbb{F}$-representations of $\mathbb{Z}/p\mathbb{Z} \times \mathbb{Z}/p\mathbb{Z}$ leads to a simply stated geometric problem involving $\mathbb{F}_p$-planes in $\mathbb{F}$. Solving this leads in turn to a family of polynomials $g_{p,r}(t) \in \mathbb{F}[t]$ for $r = 1, 2, 3, \ldots$.

It turns out that we may describe these polynomials uniformly in terms of p. This description allows us to generalize to any integer value of p. Taking $p = 1$ we recover a classical family of orthogonal polynomials the *Morgan-Voyce polynomials* which originally arose in a study of electrical resistance in 1959. These polynomials are known to have many connections with the Fibonacci sequence. This point of view yields a new description of the Morgan-Voyce polynomials in terms of an infinite sequence of binary vectors.

Using certain initial segments of this sequence as the vertices of a polytope, we recover the *zigzag order polytopes*. These polytopes were considered by Stanley and shown to have strong connections with certain elements of the permutation group. If time permits we will also illustrate a number of other surprising properties of this sequence of binary vectors. (Received August 10, 2018)

1143-13-185 **Craig Huneke**, **Ilya Smirnov** and **Javid Validashti*** (jvalidas@depaul.edu), Department of Mathematics, DePaul University, Chicago, IL. *A generalization of an inequality of Lech relating multiplicity and colength.*

A classical inequality due to Lech states that in a regular local ring the Hilbert-Samuel multiplicity of a finite colength ideal is bounded above by its normalized colength. We explore strengthening Lech's inequality and we prove one involving the multiplicity of the maximal ideal times the finite colength ideal. (Received August 11, 2018)

1143-13-189 **Ketan D Mulmuley*** (mulmuley@uchicago.edu), 1100, E. 58th. St., Chicago, IL 60637. *Algorithmic challenges in geometric complexity theory.*

This talk will give an overview of some algorithmic challenges, relevant to this workshop, which arise in the context of the geometric complexity theory approach to the fundamental lower bound problems in theory of computing. (Received August 11, 2018)

1143-13-197 **Ryan Kinser*** (ryan-kinser@uiowa.edu) and **Jenna Rajchgot**. *Type D quiver representation varieties and double Grassmannians.*

Orbit closures in representation varieties of Dynkin quivers can be thought of as generalizations of determinantal varieties. Many problems are still open for these, such characterizing their singularities, combinatorial description of the orbit closure poset, and formulas for equivariant cohomology and Grothendieck classes.

These problems for Dynkin type A quivers turn out to be "equivalent" to the corresponding problems for Schubert varieties in partial flag varieties. After a brief historical overview, I will report on recent work with

Rajchgot showing that these problems for Dynkin type D quivers are equivalent to the corresponding problems for B-orbit closures in double Grassmannians $G/P_1 \times G/P_2$, where $B \leq G$ is a Borel subgroup acting diagonally. (Received August 13, 2018)

1143-13-206 **Richard Erwin Hasenauer*** (hasenaue@nsuok.edu). *A characterization of non-Noetherian BFDs and FFDs.*

We will explore properties of non-Noetherian BFDs and FFDs. By studying the behavior of maximal ideals we will give a characterization of the bounded and finite factorization properties. (Received August 13, 2018)

1143-13-209 **Zvi Rosen** and **Jessica Sidman*** (jsidman@mtholyoke.edu), Department of Mathematics and Statistics, Mount Holyoke College, South Hadley, MA 01002, and **Jessica Sidman** and **Cynthia Vinzant**. *Algebraic matroids in rigidity theory.* Preliminary report.

Consider a framework consisting of a fixed length bars attached at flexible joints. The central question in rigidity theory is to determine if the resulting framework is rigid or flexible. In this talk we will discuss various algebraic matroids associated to frameworks and how to extract geometric data from circuit polynomials. (Received August 13, 2018)

1143-13-211 **Jesse G Smith*** (jesse.smith@maryvillecollege.edu), 502 E Lamar Alexander Pkwy, Maryville, TN 37804. *Isomorphisms of Ideal-based Zero-Divisor Graphs.* Preliminary report.

Let R be a commutative ring with nonzero identity and I a proper ideal of R. The *zero-divisor graph* of R, denoted by $\Gamma(R)$, is the graph on vertices $R^* = R \setminus \{0\}$ where distinct vertices x and y are adjacent if and only if $xy = 0$. The *ideal-based zero-divisor graph* of R with respect to the ideal I, denoted by $\Gamma_I(R)$, is the graph on vertices $\{x \in R \setminus I \mid xy \in I \text{ for some } y \in R \setminus I\}$, where distinct vertices x and y are adjacent if and only if $xy \in I$. In this presentation, we consider properties of graph isomorphisms on $\Gamma_I(R)$. In particular, we consider when $\Gamma_I(R) \cong \Gamma_J(S)$ implies $\Gamma(R/I) \cong (S/J)$. We also investigate when the converse holds. (Received August 13, 2018)

1143-13-238 **Francesca Gandini*** (fragandi@umich.edu) and **Harm Derksen**. *Resolutions of ideals associated to subspace arrangements.*

Suppose that $W_1, W_2, \ldots, W_d$ are subspaces of an n-dimensional $\mathbb{K}$-vector space $W \cong \mathbb{K}^n$ and let $I_1, I_2, \ldots, I_d \subseteq \mathbb{K}[x_1, x_2, \ldots, x_n]$ be the vanishing ideals of $W_1, W_2, \ldots, W_d$. Conca and Herzog showed that the Castelnuovo-Mumford regularity of the product ideal $I_1 I_2 \cdots I_d$ is equal to d. Derksen and Sidman showed that the Castelnuovo-Mumford regularity of the intersection ideal $I_1 \cap I_2 \cap \cdots \cap I_d$ is at most d and similar results hold for more general ideals constructed from linear ideals. In this paper we show that analogous results hold when we replace the polynomial ring with the exterior algebra and work over a field of characteristic 0. The proofs of aforementioned theorems rely on the existence of non-zero divisors, so this approach fails for the exterior algebra. Instead, we rely on the functoriality of free resolutions and construct a functor Ω from the category of polynomial functors to itself. The functor Ω transforms resolutions of ideals in the polynomial ring to resolutions of ideals in the exterior algebra. (Received August 15, 2018)

1143-13-254 **Christopher Park Mooney*** (mooneych@uwstout.edu), Department of Mathematics, 712 South Broadway Street, Menomonie, WI 54751, and **Jason Robert Juett**. *U-factorization of ideals.*

In this talk, we give a brief overview of some of the results of our new paper of the same title. We study the factorization of ideals of a commutative ring using the framework of U-factorization introduced by Fletcher. This leads to several "U-factorability" properties weaker than unique U-factorization. We characterize these properties, determine the implications between them, and give several examples to illustrate the differences. If time permits, we also examine how these "U-factorability" properties behave with respect to several ring-theoretic constructions. (Received August 15, 2018)

1143-13-281 **Jonathan Montaño** and **Luis Núñez-Betancourt*** (luisnub@cimat.mx), Guanajuato, Mexico. *Symbolic powers of square-free monomial ideals.* Preliminary report.

In this talk we will dicuss the Castelnuovo-Mumford regularity function of the symbolic powers of square-free monomial ideals. We will also discuss a sufficient condition for the equality of the ordinary and symbolic powers of this family of ideals, and relate it to the Conforti and Cornuéjols conjecture. (Received August 16, 2018)

1143-13-285 **Janet Page**, **Daniel Smolkin*** (smolkin@math.utah.edu) and **Kevin Tucker**. *Studying Symbolic Powers with Test Ideals.*

How different is the symbolic power of an ideal from its ordinary power? This is an important question in commutative algebra. In 2001, Ein–Lazarsfeld–Smith made substantial progress on this question by showing that every regular affine $\mathbb{C}$-algebra has the so-called Uniform Symbolic Topology Property. In particular, if R is such a $\mathbb{C}$-algebra and $\mathfrak{p}$ a prime ideal in R, then $\mathfrak{p}^{(dn)} \subseteq \mathfrak{p}^n$ for all n, where d is the dimension of R. Their proof uses the machinery of multiplier ideals. Their argument extends to the positive-characteristic setting by replacing multiplier ideals with their positive-characteristic analog, test ideals.

In this talk, we will explain one way to extend Ein–Lazarsfeld–Smith's result to the non-regular setting. In particular, we demonstrate a class of affine semigroup rings in which one can run a version of Ein–Lazarsfeld–Smith's argument. (Received August 16, 2018)

1143-13-304 **Stefan Bock** and **Jim Coykendall*** (jcoyken@clemson.edu), Department of Mathematical Sciences, Clemson University, Clemson, SC 29634. *Topology and Factorization.*

In this talk we will look at a certain topology on a commutative ring with identity (the principal ideal topology). After highlighting some properties of this topology, we will show some connections with factorization properties in integral domains (and more general settings). In particular we will show how notions like compactness give concrete analogs to the factorization and ideal-theoretic properties of the ring. (Received August 17, 2018)

1143-13-305 **Eloísa Grifo***, grifo@umich.edu, Ann Arbor. *Symbolic powers and free resolutions.*

The containment problem for symbolic and ordinary powers of ideals asks when the containment $I^{(a)} \subseteq I^b$ holds. Under nice enough conditions, we can replace this question by a purely homological one: whether or not a certain map between Ext modules vanishes. In this talk, we will answer this question for some classes of ideals I, and along the way compute free resolutions for all powers of I. (Received August 17, 2018)

1143-13-307 **Michael Cowen**, **James Gossell**, **Alan Hahn**, **W. Frank Moore**, **Todd Morra** and **Sean Sather-Wagstaff*** (ssather@clemson.edu). *The power edge ideal of a graph.* Preliminary report.

Motivated by questions in electrical engineering and computer science, we associate to a finite simple graph a new square-free monomial ideal called the power edge ideal. It is defined in terms of PMU covers where PMU is short for "phasor measurement unit." PMUs are devices placed on buses in electrical power systems to detect, e.g., power outages. In this talk, we will explain how the ideal is defined and characterize the trees for which this ideal is Cohen-Macaulay, showing in particular that (for trees) the Cohen-Macaulay property is equivalent to the unmixed property and the complete intersection property. (Received August 17, 2018)

1143-13-308 **Richard Erwin Hasenauer** and **Bethany Kubik*** (bakubik@d.umn.edu), University of Minnesota Duluth, 140 Solon Campus Center, 1117 University Drive, Duluth, MN 55812. *τ-factorization and τ-elasticity.* Preliminary report.

A more generalized form of factorization, called τ-factorization, was introduced in 2011 by D.D. Anderson and J. Reinkoester. In τ-factorization, all factors of a factorization must belong to the same equivalence class modulo a fixed ideal. We discuss τ-factorization in small settings and τ-elasticity in a more general setting. (Received August 17, 2018)

1143-13-311 **C-Y. Jean Chan*** (chan1cj@cmich.edu), Department of Mathematics, PE 214, Central Michigan University, Mt. Pleasant, MI 48869. *Hilbert-Kunz theory in association with lattice ideals.* Preliminary report.

Lattice ideals are binomial ideals in a polynomial ring S over a field. A prime lattice ideal is also known as a toric ideal that defines an affine toric variety in the usual sense.

The quotient of the above S by a toric ideal I has interesting interpretations: geometrically, it corresponds to the coordinate ring of certain affine toric variety; and also algebraically, the ring S/I has the structure of a semigroup ring (of dimension ≥ 1).

In this talk, the shape of the Hilbert-Kunz functions of rings of positive characteristic in the form of S/I with respect to a toric ideal will be discussed and analyzed. (Received August 20, 2018)

1143-13-312 **Alessandra Costantini*** (costanta@purdue.edu). *Cohen-Macaulayness of Rees algebras of modules.*

Rees algebras of ideals and modules arise in Algebraic Geometry as homogeneous coordinate rings of blow up or as graphs of rational maps. The Cohen-Macaulayness of the Rees algebra of an ideal I is well-understood

in connection with the Cohen-Macaulayness of the associated graded ring of I, thanks to results of Huneke, Trung and Ikeda. However, there is no module analogue for the associated graded ring, so the study of Cohen-Macaulayness of Rees algebras of modules is in general more complicated. In this talk we will present the technique of generic Bourbaki ideals introduced by Simis, Ulrich and Vasconcelos, and use it to provide sufficient conditions for the Rees algebra of a module to be Cohen-Macaulay. Our results generalize results of Johnson and Ulrich, and of Goto, Nakamura and Nishida. (Received August 17, 2018)

1143-13-319 **Greg Oman** and **Adam Salminen*** (as341@evansville.edu). *Residual Smallness in Commutative Algebra.*

An infinite ring R with identity is *residually small* if for every $r \in R\backslash\{0\}$, there exists an ideal I_r of R such that $r \notin I_r$ and $|R/I_r| < |R|$. In this talk, we continue the investigation of residually small rings and then generalize this notion to modules. (Received August 17, 2018)

1143-13-327 **Eric Bucher** (buchere1@xavier.edu) and **John Machacek*** (machacek@yorku.ca). *Reddening sequences for Banff quivers and the class $\mathcal{P}$.*

We show that a reddening sequence exists for any quiver which is Banff or in the class $\mathcal{P}$. Our proofs are combinatorial and rely on the direct sum construction for quivers. The other facts needed are that the existence of a reddening sequence is mutation invariant and passes to induced subquivers. Banff quivers define locally acyclic cluster algebras which are known to coincide with their upper cluster algebras. The existence of reddening sequences for these quivers is consistent with a conjectural relationship between the existence of either a maximal green or reddening sequence and a cluster algebra's equality with its upper cluster algebra. Moreover, this completes a verification of the conjecture for Banff quivers. We also prove that a certain subclass of quivers within the class $\mathcal{P}$ define locally acyclic cluster algebras. (Received August 17, 2018)

1143-13-351 **Eloísa Grifo***, grifo@umich.edu, and **Linquan Ma** and **Karl Schwede**. *Symbolic powers of ideals defining F-pure rings.* Preliminary report.

The containment problem for symbolic and ordinary powers of ideals asks for which a and b the containment $I^{(a)} \subseteq I^b$ holds. Over a regular ring, a theorem of Ein–Lazersfeld–Smith, Hochster–Huneke and Ma–Schwede partially answers this question, but the containments it provides are not necessarily best possible. In particular, an improvement conjectured by Harbourne has been shown to hold for nice classes of ideals. In this talk, we will discuss a generalization of prime characteristic results of Grifo–Huneke in the regular case to F-finite Gorenstein rings. (Received August 18, 2018)

1143-13-357 **Kyungyong Lee** and **LI Li*** (li2345@oakland.edu), Department of Mathematics and Statistics, Rochester, MI 48309, and **Ralf Schiffler**. *Support of cluster variables of rank 3 cluster algebras.* Preliminary report.

The support of the Laurent expansion plays an important role in the construction of greedy bases of rank 2 cluster algebras. It is not known if there is a similar construction for cluster algebras of higher rank. In this talk, I will report recent progress on the the support of cluster variables for rank 3 cluster algebras. This could be the first step toward constructing greedy bases in rank 3. (Received August 18, 2018)

1143-13-372 **Sema Gunturkun*** (sema.gunturkun@uconn.edu). *A filtration of ideals of the polynomial ring in infinitely many variables.* Preliminary report.

Ideals of a polynomial ring in countably many variables that are stable under the action of the monoid of increasing functions attract various fields including commutative algebra, algebraic statistic and representation theory. In this talk, we discuss the recent results about these ideals, and the rationality of their bigraded Hilbert series. This is a joint work with Uwe Nagel. If time permits we will also talk about the theory of representations of that monoid. This part is based on a joint work with Andrew Snowden. (Received August 19, 2018)

1143-13-377 **Rebecca R.G.*** (rrebhuhn@gmu.edu). *Characteristic-free test ideals.* Preliminary report.

We define the test ideal of a general closure operation cl, and give some of its properties. We highlight connections to the trace ideal and interior operations, and the applications of these viewpoints to the study of singularities of commutative rings. In all characteristics, test ideals coming from big Cohen-Macaulay modules or algebras can take on the role of the tight closure test ideal used in characteristic $p > 0$ to study singularities. (Received August 19, 2018)

1143-13-379 **Ranthony A.C. Edmonds*** (edmonds.110@osu.edu). *Unique Factorization in Polynomial Rings with Zero Divisors.* Preliminary report.

In this talk we will provide a brief overview of how the theory of factorization in integral domains generalizes to factorization in commutative rings with zero divisors. Of particular interest is how certain factorization properties behave with respect to the polynomial extension $R[X]$, where R is an arbitrary commutative ring. For example, if R is an integral domain, it is well known that R is a unique factorization domain (UFD) if and only if $R[X]$ is a unique factorization domain. This result does not hold if we generalize to polynomial rings with zero divisors. We will focus on several types of unique factorization rings with zero divisors and characterize when a polynomial ring over an arbitrary commutative ring has unique factorization. (Received August 19, 2018)

1143-13-387 **Eleonore Faber**, MI 48104, **Greg Muller**, MI , and **Karen E Smith***, Mathematics Department, University of Michigan, Ann Arbor, MI 48109. *Non-Commutative Resolutions of Toric Varieties.*

Let R be the coordinate ring of an affine toric variety. We show that the endomorphism ring of R-module homomorphisms of A, where A is the (finite) direct sum of all (isomorphism classes of) conic R–modules, has finite global dimension. Furthermore, we show that this endomorphism ring is a non-commutative crepant resolution if and only if the toric variety is simplicial. For toric varieties over a perfect field k of prime characteristic, we show that the ring of k-linear differential operators on R has finite global dimension. (Received August 19, 2018)

1143-13-401 **Hang Huang*** (hhuang235@wisc.edu), 218 S Bassett St, Madison, WI 53703. *Equations of Kalman Varieties.*

Given a subspace L of a vector space V, the Kalman variety consists of all matrices of V that have a nonzero eigenvector in L. We will discuss how to apply Kempf Vanishing technique with some more explicit constructions to get a long exact sequence involving coordinate ring of Kalman variety, its normalization and some other related varieties in characteristic zero. This example is also a case of extending the techniques of Kempf collapsing to get scheme theoretically defining equations and syzygies for nonnormal varieties. Time permitting we will also discuss how to extract more information from the long exact sequence including the minimal defining equations for Kalman varieties. (Received August 19, 2018)

1143-13-402 **Matthew Mastroeni*** (mmastro@okstate.edu), **Hal Schenck** and **Mike Stillman**. *Non-Koszul quadratic Gorenstein rings via idealization.*

Let R be a standard graded Gorenstein algebra over a field presented by quadrics. Conca, Rossi, and Valla showed that such a ring is Koszul if $\operatorname{reg} R \leq 2$ or if $\operatorname{reg} R = 3$ and $\operatorname{codim} R \leq 4$, and they ask whether this is true for $\operatorname{reg} R = 3$ in general. We give a negative answer to their question in almost all codimensions at least 9 by finding suitable conditions on a non-Koszul quadratic Cohen-Macaulay ring R that guarantee the Nagata idealization $\tilde{R} = R \ltimes \omega_R(-a-1)$ is a non-Koszul quadratic Gorenstein ring. (Received August 20, 2018)

1143-13-403 **Youngsu Kim*** (yk009@uark.edu), 850 W Dickson St, Fayetteville, AR 72701, and **Wenbo Niu** and **Lance Edward Miller**. *The generic link of a determinantal variety.*

We study singularities of the generic link of a determinantal variety. Let $A := \mathbb{A}^n_{\mathbb{C}}$, and let X and Y be equidimensional subschemes of A. We say that X and Y are *linked* via V if there exists a complete intersection V in A such that $\mathcal{I}_Y/\mathcal{I}_V \cong \operatorname{Hom}_{\mathcal{O}_A}(\mathcal{O}_X, \mathcal{O}_V)$ and $\mathcal{I}_X/\mathcal{I}_V \cong \operatorname{Hom}_{\mathcal{O}_A}(\mathcal{O}_Y, \mathcal{O}_V)$.

Two linked subschemes have many properties in common, and it is believed that the generic link of a variety improves singularities of the variety. Let X be a variety and Y the generic link of X. Recently, W. Niu showed that the log canonical threshold, lct for short, "improves" under taking the generic link, i.e., $\operatorname{lct} Y \geq \operatorname{lct} X$. It is not known if equality holds in general. In this talk, we show that in the case where X is a determinantal variety, then $\operatorname{lct} X = \operatorname{lct} Y$. This is joint work with Wenbo Niu and Lance Miller. (Received August 20, 2018)

1143-13-408 **John D. LaGrange*** (lagrangej@lindsey.edu). *Divisor graphs of commutative rings.*

Given an element x of a commutative ring R, define the *x-divisor graph* of R to be the simple graph $\Gamma_x(R)$ whose vertices are the elements of $\{r \in R \mid rs = x \text{ for some } s \in R\}$ such that two distinct vertices r and s are adjacent if and only if $rs = x$. For example, $\Gamma_0(R)$ is the graph introduced by I. Beck in 1988. We examine the interplay between ring-theoretic properties of R and graph-theoretic properties of $\Gamma_x(R)$. Algebraic conditions that determine structural similarities between 0-divisor graphs and the connected components of more general $\Gamma_x(R)$ are of particular interest. (Received August 20, 2018)

1143-13-411 **Hannah Altmann*** (hannah.altmann@bemidjistate.edu) and **Sean Sather-Wagstaff**.
On the Number of Semidualizing Modules over a Local Ring. Preliminary report.

Let R be a commutative local noetherian ring with identity. A finitely generated R-module C is *semidualizing* if the homothety map $\chi_C^R : R \to \mathrm{Hom}_R(C,C)$ is an isomorphism and $\mathrm{Ext}^i_R(C,C) = 0$ for all $i > 0$. It has been proven recently that the number of isomorphism classes of semidualizing modules over R is finite, but little is known about the actual number. Gherko gives some bounds in the artinian case (which are easily extended to the Cohen Macaulay case). Using differential graded algebra techniques, we discuss extensions of this to the non Cohen Macaulay case and also for semidualizing complexes. (Received August 20, 2018)

1143-13-422 **Melvin Hochster*** (hochster@umich.edu), Department of Mathematics, Univ. of Michigan, East Hall, 530 Church Street, Ann Arbor, MI 48109-1043. *Breakthroughs and open questions in commutative algebra.* Preliminary report.

Over the past two years, there have been remarkably many breakthroughs in commutative algebra, including proofs of the direct summand conjecture and the existence of big Cohen-Macaulay algebras, counterexamples to the Eisenbud-Goto conjecture, the proof of Stillman's conjecture, and progress on the Buchsbaum-Eisenbud-Horrocks question on Betti numbers. The talk will survey some of this progress and will point out, for each topic discussed, one or more major open questions that remain. (Received August 20, 2018)

1143-13-426 **K Alan Loper***, 1179 University Drive, Newark, OH 43055, and **Dario Spirito**.
Overrings of ultrapowers of integral domains. Preliminary report.

Let D be an integrally closed integral domain. Also let C(D) represent a collection of valuation overrings of D which intersect to D. Let U be a nonprincipal ultrafilter on the natural numbers. For each valuation domain V in C(D) use U to construct an ultrapower of V. Intersect all these ultrapowers of valuation domains. This is generally a proper overring of the corresponding ultrapower of D. We investigate properties of this intersection. (Received August 20, 2018)

1143-13-432 **Linquan Ma** and **Thomas Polstra***, 155 1400 E, Salt Lake City, UT 84112, and **Karl Schwede** and **Kevin Tucker**. *Prime characteristic invariants and birational maps.*

We explore the behavior of prime characteristic invariants, such as F-signature and Hilbert-Kunz multiplicity, under birational morphisms. We will discuss both positive and negative behavior. (Received August 20, 2018)

1143-13-445 **Alexander Zheglov*** (azheglov@math.msu.su). *On a Berest conjecture for elliptic and hyperelliptic curves.*

I'll talk about several results related with the following Berest conjecture, a non-commutative analogue of the Mordell conjecture. Let A_1 be the first Weyl algebra $K[x][\partial_x]$. Consider a generic polynomial equation in two variables $f(X,Y) = 0$ that has a solution in A_1. Each such solution is a pair of commuting ordinary differential operators in A_1. A conjecture proposed by Yu. Berest says that the orbit space of the group action of $Aut(A_1)$ on the set of solutions of this equation is infinite if the genus of the corresponding spectral curve is 1, and is finite otherwise. This conjecture has an intimate connection with the famous Dixmier conjecture for A_1. The conjecture is true for spectral curves of genus one and there are counterexamples for genus two curves. The talk is based on joint works together with A.E. Mironov and with I. Burban. (Received August 20, 2018)

1143-13-446 **Grace McClurkin*** (gmcclurk@svsu.edu) and **David Anderson**. *Congruence-based Zero-divisor Graphs.* Preliminary report.

In this talk, I will extend the idea of a congruence-based zero-divisor graph, first introduced by Anderson and Lewis (2016), to other variations of the zero-divisor graph, such as the annihilator graph and the extended zero-divisor graph. In addition to defining the congruence-based graphs, examples and properties of these graphs will be examined on multiple scales. (Received August 20, 2018)

1143-13-447 **D. D. Anderson**, **Sangmin Chun** and **Jason R. Juett*** (jason.juett@txstate.edu), Department of Mathematics, Texas State University, 601 University Drive, San Marcos, TX 78666. *Module-theoretic generalizations of commutative von Neumann regular rings.*

Let R be a commutative ring. It is well known (and easy to see) that R is von Neumann regular $\Leftrightarrow xR = x^2R$ for each $x \in R \Leftrightarrow$ every ideal is pure $\Leftrightarrow$ every finitely generated ideal is a direct summand $\Leftrightarrow R$ is locally simple $\Leftrightarrow R = xR \oplus (0 :_R (x))$ for each $x \in R \Leftrightarrow$ the endomorphism ring of R is von Neumann regular. By abstracting these characterizations to R-modules in the obvious way, one arrives at six distinct notions of a "regular" module. In this presentation we will examine each of these six kinds of "regular" modules (and others), discuss the implications between them, and develop several properties of each kind of "regular" module. (Received August 20, 2018)

1143-13-449 **Danny James Orton*** (dorton1@nd.edu). *Cluster Maps Connecting Exotic Cluster Structures on Rectangular Matrices.* Preliminary report.

Gekhtman, Shapiro, and Vainshtein introduced an exotic cluster structure on the affine space, Mat_n, of $n \times n$ matrices. They also constructed a sequence of cluster mutations which was used to restrict this structure to $\mathrm{Mat}_{n-1\times n}$. In this talk, we investigate conditions under which there exists a sequence of cluster mutations relating (conjectural) exotic cluster structures on $\mathrm{Mat}_{m\times n}$ and $\mathrm{Mat}_{m-1\times n}$. (Received August 20, 2018)

1143-13-450 **Kathryn Nicole Burton*** (kburton@nd.edu). *Generalized Cluster Structures Compatible with the Cremmer-Gervais Poisson Bracket on Rectangular Matrices.* Preliminary report.

Gekhtman, Shapiro, and Vainshtein have conjectured that there exists a classification of regular cluster structures on simple complex Lie groups that is completely parallel to the Belavin-Drinfeld classification. In my talk, I will outline a construction of an initial cluster for a generalized cluster structure on the space of rectangular $m \times n$ matrices that is compatible with the restriction of the Cremmer-Gervais Poisson bracket on GL_n. (Received August 20, 2018)

1143-13-454 **Harm Derksen** and **Jack Jeffries*** (jackjeff@umich.edu). *Lifting differential operators and unique splitting.* Preliminary report.

To any commutative K-algebra R is associated a ring of differential operators. Given an inclusion of K-algebras $R \subseteq S$ the question of whether every differential operator on R extends to a differential operator on S is subtle. In this talk, we will discuss some motivations, old and new, for this question, as well as some new answers to it.

This is based on joint work in progress with Harm Derksen. (Received August 20, 2018)

1143-13-479 **Jennifer Kenkel*** (kenkel@math.utah.edu), 1020 E Barbara Place, Apt 2, Salt Lake City, UT 84102. *Local Cohomology of Thickenings of Determinantal Rings.* Preliminary report.

Let R be a standard graded polynomial ring that is finitely generated over a field, and let I be a homogeneous prime ideal of R. Bhatt, Blickle, Lyubeznik, Singh, and Zhang examined the local cohomology of R/I^t, as t goes to infinity, which led to the development of an asymptotic invariant by Dao and Montaño. I will discuss their results and give concrete examples of the calculation of this new invariant in the case of determinantal rings. (Received August 20, 2018)

1143-13-495 **Jerzy Weyman*** (jerzy.weyman@uconn.edu), Department of Mathematics, University of Connecticut, Storrs, CT 06269. *On the structure of finite free resolutions of length three.* Preliminary report.

I will report on recent progress on finite free resolutions of length three concentrating on the structure of the generic ring. I will discuss application to the structure of linkage. (Received August 20, 2018)

1143-13-497 **Jonathan P Totushek*** (jtotushe@uwsuper.edu), Swenson Hall 3030, Belknap & Catlin Ave, PO Box 2000, Superior, WI 54880, and **Sean K Sather-Wagstaff**. *Complete Intersection Hom Injective Dimension.* Preliminary report.

We introduce and investigate an injective version of the complete intersection dimension of Avramov, Gasharov, and Peeva. It is like the complete intersection injective dimension of Sahandi, Sharif, and Yassemi in that it is built using quasi-deformations. Ours is different, however, in that we use a Hom functor in place of a tensor product. We show that (a) this invariant characterizes the complete intersection property for local rings, (b) it fits between the classical injective dimension and the G-injective dimension of Enochs and Jenda, (c) it provides modules with Bass numbers that are bounded by polynomials, and (d) it improves a theorem of Peskine, Szpiro, and Roberts (Bass' conjecture). (Received August 21, 2018)

1143-13-515 **Yu Xie*** (yxie@widener.edu). *Generalized mixed multiplicities.*

Mixed multiplicities of two ideals that are primary to the maximal ideal originated from Teissier's Cargèse paper on complex analytic hypersurfaces with isolated singularities. Trung, katz, Verma, etc., extended these concepts to the case where one ideal is primary to the maximal ideal and the other one is arbitrary. In this talk, we extend the concepts to two arbitrary ideals and study their properties and applications. (Received August 21, 2018)

1143-13-543 **Pedro Teixeira*** (pteixeir@knox.edu). *Syzygy gap fractals and the F-pure threshold of certain binary forms.* Preliminary report.

We examine the F-pure thresholds of certain homogeneous polynomials in two variables with four distinct roots in $\mathbb{P}^1$. Results on the structure of syzygy gap fractals, and in particular a bound on syzygy gaps obtained by Monsky, yield an explicit formula for the F-pure threshold of such a polynomial. This formula depends on the

vanishing of Deuring polynomials at the cross-ratio of the four roots of the polynomial, and reproduces and generalizes a result of Pagi. (Received August 21, 2018)

1143-13-562 **Justin Lyle*** (justin.lyle@ku.edu) and **Jonathan Montaño**. *c-Ulrich Modules.* Preliminary report.

Let $(R, \mathfrak{m}, k)$ be a commutative Noetherian local ring. We study Cohen-Macaulay R-modules with the property that $e_R(M) \leq c\mu_R(M)$, which we call c-Ulrich modules. We prove existence in some cases for small values of c, and prove some consequences of existence, extending results of Ulrich and Huneke-Hanes. (Received August 21, 2018)

1143-13-571 **Daniel J Hernández*** (hernandez@ku.edu), **Pedro Teixeira** (pteixeir@knox.edu) and **Emily Witt** (witt@ku.edu). *Frobenius powers of monomial ideals.*

In recent work with Teixeira and Witt, we extended the definition of Frobenius powers of an ideal in a regular ring of prime characteristic to allow for an arbitrary nonnegative real exponent. The resulting theory is closely related to that of test and multiplier ideals. In this talk, we consider the Frobenius powers of certain monomial ideals, and apply them to understand the test ideals of generic hypersurfaces. (Received August 21, 2018)

1143-13-572 **Chris Fraser*** (cmfra@umich.edu). *Braid group symmetries of Grassmannian cluster algebras.*

We construct an action of the extended affine braid group on d stands on the open positroid stratum in Gr(k,n), where d is the greatest common divisor of k and n. Each braid determines a quasi-automorphism of the cluster structure, inducing a homomorphism into the cluster modular group. We will state some conjectures on faithfulness of this action, and some instances in which we checked these conjectures. (Received August 21, 2018)

1143-13-573 **Dylan Rupel*** (dylanrupel@gmail.com), **Salvatore Stella** (stella@math.haifa.ac.il) and **Harold Williams** (hwilliams@math.ucdavis.edu). *Acyclic Cluster Monomials are Generalized Minors.*

Cluster algebras are commutative rings with a canonical partial basis of cluster monomials recursively defined from an initial collection of cluster variables. Cluster algebras often arise as coordinate rings of interesting well-studied varieties. In particular, a now classical result of Berenstein-Fomin-Zelevinsky (in the Dynkin case) and Williams (in the general Kac-Moody case) states that this holds for the coordinate ring of any double Bruhat cell of a Kac-Moody group. Yang and Zelevinsky showed in the special case of Coxeter double Bruhat cells for groups of finite Dynkin type that all cluster variables are given by restrictions of generalized minors. In this talk, I will discuss recent progress, joint with Salvatore Stella and Harold Williams, in extending this result to all cluster monomials for arbitrary Coxeter double Bruhat cells. (Received August 21, 2018)

1143-13-577 **Mark T Batell*** (mbatell@outlook.com). *Half-factorial theory in polynomial rings.* Preliminary report.

This talk will be on half-factorial theory in polynomial rings. (Received August 22, 2018)

14 ► Algebraic geometry

1143-14-31 **Lubjana Beshaj*** (lubjana.beshaj@usma.edu) and **Takuya Yamauchi**. *On Prym varieties for the coverings of some singular plane curves.*

Let k be a field of characteristic zero containing a primitive n-th root of unity. Let C_n^0 be a singular plane curve of degree n over k admitting an order n automorphism, n nodes as the singularities, and C_n be its normalization.

In this talk we study the factors of Prym variety $\mathrm{Prym}(\mathbb{C}_n/C_n)$ associated to the double cover $\widetilde{C}_n$ of C_n ramified at the points obtained by the blow-up of the singularities. We provide explicit models of some algebraic curves related to the construction of $\mathrm{Prym}(\widetilde{C}_n/C_n)$ as a Prym variety and determine the interesting simple factors other than elliptic curves which come up in J_n so that the endomorphism rings contains number fields related to the cyclotomic field $\mathbb{Q}(\zeta_n + \zeta_n^{-1})$. (Received June 29, 2018)

1143-14-68 **Avi Steiner*** (steinea@purdue.edu). *Using mixed Gauss–Manin systems to project, restrict, and dualize A-hypergeometric systems.*

Let A be an integer matrix, and assume that its semigroup ring $\mathbb{C}[\mathbb{N}A]$ is normal. I will discuss how to use mixed and dual mixed Gauss–Manin systems, a notion I introduced recently, to compute the holonomic dual of

an A-hypergeometric system; and to compute, for F a face of the cone of A, the projection and restriction of an A-hypergeometric system to the coordinate subspace corresponding to F. (Received July 26, 2018)

1143-14-93 **Aravind Asok*** (asok@usc.edu), 3620 S Vermont Ave KAP 104, Los Angeles, CA 90089.
Unstable rational motivic splittings of algebraic groups and applications.

I will discuss joint work with Mike Hopkins and Jean Fasel regarding analogs of unstable rational splittings of classical groups in the context of motivic homotopy theory. In particular, we show that working over a field that is not formally real, (split) special linear and symplectic groups are products of "odd-dimensional motivic spheres" after inverting sufficiently many primes. As a consequence of these kinds of results, I will show that $\mathbb{A}^n \setminus 0$ is rationally a motivic Eilenberg–Mac Lane space in the sense of Voevodsky. (Received August 02, 2018)

1143-14-104 **Andrew Obus*** (andrewobus@gmail.com), Baruch College, Department of Mathematics, One Bernard Baruch Way, Box B 6-230, New York, NY 10010, and **Padmavathi Srinivasan** (padmavathi.srinivasan@math.gatech.edu). *Conductor-Discriminant inequalities for hyperelliptic curves.* Preliminary report.

The Artin conductor A is a measure of bad reduction of a curve over a discretely valued field. If the curve is superelliptic of order prime to the residue characteristic, the valuation D of the discriminant of the branch locus is another reasonable such measure (this can also be extended to the case where the residue characteristic divides the order of the cover, but we will not consider this). For curves of genus 1, $D = A$. For curves of genus 2, $D \geq A$. It is conjectured that $D \geq A$ for all superelliptic curves. Padmavathi Srinivasan has shown that $D \geq A$ for hyperelliptic curves with rational Weierstrass points. I will speak on joint work with Srinivasan on extending this result to all hyperelliptic curves. (Received August 03, 2018)

1143-14-138 **Yaacov Kopeliovich***, University of Connecticut School of Business, Storrs, CT 06269.
p-adic analogue of Hyperelliptic lambda functions.

I will show how the classical uniformization of λ hyper-elliptic functions has exact analogues for Hyper-elliptic Mumford curves. I will outline possible applications and will indicate how this formulas can be generalized further to the case of Super-elliptic Mumford curves (Received August 06, 2018)

1143-14-149 **Aaron D Wootton*** (wootton@up.edu), 5000 North Willamette Blvd, Portland, OR 97203, and **Sean A Broughton**. *Automorphism Groups of Cyclic n-gonal Surfaces.*

A cyclic n-gonal surface is a compact Riemann surface X of genus $g \geq 2$ admitting a cyclic group of conformal automorphisms C of order n such that the quotient space X/C has genus 0. Many automorphism groups of cyclic n-gonal surfaces are normal extensions of C by a genus zero automorphism group, so finding them can be done fairly systematically, and the literature boasts rather complete results. Finding automorphism groups which do not fall into this category however is more problematic, and accordingly much less is known about such groups. In this talk, we shall present the only current complete classification of such groups, when $n = p$ a prime, and outline the difficulties for why there has not been much progress in further classification of these groups. (Received August 07, 2018)

1143-14-191 **Juliette Bruce*** (juliette.bruce@math.wisc.edu), Van Vleck Hall, 480 Lincoln Dr., Madison, WI 53706. *Asymptotic Syzygies for Products of Projective Space.*

I will discuss results describing the asymptotic syzygies of products of projective space, in the vein of the explicit methods of Ein, Erman, and Lazarsfeld's non-vanishing results on $\mathbb{P}^n$. (Received August 12, 2018)

1143-14-226 **Takumi Murayama*** (takumim@umich.edu), Department of Mathematics, University of Michigan, 530 Church St, Ann Arbor, MI 48109-1043. *Frobenius–Seshadri constants and limits in commutative algebra.*

Frobenius–Seshadri constants are positive characteristic analogues of Seshadri constants, which were introduced by Mustaţă–Schwede and the presenter as a way to measure local positivity of Cartier divisors in positive characteristic. We will describe the connection between Frobenius–Seshadri constants and other invariants in algebraic geometry and commutative algebra, in particular restricted volumes and Hilbert–Kunz multiplicity. We will also explain how Frobenius–Seshadri constants can be used to prove weak results in the spirit of Fujita's conjecture on singular varieties, some of which are new even in characteristic zero. (Received August 14, 2018)

1143-14-330 **Martha Precup*** (martha.precup@wustl.edu). *A generalization of the Springer resolution.*

The Springer correspondence relates irreducible representations of the symmetric group to a subset of simple perverse sheaves on the nilpotent cone. The Springer resolution of the nilpotent cone and its fibers play an essential role in this result.

In the 1980's, Lusztig proved that each simple perverse sheaf on the nilpotent cone corresponds to an irreducible representation of a relative Weyl group. This series of results is known as the generalized Springer correspondence. The focus of this talk will be a map defined by Graham which plays a role in the generalized Springer correspondence analogous to that of the Springer resolution in the Springer correspondence. We will describe the fibers of this map using the combinatorics of standard tableaux. This talk is based on joint work with William Graham and Amber Russell. (Received August 17, 2018)

1143-14-334 **Leonid O Chekhov*** (chekhov@msu.edu). *Quantum monodrmies of SL_k systems and quantum cluster algebras.* Preliminary report.

Our goal is to provide an effective description for Poisson and quantum algebras of monodromies for SL_k systems on Riemann surfaces $\Sigma_{g,s,n}$ of genus g, with $s > 0$ holes and with $n > 0$ bordered cusps on the boundaries of holes. We use the Fock-Goncharov coordinates for higher Teichmuller spaces associated with SL_k data on these surfaces and show that we can derive Poisson and quantum commutation relations between all monodromy matrices from the basic relation in an ideal triangle $\Sigma_{0,1,3}$ using the groupoid property. The obtained quantum algebras have an R-matrix form predicted by Korotkin and Samtleben and satisfy all relations of Fock-Rosly algebras. In the semiclassical limit, these algebras generate the Goldman bracket. (Received August 18, 2018)

1143-14-352 **Vishal Arul*** (varul@mit.edu). *Division by $1-\zeta$ on superelliptic curves and jacobians.*

In 2016, Yuri Zarhin gave formulas for "dividing a point on a hyperelliptic curve by 2." Given a point P on a hyperelliptic curve $\mathcal{C}$, Zarhin gives the Mumford's representation of every degree g divisor D such that $2(D - g\infty) \sim P - \infty$.

The paper generalizes Zarhin's result to the superelliptic situation; instead of dividing by 2, we divide by $1-\zeta$. Even though there is no Mumford's representation for superelliptic curves, we give a formula for functions which cut out D.

Furthermore, Zarhin proved that the intersection of $2^{-1}\mathcal{C}$ and the theta divisor Θ in the jacobian J is contained in the two-torsion $J[2]$. This result is also generalized to the superelliptic setting; namely, we show that the intersection of $(1-\zeta)^{-1}\mathcal{C}$ and Θ is contained in $J[1-\zeta]$. We also provide formulas for intersection multiplicities at each point of this intersection. (Received August 18, 2018)

1143-14-356 **Li Li*** (li2345@oakland.edu), Department of Mathematics and Statistics, Rochester, MI 48309. *Double determinantal varieties.* Preliminary report.

Nakajima's graded quiver varieties appear naturally in the study of bases of cluster algebras. A special family of such varieties, called double determinantal varieties, can be defined similarly to determinantal varieties which are extensively studied in algebraic geometry. I will report some results on the geometric and topological properties of these varieties and their connection to cluster algebras. (Received August 18, 2018)

1143-14-361 **Lara Bossinger**, **Juan Bosco Frías Medina**, **Timothy Magee*** (tmagee@im.unam.mx) and **Alfredo Nájera Chávez**. *Toric degenerations of cluster Poisson varieties.*

Cluster varieties come in pairs (A,X), with A and X built from dual tori. Compactifications of A and their toric degenerations were studied extensively by Gross, Hacking, Keel, and Kontsevich. These compactifications generalize the polytope construction of toric varieties– a construction which is recovered in the central fiber of the degeneration. Compactifications of X (a cluster Poisson variety) were introduced by Fock and Goncharov and generalize the fan construction of toric varieties. We introduce the notion of an X-variety with coefficients, expand upon the notion of compactified X-varieties, and for each torus in the atlas give a toric degeneration where each fiber is a compactified X-variety with coefficients. We show that these fibers are stratified, and each stratum is again a compactified X-variety with coefficients. In the central fiber, we recover the toric variety associated to the "g-fan" of (A,X), and we show that strata of the fibers degenerate to toric strata. If time permits, we will relate this to the Batyrev-Borisov construction of CY mirror families in toric Fanos.

Based on joint work with Lara Bossinger, Juan Bosco Frías Medina, and Alfredo Nájera Chávez, and if we have time to address the Batyrev-Borisov connection, Man-Wai Cheung as well. (Received August 19, 2018)

1143-14-373 **Linhui Shen** and **Daping Weng*** (dapingweng@gmail.com), 619 Red Cedar Road, C212 Wells Hall, East Lansing, MI 48824. *Cluster DT Transformations of Configuration Spaces of Flags of Kac-Moody Groups .* Preliminary report.

Let G be a Kac-Moody group associated to a symmetrizable Cartan matrix and let (b, d) be a pair of positive braids associated to the root system. We define the configuration space $\mathrm{Conf}_d^b(\mathcal{B})$ to be the moduli space of configurations of flags satisfying certain relative position condition. By using the amalgamation construction of Fock and Goncharov, we equip $\mathrm{Conf}_d^b(\mathcal{B})$ with a cluster Poisson variety structure, and we construct its cluster

Donaldson-Thomas transformation. In the cases where G is semisimple and the positive braids satisfy a certain condition we also prove the periodicity of the cluster Donaldson-Thomas transformation. This is joint work with Linhui Shen. (Received August 19, 2018)

1143-14-382 **Oscar S Kivinen*** (okivinen@ucdavis.edu). *Unramified affine Springer fibers and isospectral Hilbert schemes.*

In this talk we explain the author's recent work on certain affine Springer fibers, as well as pose some open questions. From the paper's abstract: We revisit Goresky-Kottwitz-MacPherson's description of the torus-equivariant (co)homology of affine Springer fibers $\mathrm{Sp}_\gamma \subset \mathrm{Gr}_G$, where $\gamma = at^d$, and a is a regular semisimple element in the Lie algebra of G. In the case $G = GL_n$, we relate the equivariant cohomology of Sp_γ to Haiman's work on the isospectral Hilbert scheme of points on the plane. We also explain the connection to the HOMFLY homology of (n, dn)-torus links, and formulate a conjecture describing the homology of the Hilbert scheme of points on the curve $\{x^n = y^{dn}\}$. (Received August 19, 2018)

1143-14-388 **Tony Shaska*** (shaska@oakland.edu), Rochester, MI 48309. *Heights on weighted projective spaces.*

We extend the concept height on projective spaces to that of weighted height on weighted projective spaces. We show some of the basic properties of this height and show how it can be used to study hyperelliptic curves over $\mathbb{Q}$. Some examples are provided from the weighted moduli space of binary sextics and octavics. (Received August 22, 2018)

1143-14-389 **Vladimir Dragovic*** (vladimir.dragovic@utdallas.edu), 800 W. Campbell Road, FO 35, The University of Texas at Dallas, Mathematic, Richardson, TX 75080. *Triangular Schlesinger Systems, Elliptic, Hyperelliptic, and Superelliptic Curves.*

We present algebra-geometric solutions of triangular Schlesinger systems, expressed as periods of meromorphic differentials on elliptic, hyperelliptic and superelliptic curves. The proposed approach provides a method to generate explicit rational solutions of Painleve VI equations and algebraic solutions of the Garnier systems. This presentation is based on a joint work with Renat Gontsov and Vasilisa Shramchenko. (Received August 19, 2018)

1143-14-434 **Felix Janda*** (janda@umich.edu). *Double ramification cycles.*

A double ramification (DR) locus inside the moduli space of curves is the locus of curves admitting a map to $\mathbb{P}^1$ with prescribed ramification profile over 0 and ∞. The case of a ramification profile of $(1, 1)$ (or (2)) corresponds to the case of a hyperelliptic curve with a pair of hyperelliptically congugate points (or a Weierstrass point). The DR locus is a degeneracy locus, and its class can hence be computed via the Thom-Porteus formula.

The DR cycle is an analogous class on the Deligne-Mumford compactification of the moduli of curves that is computationally more accessible than the closure of the DR locus. In this talk, I will discuss a formula for the DR cycle obtained in joint work with R. Pandharipande, A. Pixton and D. Zvonkine. (Received August 20, 2018)

1143-14-456 **Luen-Chau Li***, Department of Mathematics, Pennsylvania State University, University Park, PA 16802. *Nodal curves and a class of solutions of the Lax equations for shock clustering and Burgers turbulence.*

We consider a matrix Lax equation which describes the probability law of solutions of a scalar hyperbolic conservation law with convex flux function f where the initial data is a monotone Markov process taking values in a fixed, finite set. In this talk, we show how to solve the Lax equation explicitly. This is accomplished by means of a change of variable which maps an open, dense subset of infinitesimal generator matrices to an associated set of algebro-geometric data consisting of a nodal curve C and a set of complementary variables which can be interpreted as the gluing data of an eigenvector bundle over the normalization of C. (Received August 20, 2018)

1143-14-473 **Neriman Tokcan*** (tokcan@umich.edu), 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *Tensor decomposition and applications in Computational Medicine.* Preliminary report.

Tensors are multi-dimensional arrays and they generalize vectors and matrices to higher dimensions. One of the biggest challenges in biomedical data processing is the analysis of multi-dimensional and multi-modal data. Previously used matrix-based representations of data and related analysis methods are not compatible with multi-dimensional data. Tensors provide often a natural and compact representation for such massive multi-dimensional data. As an application of tensor decomposition methods, different similarity measures have been

suggested in order to compare and match given tensor-form data. Similarity scores for tensors have been used for matching of diffusion tensor (DT) MRIs of the human brain, and for the analysis of large amounts of EEG data and identifying location of the epileptic seizure origin. While these measures have been useful for various medical applications, their utility is limited to tensors having the same size. We develop a novel similarity score for tensors of different sizes and we utilize this score for a tensor-based machine learning framework. (Received August 20, 2018)

1143-14-508 **Antoni Rangachev*** (rangachev@math.uchicago.edu). *Asymptotics of intersection numbers and the local volume of a line bundle.*

In this talk I will describe the relation between the local volume of a line bundle and the asymptotics of certain Hilbert–Samuel-type multiplicities. I will discuss applications to equisingularity problems. (Received August 21, 2018)

1143-14-537 **Aaron Pixton*** (apixton@mit.edu). *The homogeneous double ramification cycle.*

The double ramification cycle parametrizes curves of genus g admitting maps to the projective line with specified ramification profiles over two points. Recent formulas for this cycle in terms of tautological classes (on the moduli space of stable curves) have established that it is polynomial in the parts of the ramification profiles. I will discuss some aspects of the top degree part of this polynomial, a homogeneous polynomial of degree 2g. (Received August 21, 2018)

1143-14-559 **Matej Penciak***, 706 W Columbia Ave., Champaign, IL 61820. *Spectral Description of the Ruijsenaars-Schneider System.* Preliminary report.

The Calogero-Moser integrable system has a well-known Hitchin description in terms of flows on the space of twisted Higgs bundles on cubic curves. The associated spectral description was spelled out by Tom Nevins and David Ben-Zvi as spectral curves lying in the total space of the Atiyah bundle of the curve. The goal of this talk is to describe a similar Hitchin and spectral description for the Ruijsenaars-Schneider (RS) integrable system. The RS spectral curves can be shown to live on the total space of a degree zero line bundle, with a dual description as associated meromorphic invertible twisted Higgs bundles. (Received August 21, 2018)

1143-14-566 **Andreas Malmendier*** (andreas.malmendier@usu.edu), Utah State University, Department of Mathematics & Statistics, Logan, UT 84322, and **Adrian Clingher**. *Geometry of (1,2)-polarized Kummer surfaces and theta identities.*

In this talk, we give an explicit description for the relation between algebraic Kummer surfaces of Jacobians of genus-two curves with principal polarization and those associated to $(1,2)$-polarized abelian surfaces from three different angles: the point of view of 1) the binational geometry of quartic surfaces in $\mathbb{P}^3$ and intersections of quadrics in $\mathbb{P}^5_+$ using even-eights, 2) elliptic fibrations on K3 surfaces of Picard-rank 17 over $\mathbb{P}^1$ using Nikulin involutions, 3) theta-functions of genus-two using two-isogeny. Finally, we will explain how these $(1,2)$-polarized Kummer surfaces naturally allow for an identification of the complex gauge coupling in Seiberg-Witten gauge theory with the axion-dilaton modulus in string theory using an old idea of Sen. (Received August 21, 2018)

1143-14-578 **Askold Khovanskii*** (askold@math.toronto.edu), Department of Mathematics, University of Toronto, Toronto, Ontario M5S 2E4, Canada. *The ring of conditions of* $(\mathbf{C}^*)^n$.

The ring of conditions of a spherical homogeneous space H (in particular of $(\mathbf{C}^*)^n$) was introduced by De Concini and Procesi in 1980-s. It is a version of intersection theory for algebraic cycles in H. Its construction is based on the good compactification theorem.

Recently two nice geometric descriptions of this ring for $H = (\mathbf{C}^*)^n$ were found. The first of them is formulated in terms of the volume function on the cone of convex polyhedra with integral vertices in $\mathbf{R}^n$. The second one is provided by tropical geometry. These descriptions are unified by the theory of toric varieties.

I am going to discuss these descriptions of the ring of conditions of $(\mathbf{C}^*)^n$ and present an elementary proof of the good compactification theorem. (Received August 22, 2018)

15 ► Linear and multilinear algebra; matrix theory

1143-15-225 **Shmuel Friedland*** (friedlan@uic.edu), Department of Math, Stat & CS, University of Illinois at Chicago, 851 S. Morgan Street, Chicago, IL 60607-7045. *Spectral and nuclear norms of homogeneous polynomials and applications to entanglement and separability.* Preliminary report.

We define the spectral and the nuclear norm of a homogeneous polynomial f of degree d in n variables, over real or complex numbers, as the maximum of the absolute value of f on the unit sphere, and the minimum"energy" of the decomposition of f as a sum of powers of linear forms. We show that for a fixed n the spectral and nuclear norms can be approximated polynomially in d. These results imply that the entaglement of symmetric tensors and the separabiity of symmetric density tensors can be compute polynomially in d for a fixed n. The proof uses recent results of Friedland-Lim, Friedland-Wang and Derksen-Friedland-Lim-Wang. (Received August 14, 2018)

1143-15-300 **Andrew T Azzam*** (atazzam@mtu.edu), **Benjamin W Ong** and **Allan A Struthers**. *Randomized Sub-Sampled Methods for Matrix Approximation.* Preliminary report.

This talk introduces a framework for randomized sub-sampling methods for matrix approximation. Modern computational problems require solving linear systems relating to increasingly larger data sets. In most cases it is impractical to use all of the data available and unnecessary for reasonable approximations. Current work uses sampling methods to iteratively construct an approximation to a matrix. Sub-sampling methods require less work per iteration and are more adaptable to different problem settings when compared to full sampling. Convergence of the sub-sampled iterates is proven in expectation. An accelerated sampling scheme is presented and experimentally shown to be comparable to current accelerated sampling methods. (Received August 17, 2018)

1143-15-326 **Akram Aldroubi** and **Keaton Hamm***, hamm@math.arizona.edu, and **Bugra Koku** and **Ali Sekmen**. *CUR Decompositions and the Subspace Clustering Problem.*

The subspace clustering problem seeks to cluster data in a high-dimensional space that is drawn from the union of much smaller dimensional subspaces. One method of attack for this problem is to find a similarity matrix from the data which identifies the clusters. This talk will discuss an intriguing matrix decomposition method called CUR decomposition, and describe how many similarity matrix methods are special cases of this general decomposition, and how it ties this technique to other minimization problems used to find the clusters. In addition, applications to motion segmentation will be discussed. (Received August 17, 2018)

1143-15-341 **J. Fan** and **Jiawang Nie*** (njw@math.ucsd.edu), San Diego, CA 92093, and **A. Zhou**. *Tensor Eigenvalue Complementarity Problems.*

This talk discusses tensor eigenvalue complementarity problems. Basic properties of standard and complementarity tensor eigenvalues are discussed. We formulate tensor eigenvalue complementarity problems as constrained polynomial optimization. When one tensor is strictly copositive, the complementarity eigenvalues can be computed by solving polynomial optimization with normalization by strict copositivity. When no tensor is strictly copositive, we formulate the tensor eigenvalue complementarity problem equivalently as polynomial optimization by a randomization process. The complementarity eigenvalues can be computed sequentially. The formulated polynomial optimization can be solved by Lasserre's hierarchy of semidefinite relaxations. We show that it has finite convergence for general tensors. (Received August 18, 2018)

1143-15-390 **Harm Derksen*** (hderksen@umich.edu) and **Neriman Tokcan** (tokcan@umich.edu). *An algebraic approach to tensor analysis.* Preliminary report.

A tensor is a higher-dimensional array. The structure of tensor in Big Data applications can be exploited using the CP decomposition, but computing CP decompositions can be challenging. In this talk I will discuss how representation theory can be used to develop scalable algebraic algorithms for manipulating tensors. One application is denoising of tensor data. (Received August 19, 2018)

1143-15-399 **Han Huang*** (sthhan@umich.edu) and **Mark Rudelson**. *The size of Nodal Domain for an Erdős–Rényi Graph.*

Let A be the adjacency matrix of an Erdős–Rényi graph G(n, p). A Nodal Domain D corresponding to an eigenvector u=(u(1),...,u(n)) of A is a maximal connected subgraph of G(n, p) such sign[u(i)]=sign[u(j)] whenever i,j lies in D. It was shown by Dekel, Lee and Linial that with high probability there are only two nodal domains.

In this talk, we would like to show these two nodal domains have roughly the same size n/2. Based on a joint work with Mark Rudelson. (Received August 19, 2018)

16 ► Associative rings and algebras

1143-16-103 **Nicholas Ovenhouse*** (ovenhou3@msu.edu). *Noncommutative Integrability of the Grassmann Pentagram Map.*

The pentagram map is a discrete integrable system first introduced by Schwartz in 1992. Gekhtman, Shapiro, and Vainshtein studied Poisson geometry associated to certain networks embedded in a disc or annulus, and its relation to cluster algebras. Later, Gekhtman et al. and Tabachnikov reinterpreted the pentagram map in terms of these networks, and used the associated Poisson structures to give a new proof of integrability. In 2011, Beffa and Felipe introduced a generalization of the pentagram map to certain Grassmannians, and proved it was integrable. We reinterpret this Grassmann pentagram map in terms of noncommutative algebra, in particular the double brackets of Van den bergh, and generalize the approach of Gekhtman et al. to establish a noncommutative version of integrability. (Received August 03, 2018)

1143-16-221 **Alexander Garver*** (alexander.garver@gmail.com) and **Monica Garcia**. *Semistable subcategories and noncrossing tree partitions.*

Semistable subcategories were introduced in the context of Mumford's GIT and interpreted by King in terms of representation theory of finite dimensional algebras. Ingalls and Thomas later showed that for path algebras of Dynkin and extended Dynkin quivers, the poset of semistable subcategories is isomorphic to the corresponding lattice of noncrossing partitions. We classify semistable subcategories for a family of algebras each of which is defined by the choice of a partial triangulation of the disk. Our description also shows that each such semistable subcategory is equivalent to a generalized noncrossing partition. This is joint work with Monica Garcia. (Received August 14, 2018)

1143-16-240 **Alexander Garver*** (alexander.garver@gmail.com), **Rebecca Patrias** and **Hugh Thomas**. *Reverse plane partitions via representations of quivers II.*

We start from a Dynkin quiver and a choice of minuscule vertex. As in part I, we can then define a map from a subcategory of the representations of the quiver to reverse plane partitions of whose shape is the minuscule poset corresponding to the chosen vertex. This maps turns out to be a bijection and is an analogue of the classical Robinson-Schensted-Knuth correspondence. We also discuss part of the proof that this is a bijection. (Received August 15, 2018)

1143-16-298 **Chelsea Walton** and **Xingting Wang***, Department of Mathematics, 204 Academic Support Building B, Washington, DC 20059, and **Milen Yakimov**. *Representations of 4-dimensional Sklyanin algebras through Poisson geometry.*

In 1982, Sklyanin constructed a certain noncommutative graded algebra $A(E, \tau)$ depending on an elliptic curve E embedded in $\mathbb{P}^3$ and a point $\tau \in E$ related to the Yang-Baxter equation in "quantum inverse scattering method". It was shown by Smith and Stafford that these so-called 4-dimensional Sklyanin algebras have the same Hilbert series as the polynomial algebra on four variables and possess excellent homological property. When τ is torsion-free, Smith and Staniszkis proved that there are exactly 4-parametric families of non-trivial irreducible representations at each dimension of $k \geq 1$. In this talk, we give all irreducible representations of $A(E, \tau)$ when τ is of finite order $n > 4$ with the help of Poisson geometry and deformation quantization. This is a joint work of Chelsea Walton and Milen Yakimov. (Received August 17, 2018)

1143-16-459 **Kyungyong Lee**, **Li Li**, **Matthew Mills*** (millsm12@msu.edu), **Ralf Schiffler** and **Alexandra Seceleanu**. *Frieze varieties : A characterization of the finite-tame-wild trichotomy for acyclic quivers.*

We introduce a new class of algebraic varieties which we call frieze varieties. Each frieze variety is determined by an acyclic quiver. The frieze variety is defined in an elementary recursive way by constructing a set of points in affine space. We give a new characterization of the finite–tame–wild trichotomy for acyclic quivers in terms of their frieze varieties. We show that an acyclic quiver is representation finite, tame, or wild, respectively, if and only if the dimension of its frieze variety is 0, 1, or at least 2, respectively. (Received August 20, 2018)

1143-16-464 **Bach Nguyen**, **Kurt Trey Trampel*** (ktramp2@lsu.edu) and **Milen Yakimov**.
Quantum Cluster Algebras and Discriminants. Preliminary report.

A general construction is built for quantum cluster algebras at roots of unity. For such an algebra, we construct a canonical central subalgebra that is isomorphic to the classic cluster algebra with the same exchange matrix. In special cases, this recovers the central subalgebras of quantum groups at roots of unity used by De Concini-Kac-Procesi. We take first steps to study the representation theory of these quantum cluster algebras. In particular, we prove a general theorem on the form of the discriminants of these algebras. Applicable examples are quantum Schubert cells and quantum double Bruhat cells. (Received August 20, 2018)

1143-16-472 **Calin I Chindris*** (chindrisc@missouri.edu). *The capacity of quiver representations and Brascamp-Lieb constants.* Preliminary report.

This talk is based on joint work with Harm Derksen. It is about studying Brascamp-Lieb constants (more generally, the capacity of completely positive operators) via quiver invariant theory. For a bipartite quiver Q, real representation V, and integral weight σ of Q, we first explain how to attach to the quiver datum (V, σ), a completely positive operator whose capacity defines the capacity of (V, σ). Next, we describe several structural results about the capacity of quiver data. In particular, we show that the capacity of (V, σ) is positive if and only if V is σ-semi-stable. Furthermore, we explain how the quiver version of the Kempf-Ness theorem in invariant theory can be used to study of the capacity of quiver data. When these results are applied to the m-subspace quiver, one recovers the main structural results on the classical Brascamp-Lieb constant due to J. Bennett, A. Carbery, M. Christ, and T. Tao. (Received August 20, 2018)

17 ► Nonassociative rings and algebras

1143-17-349 **Ben Salisbury*** (salis1bt@cmich.edu), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859, and **Travis Scrimshaw** (tcscrims@gmail.com), School of Mathematics and Physics, The University of Queensland, St. Lucia, QLD 4072, Australia. *Rigged configurations for generalized Kac–Moody algebras.* Preliminary report.

Crystal bases are combinatorial analogues of representations of the quantized universal enveloping algebra of a symmetrizable Kac–Moody algebra. Defined by Kashiwara in the early 1990s, crystals have become an integral part of combinatorial representation theory and have seen application to algebraic combinatorics, mathematical physics, the theory of automorphic forms, and more. In recent years, Kashiwara's construction of the crystal basis and its associated abstraction was extended to the symmetrizable generalized Kac–Moody algebra setting. These generalized Kac–Moody algebras, also known as Borcherds algebras, are infinite-dimensional Lie algebras introduced by Borcherds as a result of his study of the "Monstrous Moonshine" conjectures of Conway and Norton. In this talk, a rigged configuration model for the infinity crystal $B(\infty)$, including the $*$-crystal operators, will be described when the underlying algebra is a generalized Kac–Moody algebra. This is joint work with Travis Scrimshaw. (Received August 18, 2018)

19 ► K-theory

1143-19-36 **A. D. Elmendorf*** (adelmend@pnw.edu), Department of Mathematics, Purdue University Northwest, Hammond, IN 46323. *Multiplicative structure in inverse algebraic K-theory.* Preliminary report.

We show that Mandell's inverse K-theory functor preserves multiplicative structure. The motivation for this result is to find an inverse functor to the equivariant algebraic K-theory functor of Bohmann and Osorno, and in particular to answer the question of which G-spectra are represented by their construction. We will discuss how Mandell's result fits into this picture. (Received July 05, 2018)

1143-19-56 **Sophie Kriz*** (skriz@umich.edu), Department of Mathematics, University of Michigan, 530 Church Street, Ann Arbor, MI 48109-1043. *On Weil Reciprocity in Motivic Cohomology.*

I will talk about Voevodsky's derived category of motives, and how it can be used to prove a reciprocity law in motivic cohomology of a smooth projective morphism of dimension 1 over a smooth scheme over a perfect field. (Received July 22, 2018)

20 ► Group theory and generalizations

1143-20-7 **Wayne A Johnson*** (johnsonway@uwplatt.edu). *Exponential Hilbert series of equivariant embeddings.*

Let G be a semisimple, simply-connected linear algebraic group over $\mathbb{C}$. We study G-equivariant embeddings of projective varieties by considering an exponential version of the classical Hilbert series. We show that, for any such embedding, the exponential Hilbert series converges to the product of a rational polynomial, $p(x)$, and an exponential term. We give a combinatorial formula for the coefficients of $p(x)$, and show that it encodes both representation-theoretic information about G and algebro-geometric data about the embedding. In particular, we show that the linear coefficient of $p(x)$ is one less than the dimension of a particular finite-dimensional, irreducible representation of G and the highest order term encodes both the degree of the embedding and the dimension of the projective variety. (Received August 09, 2018)

1143-20-376 **Amrita Acharyya*** (amrita.acharyya@utoledo.edu), **Jon M Corson** and **Bikash C Das**. *Cofinite Connectedness and Cofinite Group Actions.*

We extend the idea of B. Hartley's cofinite groups in cofinite graphs. First we define cofinite spaces in general. Then, as a special situation, we study cofinite graphs and their uniform completions. The idea of constructing a cofinite graph starts with defining a uniform topological graph Γ, in an appropriate fashion. We endow abstract graphs with uniformities corresponding to separating filter bases of equivalence relations with finitely many equivalence classes over Γ. It is established that for any cofinite graph there exists a unique cofinite completion.

In this work, we have defined cofinite connectedness of a cofinite graph. Many of the properties of connectedness of topological spaces are analogous to cofinite connectedness. We defined group actions on cofinite graphs to characterize a unique way of uniformly topologize an abstract group with a cofinite structure, induced by the cofinite structure of the graph, so that the aforesaid action becomes uniformly continuous. (Received August 19, 2018)

1143-20-392 **Ramón Flores**, **Delaram Kahrobaei** and **Thomas Koberda*** (thomas.koberda@gmail.com). *Group and graph theoretic problems through right-angled Artin groups.*

I will survey a dictionary of decision problems in right-angled Artin group theory and graph theory. I will indicate some applications to group based cryptography. (Received August 19, 2018)

1143-20-493 **Sarah Wolff*** (wolffs@denison.edu). *The ballots are missing, who won the election? Inferring rankings from first order marginals.* Preliminary report.

Motivated by applications in rankings-based elections we consider the question of recovering election results using partial data. In particular, when given first-order marginals, can one recover the original probability distribution on the symmetric group S_n? For example, in an election between candidates A, B, C, a voter ranks the candidates in her preferred order, and a function $f : S_3 \to [0, 1]$ gives the normalized count of the votes for each ranking. The first-order marginals in this situation tell how many people voted for candidate A (respectively B, C) in first place, second place, and third place. Given this information, can one uniquely recover the original function f? Capturing the first order marginals using a 'first-order matrix' allows us to rephrase the question in terms of the combinatorial structure of the matrix. We give an explicit characterization of the structure, which in turn allows us to determine the original function. (Received August 20, 2018)

1143-20-565 **Gus Schrader*** (guskschrader@gmail.com). *Dehn twists in higher Teichmuller theory and Q–systems.*

I will explain how the operators representing Dehn twists in quantum higher Teichmuller theory can be understood in terms of Q-systems. Joint work with Alexander Shapiro. (Received August 21, 2018)

22 ► Topological groups, Lie groups

1143-22-29 **Mireille Boutin*** (mboutin@purdue.edu), 465 Northwestern Avenue, West Lafayette, IN 47907. *Structure-from-Motion is ill-conditioned - invariants can help!*

Structure-from-motion is the problem of reconstructing the 3D shape of an object from a set of pictures (or movie) of the object. When the positions and orientations of the camera are unknown, the problem is typically addressed in one of two ways, or a mix thereof: 1) first recover the camera parameters, and subsequently infer the object shape, 2) recover the camera parameters and object shape simultaneously. Unfortunately, the problem is ill-conditioned with respect to the camera parameters (esp. the camera angles). In this talk, we will show

how the camera parameters can be viewed as the parameters of a Lie group action, and how to eliminate these extraneous parameters using invariant theory. These invariants can be used to formulate a set of camera-pose-free structure-from-motion equations, thereby providing a much better-conditioned formulation of the problem.

Collaborators on this work include Daniel Aliaga, Pierre-Louis Bazin and Jeffrey Zhang. (Received June 26, 2018)

1143-22-54 **Alexander Heaton*** (aheaton@uwm.edu). *Graded multiplicity in harmonic polynomials from the Vinberg setting.*

We describe the graded multiplicity of irreducible representations by counting integral points on faces of a polyhedron. This description applies to a family of examples from the following context (first considered by Vinberg): Let G be a connected reductive algebraic group over the complex numbers. A subgroup, K, of fixed points of a finite-order automorphism acts on the Lie algebra of G. Each eigenspace of the automorphism is a representation of K. The harmonic polynomials on an eigenspace are graded by homogeneous degree, giving us a graded representation of K. Given any irreducible representation of K, we will see how its multiplicity in the harmonic polynomials is distributed among the various graded components. The results are described geometrically by counting integral points on faces of a polyhedron. The multiplicity in each graded component is given by intersecting these faces with an expanding sequence of shells. (Received July 21, 2018)

1143-22-92 **Jerrod M Smith*** (jerrod.smith@ucalgary.ca), Department of Mathematics and Statistics, University of Calgary, Calgary, Alberta T2N 1N4, Canada. *Support of closed orbit relative matrix coefficients.*

Let F be a p-adic field and let G be the F-points of a connected reductive group defined over F. Let θ be an F-involution of G. Let H be the subgroup of θ-fixed points in G. Let χ be a quasi-character of H. A smooth complex representation (π, V) of G is (H, χ)-distinguished if there exists a nonzero element λ in $\mathrm{Hom}_H(\pi, \chi)$. We generalize a construction of descended invariant linear forms on Jacquet modules first carried out independently by Kato and Takano, and Lagier to the setting of (H, χ)-distinction. Moreover, we give an (H, χ)-analogue of Kato and Takano's relative version of the Jacquet Subrepresentation Theorem. In the case that π is parabolically induced from a θ-stable parabolic subgroup of G, and λ arises via the closed orbit in $Q\backslash G/H$, we study the (non)vanishing of the descended forms via the support of λ-relative matrix coefficients. (Received August 01, 2018)

1143-22-174 **Dubravka Ban*** (dban@siu.edu), Department of Mathematics, Carbondale, IL 62901, and **Matthias Strauch**. *Locally algebraic vectors in p-adic Banach space representations.* Preliminary report.

Locally algebraic representations play an important role in the p-adic Langlands program. We study the restriction of p-adic Banach space representations of a connected reductive group G to a subgroup H containing the derived subgroup of G, and the properties related to locally algebraic vectors. (Received August 09, 2018)

1143-22-180 **Martin H Weissman*** (weissman@ucsc.edu), Dept of Mathematics, UCSC, 1156 High Street, Santa Cruz, CA 95064. *Sheaves on Bruhat-Tits trees, with applications to supercuspidal representations.*

In their influential 1997 Pub. Math. IHES paper, Schneider and Stuhler realized irreducible representations of p-adic groups in the cohomology of equivariant sheaves on the building. For semisimple p-adic groups of relative rank one, this realizes every supercuspidal representation as H^0 of a sheaf on the Bruhat-Tits tree.

In this talk, I will introduce the Schneider-Stuhler method in the concrete setting of sheaves on trees. Then I will describe refinements that allow one to prove that supercuspidals are compactly induced for groups of relative rank one. Notably, this method avoids tameness assumptions, while illustrating differences in wild settings. (Received August 10, 2018)

1143-22-258 **Fiona Murnaghan*** (fiona@math.toronto.edu). *Distinguished representations and tame types.*

We will discuss various results about distinguished representations of reductive p-adic groups. The representations are distinguished by an involution of the underlying group and are assumed to contain tame types (in the sense of J.-L. Kim and J.-K. Yu). We will discuss symmetry properties of tame types contained in distinguished representations, and construction of relatively supercuspidal tame representations. (Received August 15, 2018)

1143-22-271 **Laura Rider*** (laurajoy@uga.edu), **Roman Bezrukavnikov**, **Dennis Gaitsgory**, **Ivan Mirkovic** and **Simon Riche**. *An Iwahori–Whittaker model for the Satake category.*

The geometric Satake equivalence gives a topological incarnation of the representation theory of a connected, reductive algebraic group over any field. This description uses so-called "spherical" perverse sheaves on the affine Grassmannian. In my talk, I'll discuss an "Iwahori–Whittaker" model for this category. This model takes advantage of a cellular stratification of the affine Grassmanian, and as a result, allows for some nice applications of the equivalence. This work is joint with Roman Bezrukavnikov, Dennis Gaitsgory, Ivan Mirkovíc, and Simon Riche. (Received August 16, 2018)

1143-22-283 **Loren Spice*** (l.spice@tcu.edu). *Asymptotic expansions for characters of reductive, p-adic groups.*

We combine the ideas of a Harish-Chandra–Howe local character expansion, which can be centred at an arbitrary semisimple element, and a Kim–Murnaghan asymptotic expansion, which so far has been considered only around the identity. We show that, for most smooth, irreducible representations (those containing a good, minimal K-type), Kim–Murnaghan-type asymptotic expansions are valid on explicitly defined neighbourhoods of nearly arbitrary semisimple elements. We then give an explicit, inductive recipe for computing the coefficients in an asymptotic expansion for a tame supercuspidal representation. The only additional information needed in the inductive step is a fourth root of unity, which we expect to be useful in proving stability and endoscopic-transfer identities. (Received August 16, 2018)

1143-22-502 **Jeffrey Adams*** (jda@math.umd.edu). *Calculating the Hodge filtration.* Preliminary report.

Suppose π is an irreducible representation of a real reductive group. The Hodge filtration is a canonical, K-invariant filtration of π, defined geometrically. On the other hand π admits a canonical Hermitian form, known as the c-invariant form, which plays a crucial role in computing the unitary dual.

According to a conjecture of Wilfried Schmid and Kari Vilonen, there is a close relationship between the Hodge filtration and the c-invariant form. In this talk I will describe an algorithm to compute the Hodge filtration, which is a generalization of an algorithm to compute the c-form. (Received August 21, 2018)

1143-22-535 **Dale Bigler*** (dpbigler@mtu.edu) and **Jie Sun** (sjie@mtu.edu). *Universal Central Extensions of Direct Limits of Hom-Lie Superalgebras.*

Hom-Lie superalgebras are generalizations of Lie superalgebras. We define the $\mathfrak{uce}$ functor for the category of Hom-Lie superalgebras. When a Hom-Lie superalgebra L is perfect, we show that $\mathfrak{uce}(L)$ provides a model for the universal central extension of L. We prove that the $\mathfrak{uce}$ functor commutes with the direct limit functor for the category of Hom-Lie superalgebras. As an application, we describe the universal central extensions of the special linear Hom-Lie superalgebras. (Received August 21, 2018)

30 ► Functions of a complex variable

1143-30-97 **Leokadia Bialas-Ciez**, **Marta Kosek** and **Malgorzata Stawiska-Friedland*** (stawiska@umich.edu). *Lebesgue constants for pseudo-Leja sequences of bounded growth in compact planar sets.*

We consider pseudo-Leja sequences of bounded growth associated with a compact set in $\mathbb{C}$ and prove certain separation properties for them. We use these properties to deduce subexponential growth of Lebesgue constants for pseudo-Leja sequences of bounded growth on bounded quasiconformal curves. We also prove another condition equivalent to subexponential growth of their Lebesgue constants. (Received August 02, 2018)

32 ► Several complex variables and analytic spaces

1143-32-9 **Beyaz B Koca*** (kocabasa@msu.edu), 21 Middlevale road 1637 G, East Lansing, MI 48823. *Some classes of invariant subspaces in the polydisc.*

An important open problem in multivariable operator theory and function theory of several complex variables is the problem of classification or an explicit description (in some sense) of all invariant subspaces of the Hardy space $H^2(D^n)$ on the polydisc D^n given by W. Rudin [1, p.78]. This problem seems out of reach. Hence we need good examples help us to understand the structure of invariant subspaces of $H^2(D^n)$. In this talk, we completely classify the singly-generated invariant subspaces and define two types of invariant subspaces of $H^2(D^n)$.

Then, we give a characterization of these types invariant subspaces in view of the Beurling-Lax-Halmos Theorem.

[1] W.Rudin, Function Theory in Polydisks, W.A.Benjamin, Inc., NewYork-Amsterdam, 1969. (Received May 11, 2018)

1143-32-78 **Debraj Chakrabarti*** (chakr2d@cmich.edu) and **Sonmez Sahutoglu** (sonmez.sahutoglu@utoledo.edu). *The restriction operator on Bergman spaces.*

Let Ω be a domain in $\mathbb{C}^n$, and U an open subset of Ω. We study the analytic properties of the restriction operator from the Bergman space $A^2(\Omega)$ to the Bergman space $A^2(U)$. We are particularly interested in properties such as closed range and compactness. It turns out that the restriction operator is closely related to the Toeplitz operator on $A^2(\Omega)$ whose symbol is the the characteristic function of U, and this allows us to use methods from the theory of Toeplitz operator to answer some of the natural questions about the restriction operator. (Received July 30, 2018)

1143-32-81 **Bernhard Lamel** and **Nordine Mir*** (nordine.mir@qatar.tamu.edu), Texas A&M University at Qatar, Science program, Doha, 23874, Qatar. *On the $\mathcal{C}^\infty$ regularity of CR mappings of positive codimension.*

We discuss the $\mathcal{C}^\infty$ regularity problem for CR maps $h\colon M \to M'$ between $\mathcal{C}^\infty$-smooth CR submanifolds M, M' embedded in complex spaces of possibly different dimensions. For real hypersurfaces $M \subset \mathbb{C}^{n+1}$ and $M' \subset \mathbb{C}^{n'+1}$ with $n' > n \geq 1$ and M strongly pseudoconvex, we prove that every CR transversal map of class $\mathcal{C}^{n'-n+1}$ that is nowhere $\mathcal{C}^\infty$ on some non-empty open subset of M must send this open subset to the set of D'Angelo infinite points of M'. As a consequence we establish the following boundary regularity result for proper holomorphic maps in positive codimension: given $\Omega \subset \mathbb{C}^{n+1}$ and $\Omega' \subset \mathbb{C}^{n'+1}$ pseudoconvex domains with smooth boundaries $\partial\Omega$ and $\partial\Omega'$ both of D'Angelo finite type, $n' > n \geq 1$, any proper holomorphic map $h\colon \Omega \to \Omega'$ that extends $\mathcal{C}^{n'-n+1}$-smoothly up to $\partial\Omega$ must be $\mathcal{C}^\infty$-smooth on a dense open subset of $\partial\Omega$. We shall also discuss more general regularity results for CR submanifolds of higher codimensions, in which the target manifolds are allowed to be even of D'Angelo infinite type. (Received July 31, 2018)

1143-32-91 **John P. D'Angelo*** (jpda@illinois.edu). *Invariant holomorphic mappings.*

This talk will focus on certain aspects of groups associated with proper rational holomorphic mappings between balls. Years ago Lichtblau showed that if G is a finite subgroup of the unitary group, and f is a proper rational map invariant under G, then G is cyclic. The author and Lichtblau then found the complete list of possible representations of cyclic groups that can arise. Recent work by the speaker and Ming Xiao has provided a new perspective on this topic. This recent work associates a source group Γ_f and a target group T_f to any holomorphic mapping. In many settings there is a group homomorphism $\Phi : \Gamma_f \to T_f$ whose kernel is the invariant group G_f. We compute these objects in several interesting situations. We also show that, if G is an arbitrary subgroup of the unitary group, then there a rational proper map f with $G = \Gamma_f$. We pose a difficult but basic question about the complexity of this map f. (Received August 01, 2018)

1143-32-94 **Shif Berhanu*** (berhanu@temple.edu), PA. *Boundary unique continuation for elliptic operators.*

We will present recent results on unique continuation at the boundary for solutions of a class of second order elliptic partial differential operators with real analytic coefficients. The results generalize previous works on harmonic functions by M. S. Baouendi and L. P. Rothschild. (Received August 02, 2018)

1143-32-95 **Timothy G. Clos*** (timothy.clos@utoledo.edu), **Mehmet Celik** and **Sonmez Sahutoglu**. *Compactness of Hankel operators on the Bergman spaces of some pseudoconvex domains in $\mathbb{C}^n$.*

Motivated by some previous results about compactness of Hankel operators on Bergman spaces, we partially characterize the compactness of such operators with symbols continuous up to the closure of bounded convex and bounded Lipschitz domains in $\mathbb{C}^n$ for $n \geq 2$. These results use the geometric structure of analytic varieties in the boundary of such domains. In this manner we obtain a complex geometric condition on the symbol from an operator theoretic condition on the associated Hankel operator. (Received August 02, 2018)

1143-32-129 **Sonmez Sahutoglu*** (sonmez.sahutoglu@utoledo.edu), Toledo, OH 43606, and **Akaki Tikaradze** (akaki.tikaradze@utoledo.edu), Toledo, OH 43606. *On a theorem of Bishop and commutants of Toeplitz operators.*

We prove an approximation theorem on a class of domains in $\mathbb{C}^n$ on which the $\overline{\partial}$-problem is solvable in L^∞. Furthermore, as a corollary, we obtain a version of the Axler-Cuckovic-Rao Theorem in higher dimensions. This is joint work with Akaki Tikaradze. (Received August 06, 2018)

1143-32-145 **Loredana Lanzani*** (llanzani@syr.edu), Department of Mathematics, Syracuse University, Syracuse, NY 13244, and **Elias M Stein**, Mathematics Department, Princeton University, Princeton, NJ 08544. *On regularity and irregularity of the Cauchy-Szego projection in several complex variables.* Preliminary report.

It is known that for domains $D \Subset \mathbb{C}^n$ that are of class C^2 and are strongly pseudo-convex, the Cauchy-Szegő projection is bounded in $L^p(\mathrm{b}D, d\Sigma)$ for $1 < p < \infty$. (Here $d\Sigma$ is induced Lebesgue measure.) We show, using appropriate worm domains, that this fails for any $p \neq 2$, when we assume that the domain in question is only weakly pseudo-convex. Our starting point are the ideas of Kiselman-Barrett introduced more than 30 years ago in the analysis of the Bergman projection. However the study of the Cauchy-Szegő projection raises a numer of new issues and obstacles that need to be overcome. Time permitting, we will also compare these results to the analogous problem for the Cauchy-Leray integral, where however the relevant counter-example is of much simpler nature. This is joint work with E. M. Stein (Princeton U.) (Received August 07, 2018)

1143-32-182 **Kenneth D Koenig*** (koenig@math.ohio-state.edu), Department of Mathematics, Ohio State University, 231 W. 18th Avenue, Columbus, OH 43210. *Percolation of estimates for $\overline{\partial}$.*

We will discuss the problem of determining when various regularity properties for the $\overline{\partial}$-Neumann problem and associated operators percolate up the $\overline{\partial}$-complex. Our method revolves around operator identities, rather than estimates, that relate certain natural operators at consecutive form levels on domains in $\mathbb{C}^n$ (not necessarily bounded or smooth or pseudoconvex). One important advantage to our approach is that it does not require an estimate for "barred" derivatives. This talk is based on joint work with Jeff McNeal. (Received August 10, 2018)

1143-32-235 **Debraj Chakrabarti** and **Phillip Harrington*** (psharrin@uark.edu), 309 SCEN, University of Arkansas, Fayetteville, AR 72704. *Closed Range for the Cauchy-Riemann Operator on Annuli.*

One of the simplest classes of non-pseudoconvex domains is the annuli between two pseudoconvex domains. When the boundaries of these pseudoconvex domains are smooth, closed range for the Cauchy-Riemann operator is well understood due to work of Shaw (1985) and Hormander (2004). In this talk, we will look at recent work on the annuli between non-smooth pseudoconvex domains. In particular, we will highlight a geometric obstruction which seems to play a key role. (Received August 15, 2018)

1143-32-251 **Mei-Chi Shaw*** (shaw.1@nd.edu), Department of Mathematics, University of Notr, Notre Dame, IN 46556, and **Christine Laurent-Thiebaut**. *Solving $\bar{\partial}$ with prescribed support on Hartogs triangles.*

In this talk we study the Cauchy-Riemann operator with prescribed support in complex manifolds. In particular, we show that the strong L^2 Dolbeault cohomology group on the Hartogs triangle in the complex projective space of dimension two is infinitely dimensional. (joint work with Christine Laurent-Thiébaut). (Received August 15, 2018)

1143-32-269 **Dusty Grundmeier*** (deg@math.harvard.edu), 1 Oxford St, Cambridge, MA 02138, and **Jennifer Brooks**. *Algebraic Approaches to Hermitian Sums of Squares.*

We study the class of bihomogeneous polynomials $r(z, \bar{z})$ for which there is a positive integer d such that $r(z, \bar{z})\|z\|^{2d}$ can be written as a Hermitian sum of squares. We reinterpret this problem in terms of commutative algebra, and we give necessary algebraic conditions on this class of polynomials. (Received August 16, 2018)

1143-32-282 **Liwei Chen*** (chen.1690@osu.edu). *How about H^2 minimal solutions of $\bar{\partial}$?*

In literature, the canonical solution of the $\bar{\partial}$ equation stands for the L^2 minimal solution. It is not usually easy to find the explicit formula for this solution. However, if we use integral transforms, we are able to construct new solutions. When we are working on the polydisks, it turns out that the solutions obtained by the integral formula have minimal H^2 norms. Moreover, these solutions behave well in several function spaces. (Received August 16, 2018)

1143-32-314 **Emil J Straube***, Department of Mathematics, Texas A&M University, College Station, TX 77843-3368. *On* a priori *estimates for the Bergman projection.* Preliminary report.

Whether or not the Bergman projection on a bounded domain in $\mathbb{C}^n$ always satisfies *a priori* estimates has been open for quite some time. In this talk, I will discuss some ideas related to this issue. (Received August 17, 2018)

1143-32-320 **James J Heffers*** (heffers@umich.edu). *Lelong Numbers of Currents on* $\mathbb{P}^2$.

Let T be a positive closed current of bidegree $(1,1)$ with unit mass on the complex projective space $\mathbb{P}^2$. For $\alpha > 2/5$ and $\beta = (2-2\alpha)/3$ it has been shown that if T has four points with Lelong number at least α, the upper level set $E^+_\beta(T)$ of points of T with Lelong number strictly larger than β is contained within a conic with the exception of at most one point. In this talk we will recap the necessary basics before investigating this result, and then discuss some of the difficulties that arise in trying to generalize the result to $\mathbb{P}^n$, for $n > 2$. (Received August 17, 2018)

1143-32-394 **Siqi Fu*** (sfu@camden.rutgers.edu), Department of Mathematical Sciences, Rutgers University, Camden, NJ 08102, and **Weixia Zhu**. *Spectral stability of the* $\bar\partial$*-Neumann Laplacian.* Preliminary report.

We study spectral stability of the $\bar\partial$-Neumann Laplacian when either the operator or the underlying domain is perturbed. In particular, we establish spectral stability of the $\bar\partial$-Neumann Laplacian under the Kohn-Nirenberg elliptic regularization and under perturbation for smoothly bounded pseudoconvex domains. (Received August 19, 2018)

1143-32-407 **David E Barrett** and **Michael D Bolt*** (mdb7@calvin.edu). *Invariant arc length for plane curves.*

This project is motivated by a desire to identify special surfaces and parameters on surfaces in higher dimensions. We consider the problem of defining arc length for a plane curve that is invariant under group action. Initially one partitions the curve and sums a distance function applied to adjacent support elements. Arc length then is defined as a limit of approximating sums. Alternatively, arc length is defined by the integral that arises when applying the method to smooth curves. That the definitions agree in the general case for the euclidean group was an early victory of the Lebesgue integral; the equivalence also is known for the affine group. Here we present a unified treatment that applies to affine, Laguerre, pseudo-arc, and inversive geometries. These are alike in that arc length corresponds with a geometric average of finite Borel measures. (Received August 20, 2018)

1143-32-415 **Adam Coffman*** (coffmana@pfw.edu), Department of Mathematical Sciences, Purdue University Fort Wayne, 2101 E. Coliseum Blvd., Fort Wayne, IN 46805. *Normal forms for non-isolated CR singularities in high codimension.* Preliminary report.

For $m < n$, a real m-submanifold of $\mathbb{C}^n$ may have some points where the tangent plane contains a complex line. The simplest kinds of such CR singularities are isolated points satisfying some non-degeneracy conditions, and have a well-understood normal form. We will present some new normal forms for degenerate or non-isolated cases. (Received August 20, 2018)

1143-32-423 **Jeffery McNeal*** (mcneal@math.ohio-state.edu), **Debraj Chakrabarti** and **Luke Edholm**. *Duality and approximation in Bergman spaces.*

We will discuss the breakdown of expected duality and approximation theorems on domains with non-smooth boundary. Sharp positive results are given to complement these negative results on some classes of domains. On generalized Hartogs triangles, "sub-Bergman projections" are shown to fill in some of the defects recently discovered in the full Bergman projection. (Received August 20, 2018)

1143-32-477 **Mohit Bansil*** (bansilmo@msu.edu), 28959 Augusta, Farmington Hills, MI 48331. *Spectral Theory of Perturbed Kohn Laplacians on Spheres.*

A CR-manifold is a submanifold in $\mathbb{C}^M$ with extra structure stipulating that the dimension of the complex part of its tangent space is pointwise invariant under some complex structure map. The Kohn Laplacian $\Box_b$ is a second order differential operator intrinsically defined on any CR-manifold whose spectrum reveals important geometric information.

In the case of the Rossi sphere $(\mathbb{S}^3, \mathcal{L}^t)$ showing that 0 is in the essential spectrum of $\Box_b$ is enough to conclude that $(\mathbb{S}^3, \mathcal{L}^t)$ is not embeddable into $\mathbb{C}^M$ for any $M > 0$. Furthermore, Folland explicitly computes the spectrum of $\Box_b$ on any sphere $\mathbb{S}^{2N-1} \subset \mathbb{C}^N$ with the CR structure induced from $\mathbb{C}^N$.

In this project we expand on the previous work and study asymptotics of the spectrum on the Rossi sphere, and we provide sharp upper and lower bounds on the maximum eigenvalues on the invariant subspaces. As for

the spheres in higher dimensions, we use *Mathematica* to compute eigenvalues of perturbed Kohn Laplacians and implement Folland's results. (Received August 20, 2018)

1143-32-478 **Luke D Edholm*** (edholm@umich.edu) and **David E Barrett** (barrett@umich.edu). *The Leray Transform: Factorization, Dual CR-structures and Model Hypersurfaces in* $\mathbb{CP}^2$.

The Leray transform is the most natural higher dimensional analogue of the familiar Cauchy transform in one complex variable. But unlike its one dimensional cousin, the most usual presentation of Leray makes explicit reference to the underlying domain. We will present an alternative, universal description in terms of projective dual coordinates. This leads to the definition of projective dual CR-structures and a corresponding pair of canonical Hardy spaces associated to any strongly $\mathbb{C}$-convex hypersurface. The Leray transform is shown to factor through orthogonal projection onto the conjugate dual Hardy space. These results will be demonstrated with explicit computations on a family of model hypersurfaces. (Received August 20, 2018)

1143-32-481 **Alexander J. Izzo*** (aizzo@bgsu.edu). *Polynomial hulls and analytic structure.*

It was once hoped that whenever a compact set in $\mathbb{C}^n$ has a nontrivial polynomial hull, the hull must contain an analytic disc. This hope was shattered by a counterexample given by Stolzenberg in 1963. Over the 55 years since then, several additional constructions of hulls without analytic discs have been found. Nevertheless, the issue of analytic structure in polynomial hulls is still not well understood. I will present new results regarding (the absence of) analytic structure in polynomial hulls. (Received August 20, 2018)

1143-32-524 **Xin Dong*** (xin.dong@uci.edu), 510P Rowland Hall, University of California, Irvine, CA 92697. *Equality in Suita's conjecture.* Preliminary report.

For any open Riemann surface X admitting Green functions, Suita asked about the precise relations between the Bergman kernel and the logarithmic capacity. It was conjectured that the Gaussian curvature of the Suita metric is bounded from above by -4, and moreover the curvature is equal to -4 at some point if and only if X is conformally equivalent to the unit disc less a (possible) closed polar subset. After the contributions made by Błocki, Guan & Zhou and Berndtsson & Lempert, we provide a new proof of the equality part in Suita's conjecture by using the plurisubharmonic variation properties of Bergman kernels. This talk is mostly based on the preprint arXiv:1807.05537. (Received August 21, 2018)

34 ► Ordinary differential equations

1143-34-64 **Andrew D Lewis*** (andrew.lewis@queensu.ca), Department of Mathematics and Statistics, Queen's University, Kingston, ON K7L 3N6, Canada. *Characterisation of flows using locally convex topologies.*

We consider the problem of characterising the flows of vector fields depending on time and parameter, and depending on the state with various degrees of regularity, e.g., Lipschitz, finitely differentiable, smooth, real analytic, and holomorphic. Dependence on time is measurable, and parameters reside in a general topological space and with dependence on the parameters being continuous.

We give conditions on such vector fields that ensure that the flows depend continuously on parameter and depend on initial condition with the same degree of regularity as the vector field.

The conditions we give are in terms of locally convex topologies for the spaces of vector fields with the prescribed regularity. The topologies are classical in all cases except the real analytic case. In the real analytic case, we give defining seminorms for the topology. The conditions on the vector fields are interesting in that (1) they are given succinctly in terms of the topologies, (2) they agree with known conditions when these exist, and (3) they apply in cases not currently treated in the literature, mainly the real analytic case. (Received July 25, 2018)

1143-34-122 **Anton Dzhamay***, School of Mathematical Sciences, University of Northern Colorado, 501 20th Street, Greeley, CO 80639, and **Alisa Knizel**. *Gap Probabilities in Tiling Models and Discrete Painlevé Equations.*

It is well-known that important statistical quantities, such as gap probabilities, in various discrete probabilistic models of random matrix type satisfy discrete Painlevé equations, which provides an effective way to compute them. In this talk we discuss this correspondence for a particular class of models, known as boxed plane partitions (equivalently, lozenge tilings of a hexagon). For uniform probability distribution, this is one of the most studied models of random surfaces. Borodin, Gorin, and Rains showed that it is possible to assign a very general elliptic weight to the distribution, with various degenerations of this weight corresponding to the degeneration

cascade of discrete polynomial ensembles, such as Racah and Hahn ensembles and their q-analogues. This also correspond to the degeneration scheme of discrete Painlevé equations, due to the work of Sakai. In this talk we consider the q-Hahn and q-Racah ensembles and corresponding discrete Painlevé equations of types $q-P(A_2^{(1)})$ and $q-P(A_1^{(1)})$. We show how to use the algebro-geometric techniques of Sakai's theory to pass from the isomonodromic coordinates of the model to the discrete Painlevé coordinates that is compatible with the degeneration. (Received August 05, 2018)

1143-34-309 **Alexander Its** and **Andrei Prokhorov*** (aprokhor@iupui.edu), 402 North Blackford Street, LD 270, Indianapolis, IN 46202. *On some Hamiltonian properties of isomonodromic tau functions.*

Painlevé equations are nonlinear ODEs, which appear in random matrix theory, conformal field theory and other places in mathematics and physics. They admit isomonodromic deformations representation and therefore are integrable. Painlevé equations are also equivalent to some Hamiltonian systems.

In 1981 Jimbo Miwa and Ueno introduced the tau function for general isomonodromic deformations. In the case of Painlevé equations the corresponding tau function satisfy σ-form of Painlevé equations. We establish the relation between the Painlevé tau functions and corresponding classical actions. This relation provides differential identities required for asymptotic analysis of tau functions. It turns out that similar identities hold for general isomonodromic tau functions.

Hamiltonian structure for Painlevé equations was established by Okamoto in 1980. We extend it to isomonodromic deformations corresponding to Painlevé equations and we conjecture the Hamiltonian structure for general isomonodromic deformations. (Received August 19, 2018)

1143-34-416 **Todd R. Young*** (youngt@ohio.edu), **Jan Rombouts** and **Kaittisak Prathom**. *Temporal Clusters Prefer to be Equally Distributed - an example from the Yeast Cell Cycle.*

Temporal Clustering or Phase Synchrony, is where cohorts of components synchronize among themselves, but are out of phase with other cohorts. In bioreactor experiments on yeast metabolic oscillations we discovered a case where a culture of yeast exhibits temporal clustering into two groups of cells in anti-phase. The discovery raises a number of mathematical questions such as: 'What determines the number of clusters that appear?', and 'How do individual cells distribute among clusters?'.

We focus on the last question using a biologically motivated non-linear model. We observe that the clusters tend very strongly toward having nearly equal numbers of cells. We study the case of two unequal clusters and conclude that solutions with two unequal clusters are locally asymptotically stable in the clustered subspace, but, local asymptotic stability of unbalanced clusters in the full phase space depends delicately on the model. Global dynamics reveal that if clusters become unbalanced, the influence of the larger cluster can shift the basins of attraction of individual clusters, making it more likely for a cell to join a smaller cluster. This points to a general principle: systems that form temporal clusters via non-local coupling tend to form nearly equal clusters. (Received August 20, 2018)

1143-34-470 **Taylor Klotz***, Taylor.Klotz@colorado.edu, and **Peter Vassiliou** and **Jeanne Clelland**. *Cascade Static Feedback Linearization for the P.V.T.O.L. System.* Preliminary report.

Cascade static feedback linearization (Cascade SFL) is a way to express solutions to some nonlinear control systems with symmetry as a "composition" of solutions to SFL systems. Since the solutions to SFL systems can be written down in terms of arbitrary functions and their derivatives then so too can solutions to the original nonlinear system. One SFL system comes from a quotient of the system by a control symmetry group. The other(s) come from a combination of an equation of Lie type and the prior SFL system together restricted to a certain submanifold of a principal G-bundle. In this talk we'll explore various cascade SFLs of the well known planar vertical take off and landing vehicle (PVTOL) control system and see how cascade linearization also sheds light on the phenomenon of dynamic feedback linearization. This is joint work with Jeanne Clelland and Peter Vassiliou. (Received August 20, 2018)

35 ► Partial differential equations

1143-35-14 **Isaac Harris*** (iharris1107@gmail.com), **Bondarenko** and **Kleefeld**. *Transmission Eigenvalues for Materials with a Conductive Boundary Condition.*

In this talk we will investigate the inverse scattering problem associated with an inhomogeneous media with a conductive boundary. We consider the corresponding interior transmission eigenvalue problem. This is a new class of eigenvalue problem that is not elliptic, not self-adjoint, and non-linear, which gives the possibility of

complex eigenvalues. We investigate the convergence of the eigenvalues as the conductivity parameter tends to zero as well as prove existence and discreteness for the case of an absorbing media. (Received May 25, 2018)

1143-35-19 **Samuel Cogar*** (cogar@udel.edu), **David Colton** and **Peter Monk**. *Using eigenvalues to detect anomalies in the exterior of a cavity.*

We use modified near field operators and a nonsymmetric version of the generalized linear sampling method to investigate an inverse scattering problem for anisotropic media with data measured inside a cavity. The aim is to determine information on possible changes in the material properties of the medium surrounding the cavity, and to this end we introduce a new class of eigenvalue problems for which the eigenvalues can be determined from the measured scattering data. We augment our analysis with numerical testing of both the computation of eigenvalues from near field data and the behavior of the eigenvalues following changes in the material properties of the medium. (Received June 07, 2018)

1143-35-23 **Zecheng Gan*** (zecheng@umich.edu), 530 Church street, ann arbor, MI 48109, and **Weihua Geng** and **Robert Krasny**. *Fast algorithms for the electrostatic interaction in charged systems with dielectric boundaries.*

We present fast algorithms for investigating the electrostatic interaction for charged physical/biological systems in the presence of dielectric boundaries. Specifically, we present efficient, tailored, numerical or semi-analytical methods for solving the 3D Poisson equation with complicated interfaces geometries, or special geometries such as spheres, planes and spheroids which can be closely compacted. Involved techniques include boundary element method with extrapolation and singularity subtraction; spherical harmonic expansion; image charge method, etc. We further implement these methods to explore the role of dielectric effect in varies problems such as like-charge attraction, self-assembly, and protein-protein interaction. We will show that the dielectric effect can play an important role in such charged physical/biological systems. (Received June 15, 2018)

1143-35-27 **Kulyash Kaliyeva*** (abil_nse@mail.ru), Almaty, Kazakhstan. *Turbulent Motion in the Free Atmosphere.* Preliminary report.

This research presents convergent-divergent flow in the free atmosphere which is governed by the three dimensional Navier-Stokes equations and deals with the fundamental problem of fluid dynamics. Considering air movement under influence divergence and rotation were found the true dependencies between the velocity vector and the pressure distribution. There were obtained the second kind nonlinear Volterra-Fredholm integral equations in a matrix form which contained only three components of the velocity vector. According to the theory of the matrix operators were defined the velocity components by the successive approximation method. According to the obtained balance equation for the pressure distribution were defined significant properties of the transient convergent-divergent flow which provide a description of the constitutive relationships between three physical quantities: the velocity vector, the external and internal forces, the pressure distribution (Received June 25, 2018)

1143-35-51 **Juan Liu** and **Jiguang Sun***, jiguangs@mtu.edu. *Extended Sampling Method in Inverse Scattering.*

A new sampling method for inverse scattering problems is proposed to process far field data of one incident wave. The method sets up ill-posed integral equations and uses the (approximate) solutions to reconstruct the target. In contrast to the classical linear sampling method, the kernels of the associated integral operators are the far field patterns of sound-soft balls. The measured data is moved to right hand sides of the equations, which gives the method the ability to process limited aperture data. Furthermore, a multilevel technique is employed to improve the reconstruction. Numerical examples show that the method can effectively determine the location and approximate the support with little a priori information of the unknown target. (Received July 20, 2018)

1143-35-69 **Niles Armstrong*** (niles@ksu.edu). *Mean value sets for general divergence form uniformly elliptic operators.*

The mean value theorem for the Laplacian has been an immensely important result in the study of harmonic functions. In his Fermi Lectures, Caffarelli gave a very nice proof of the mean value theorem, which he then notes can be extended to general divergence form uniformly elliptic operators. The details of this claim were eventually proved by Blank-Hao in 2015. This generalized mean value theorem states that the value of an L-harmonic function, u, at a point x_0 is equal to the average value of the function over a set $D_r(x_0)$, which comes from solving a specific obstacle problem. We will explore the current landscape of what is known about the sets $D_r(x_0)$ and look at a particularly surprising example which shows that the property of convexity is unstable under smooth perturbations of the operator. (Received July 26, 2018)

1143-35-70 **Nam Q. Le*** (nqle@indiana.edu), Department of Mathematics, Indiana University, Bloomington, IN 47405. *Hölder regularity of the 2D dual semigeostrophic equations.*

The system of 2D dual semigeostrophic equations is a fully nonlinear version of the 2D incompressible Euler equations in vorticity-stream formulation where the Monge-Ampère operator replaces the Laplace operator. It arises in a meteorology model used to describe large scale atmospheric flows. In this talk, we discuss the Hölder regularity of time derivative of solutions to the 2D dual semigeostrophic equations when the initial potential density is bounded away from zero and infinity. Our main tool is an interior Hölder estimate in 2D for an inhomogeneous linearized Monge-Ampère equation when the source term is the divergence of a bounded vector field but not of high integrability. (Received July 27, 2018)

1143-35-89 **Tuoc Phan*** (phan@math.utk.edu), University of Tennessee, Knoxville, TN 37996. *Regularity estimates for* BMO*-weak solutions of quasilinear elliptic equations with inhomogeneous boundary conditions.*

We discuss some recent results on regularity estimates in Lebesgue spaces for gradients of weak solutions of a class of general quasilinear equations of p-Laplacian type in bounded domains with inhomogeneous conormal boundary conditions. In the considered class of equations, the principals are vector field functions measurable x-variable, and nonlinearly depending on both solution and its gradient. This class of equations consists of the well-known class of degenerate p-Laplace equations for $p > 1$. Under some sufficient conditions, we establish local interior, local boundary, and global $W^{1,q}$-regularity estimates for weak solutions with $q > p$, assuming that the weak solutions are in the John-Nirenberg BMO space. The results therefore improve available results because they remove the boundedness and the continuity assumptions on solutions. The results also unify and cover known results for equations in which the principals are only allowed to depend on x-variable and gradient of solution variable. More than that, we also provide a method to treat non-homogeneous boundary value problems directly without using any form of translations that is sometimes complicated due to the nonlinearities. (Received August 01, 2018)

1143-35-100 **Siddhant Agrawal*** (sidagr@umich.edu). *Angled crested type water waves.*

We consider the two-dimensional gravity water wave equation with or without surface tension. We assume that the fluid is inviscid, incompressible and irrotational and the air density is zero. In the case of zero surface tension, we show that the singular solutions (which includes angled crested solutions) recently constructed by Wu are rigid. In the case of non-zero surface tension, we construct an energy functional and prove an a priori estimate without assuming the Taylor sign condition. This energy reduces to the energy obtained by Kinsey and Wu in the zero surface tension case for angled crest water waves. We show that in an appropriate regime, the zero surface tension limit of our solutions is the one for the gravity water wave equation which includes waves with angled crests. (Received August 03, 2018)

1143-35-108 **Mimi Dai*** (mdai@uic.edu) and **Han Liu**. *Low modes regularity criterion for a full chemotaxis-Navier-Stokes system.*

We consider a full chemotaxis-Navier-Stokes system in three dimensions, which describes bacteria swimming in environmental flows. This complex fluid system involves intricate interactions of microstructure and macroscopic physics. A new regularity criterion is obtained via the developed wavenumber splitting approach from our previous work. The criterion is in terms of only low modes of the oxygen concentration and the fluid velocity, and does not make any reference to the third function, the bacteria density. The result improves many existing criteria in the literature. (Received August 03, 2018)

1143-35-110 **Weiwei Hu*** (weiwei.hu@okstate.edu), 416 Math Science Building, Dept. of Math., Oklahoma State University, Stillwater, OK 74078. *Boundary Control of Optimal Mixing via Fluid Flows.*

We discuss the problem of optimal mixing of an inhomogeneous distribution of a scalar field via an active control of the flow velocity, governed by Stokes or Navier-Stokes equations, in a two dimensional open bounded and connected domain. We consider the velocity field steered by a control input that acts tangentially on the boundary of the domain through the Navier slip boundary conditions. This is motivated by the problem of mixing within a cavity or vessel by moving the walls or stirring at the boundaries. Our main objective is to design an optimal Navier slip boundary control that optimizes mixing at a given final time. Non-dissipative scalars, both passive and active, governed by the transport equation will be discussed. In the absence of diffusion, transport and mixing occur due to pure advection. This essentially leads to a nonlinear control problem of a semi-dissipative system. A rigorous proof of the existence of an optimal controller and the first-order necessary conditions for optimality will be presented. (Received August 03, 2018)

1143-35-118 **Farhan Abedin***, Michigan State University, Department of Mathematics, 619 Red Cedar Road, C212 Wells Hall, East Lansing, MI 48824, and **Giulio Tralli**, Dipartimento di Matematica, Sapienza Universita di Roma, P.le Aldo Moro, 5, 00185 Rome, Italy. *Harnack Inequality for a class of Kolmogorov-Fokker-Planck equations in non-divergence form.*

I will discuss recent work on establishing Harnack's inequality for a class of second-order parabolic equations in non-divergence form. The operators under consideration can be highly degenerate, but exhibit invariance properties with respect to a homogeneous Lie group structure. An interesting open problem is to prove theorems of Krylov-Safonov type (i.e. Harnack's inequality and Holder regularity) for non-negative solutions to these equations. We manage to obtain such results under the assumption that the leading order coefficients of the operators satisfy either a Cordes-Landis condition on the eigenvalues, or admit a uniform modulus of continuity. (Received August 04, 2018)

1143-35-121 **Tao Huang***, Wayne State University, and **Na Zhao**, Fudan University. *Regularity of weak solutions of a gradient flow of the Landau-de Gennes energy.*

For a gradient flow of the Landau-de Gennes energy, the unique global weak solution of initial and boundary value problem in dimension two has been constructed by Iyer-Xu-Zarnescu 2015 with small initial data. We investigate the regularity of such solution, and prove that the weak small solution constructed in Iyer-Xu-Zarnescu's paper is actually regular. (Received August 05, 2018)

1143-35-127 **Anna Ghazaryan*** (ghazarar@miamioh.edu), 301 Patterson Ave, Bachelor Hall, Rm 123, Oxford, OH 45056, and **Yuri Latushkin** and **Xinyao Yang**. *On the stability of planar fronts.*

We consider planar fronts in a class of reaction-diffusion systems with the following property: the linearization of the system about the front has no unstable discrete eigenvalues, but its essential spectrum touches the imaginary axis. For perturbations that belong to the intersection of the exponentially weighted space with the original space without a weight, we use a bootstrapping argument to show that initially small perturbations to the front remain bounded in the original norm and decay algebraically in time in the exponentially weighted norm. (Received August 06, 2018)

1143-35-139 **John K. Hunter** and **Jingyang Shu*** (jyshu@ucdavis.edu), Department of Mathematics, University of California at Davis, One Shields Ave., Davis, CA 95616, and **Qingtian Zhang**. *Fronts for the SQG Equation.*

Temperature discontinuities in the Surface Quasi-Geostrophic (SQG) equations support surface waves. For weakly nonlinear surface waves on SQG fronts that are described as a graph, we derive a nonlocal and nonlinear equation with logarithmic dispersion. With the help of Weyl quantization, dispersive decay, and modified scattering, we prove global-in-time well-posedness of the initial value problem for the SQG front equation with sufficiently small and smooth initial data. (Received August 06, 2018)

1143-35-143 **Erhan Bayraktar** (erhan@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, and **Christian Keller*** (christian.keller@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Path-dependent Hamilton-Jacobi equations in infinite dimensions.*

We propose notions of minimax and viscosity solutions for a class of fully nonlinear path-dependent PDEs with nonlinear, monotone, and coercive operators on Hilbert space. Our main result is well-posedness (existence, uniqueness, and stability) for minimax solutions. A particular novelty is a suitable combination of minimax and viscosity solution techniques in the proof of the comparison principle. One of the main difficulties, the lack of compactness in infinite-dimensional Hilbert spaces, is circumvented by working with suitable compact subsets of our path space. As an application, our theory makes it possible to employ the dynamic programming approach to study optimal control problems for a fairly general class of (delay) evolution equations in the variational framework. Furthermore, differential games associated to such evolution equations can be investigated following the Krasovskii-Subbotin approach similarly as in finite dimensions. (Received August 07, 2018)

1143-35-151 **Jinping Zhuge*** (jinping.zhuge@uky.edu) and **Zhongwei Shen**. *Regularity of Homogenized Boundary Data in Periodic Homogenization of Elliptic Systems.*

This paper is concerned with periodic homogenization of second-order elliptic systems in divergence form with oscillating Dirichlet data or Neumann data of first order. For example, the Dirichlet problem with oscillating data reads as follows

$$-\mathrm{div}(A(x/\varepsilon)\nabla u_\varepsilon) = 0 \quad \text{in } \Omega, \qquad u_\varepsilon(x) = f(x, x/\varepsilon) \quad \text{on } \partial\Omega,$$

where $A(y)$ and $f(x,y)$ are 1-periodic in y, and $\varepsilon > 0$ is tiny. It has been proved previously that, if Ω is uniformly convex, the above system homogenizes to

$$-\mathrm{div}(\widehat{A}\nabla u_0) = 0 \quad \text{in } \Omega, \qquad u_0(x) = \bar{f}(x) \quad \text{on } \partial\Omega, \tag{1}$$

where $\widehat{A}$ is the homogenized coefficient matrix (constant) and $\bar{f}$ is the homogenized boundary data. In this paper, we prove that the homogenized boundary data $\bar{f}$ belongs to $W^{1,p}(\partial\Omega)$ for any $1 < p < \infty$. In particular, this implies that $\bar{f}$ is Hölder continuous of order α for any $\alpha \in (0,1)$. (Received August 07, 2018)

1143-35-152 **Baofeng Feng*** (baofeng.feng@utrgv.edu), 213 E Baylor Ave, Mcallen, TX 78504.
General breather and rogue wave solutions to the complex short pulse equation.

Based on the KP hierarchy reduction method, we construct multi-breather solutions to the multi-breather and multi-rogue wave solutions to the complex short pulse (CSP). Starting from the tau functions of the Kadomtsev-Petviashvili (KP) hierarchy with singular shift points, we firstly derive a set of bilinear equations. Then by dimension and complex conjugate reductions, the multi-breather solution of the CSP equation is constructed. Furthermore, we construct multi-rogue wave solutions to the CSP equation. (Received August 21, 2018)

1143-35-156 **Gino Biondini**, **Sitai Li*** (sitaili@umich.edu), **Dionyssios Mantzavinos** and **Stefano Trillo**.
Universal behavior of modulationally unstable media with non-zero boundary conditions.

This talk is divided into three parts. First, I will briefly describe the inverse scattering transform for the focusing nonlinear Schrodinger (NLS) equation with nonzero boundary conditions at infinity, and then I will present the long-time asymptotics of pure soliton solutions on the nonzero background. Second, I will describe in detail the properties of the asymptotic state of the modulationally unstable solutions of the NLS equation, including the number of oscillations and the local structure of the solution near each peak, showing in particular that in the long-time limit the solution tends to an ensemble of classical (i.e., sech-shaped) solutions of the NLS equation. Third, I will show that a similar asymptotic state is shared among a broad class of systems of NLS-type possessing modulational instability. (Received August 08, 2018)

1143-35-158 **Nathan Edward Glatt-Holtz*** (negh@tulane.edu), Department of Mathematics, Tulane University, New Orleans, LA 70118.
A Bayesian Approach to Quantifying Uncertainty Divergence Free Flows.

We treat the statistical regularization of the ill-posed inverse problem of estimating a divergence free flow field $\mathbf{u}$ from the partial and noisy observation of a passive scalar θ. Our solution is Bayesian posterior distribution, a probability measure μ which precisely quantifies uncertainties in $\mathbf{u}$ once one specifies models for measurement error and prior knowledge for $\mathbf{u}$. We present some of our recent work which analyzes μ both analytically and numerically. In particular we discuss a posterior contraction (consistency) result as well as some Markov Chain Monte Carlo (MCMC) algorithms which we have developed and refined to effectively sample from μ. This is joint work with Jeff Borggaard and Justin Krometis (Virginia Tech). (Received August 08, 2018)

1143-35-159 **Nathan Edward Glatt-Holtz*** (negh@tulane.edu), Department of Mathematics, Tulane University, New Orleans, LA 70118.
Stochastic Models for Turbulent Convection.

Buoyancy driven convection plays a fundamental role in diverse physical settings: from cloud formation to large scale oceanic and atmospheric circulation processes to the internal dynamics of planets and stars. Typically, such fluid systems are driven by heat fluxes acting both through boundaries (i.e. heating from below) and in the bulk (i.e. internal 'volumetric' heating sources) both of which can have an essentially stochastic nature. In this talk I will discuss some recent mathematical developments concerning ergodicity, singular parameter limits and the onset of instability in the stochastic Boussinesq and Magnetohydrodynamics equations. (Received August 08, 2018)

1143-35-166 **Peter J Olver*** (olver@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55433.
Fractalization and Quantization in Dispersive Systems.

The evolution, through spatially periodic linear dispersion, of rough initial data produces fractal, non-differentiable profiles at irrational times and, for asymptotically polynomial dispersion relations, quantized structures at rational times. Such phenomena have been observed in dispersive wave models, optics, and quantum mechanics, and lead to intriguing connections with exponential sums arising in number theory. Ramifications and recent progress on the analysis, numerics, and extensions to nonlinear wave models, both integrable and non-integrable, will be presented. (Received August 09, 2018)

1143-35-171 **Cheng Zhang*** (czhang67@jhu.edu), 3101 Huntingdon ave, Baltimore, MD 21211. *Improved critical eigenfunction restriction estimates on Riemannian manifolds with constant negative curvature.*

We show that one can obtain logarithmic improvements of L^2 geodesic restriction estimates for eigenfunctions on 3-dimensional compact Riemannian manifolds with constant negative curvature. We obtain a $(\log \lambda)^{-1/2}$ gain for the L^2-restriction bounds, which improves the corresponding bounds of Burq, Gérard and Tzvetkov, Hu, Chen and Sogge. (Received August 09, 2018)

1143-35-172 **Farhan Abedin***, Michigan State University, Department of Mathematics, 619 Red Cedar Road, C212 Wells Hall, East Lansing, MI 48824, and **Cristian Gutierrez**, Temple University, Department of Mathematics, 1022 Wachman Hall, Philadelphia, PA 19122. *An Iterative Method for Generated Jacobian Equations.*

I will describe an iterative algorithm for constructing approximate weak solutions to generated Jacobian equations (GJEs). Introduced by Trudinger, GJEs are general enough to include as special cases problems from optimal mass transport and geometric optics. The iterative method considered here is inspired by earlier work of Caffarelli, Kochengin and Oliker on the reflector problem. We will focus on identifying minimal structural requirements on the GJEs that guarantee convergence of the iteration in a finite number of steps. (Received August 09, 2018)

1143-35-183 **Nestor Guillen** and **Chenchen Mou*** (muchenchen@math.ucla.edu), 520 Portola Plaza, MS6363, Los Angeles, CA 90095, and **Andrzej Swiech**. *Coupling Levy measures and comparison principles for viscosity solutions.*

We prove new comparison principles for viscosity solutions of non-linear integro-differential equations. The operators to which the method applies include but are not limited to those of Levy-Ito type. The main idea is to use an optimal transport map to couple two different Lévy measures, and use the resulting coupling in a doubling of variables argument. This is a joint work with N. Guillen and A. Swiech. (Received August 10, 2018)

1143-35-187 **Xiaoyutao Luo*** (xluo24@uic.edu). *Stationary weak solutions for the Navier-Stokes equations in high dimensions.*

Let $d \geq 4$ be the space dimension and consider the unforced incompressible homogeneous Navier-Stokes equations on the d-torus $\mathbb{T}^d$. It is shown that there exist nontrivial steady-state weak solutions $u \in L^2(\mathbb{T}^d)$. The result implies the nonuniqueness of finite energy weak solutions for the Navier-Stokes equations in dimensions $d \geq 4$. (Received August 11, 2018)

1143-35-195 **Mimi Dai**, 851 S. Morgan St., SEO 322 (M/C 249), Chicago, IL 60607, and **Han Liu***, 851 S Morgan St, SEO 322 (M/C 249), Chicago, IL 60607. *Low modes regularity criterion for a chemotaxis-Navier-Stokes system.*

We study the regularity problem of a three dimensional chemotaxis-Navier-Stokes system on a periodic domain. A new regularity criterion in terms of only low modes of the oxygen concentration and the fluid velocity is obtained via a wavenumber splitting approach. The result improves many existing criteria in the literature. (Received August 13, 2018)

1143-35-198 **Qingtang Su*** (qingtang@umich.edu), 5080 East Hall, 530 Church St, Ann Arbor, MI 48109. *Long time behavior of the 2d water waves with point vortices.*

We consider the motion of inviscid, incompressible and infinite depth water waves with point vortices in the fluid in two space dimensions. We show that the Taylor sign condition $-\frac{\partial P}{\partial n} > 0$ can fail if the point vortices are sufficiently close to the free boundary, so the motion of the water waves can be subject to the Taylor instability. And we show that for certain initial configurations, the point vortices will keep moving away from the interface, so that the free interface will remain smooth for a long time; and for initial data of size $\epsilon \ll 1$, the lifespan of the smooth solution is at least of order ϵ^{-2}. (Received August 13, 2018)

1143-35-217 **Marcelo Disconzi*** (marcelo.disconzi@vanderbilt.edu), 1326 Stevenson Center, Nashville, TN 37240, and **Chenyun Luo** (chenyun.luo@vanderbilt.edu), 1326 Stevenson Center, Nashville, TN 37240. *The incompressible limit of the compressible free-boundary Euler equations with surface tension.*

We consider the compressible free-boundary Euler equations with surface tension. We prove that its solutions converge to solutions of the incompressible free-boundary Euler equations when the sound speed tends to infinity. (Received August 14, 2018)

1143-35-231 **Alessandro Arsie*** (alessandro.arsie@utoledo.edu), 2801 W. Bancroft St. Mail Stop 942, Toledo, OH 43606, and **Paolo Lorenzoni**. *Flat F-manifolds, Miura invariants and integrable systems of conservation laws.*

In this talk, I will present the extension to the case of systems of integrable conservation laws of some of the results proved for scalar equations in Arsie, Moro, Lorenzoni (Integrable viscous conservation laws, Nonlinearity 2015) and in Arsie, Moro, Lorenzoni (On Integrable Conservation Laws, Proceedings of the Royal Society A, 2014).

For such systems, I will show that the eigenvalues of a matrix obtained from the quasilinear part of the system are invariants under Miura transformations, and I will highlight how these invariants are related to dispersion relations. Furthermore, focusing on one-parameter families of dispersionless systems of integrable conservation laws associated to the Coxeter groups of rank 2 found in Arsie, Lorenzoni (Complex reflection groups, logarithmic connections and bi-flat F-manifolds, Letters in Math. Physics 2017), I will discuss the corresponding integrable deformations up to order 2 in the deformation parameter ϵ.

Each family contains both bi-Hamiltonian and non-Hamiltonian systems of conservation laws and therefore we use it to probe to which extent the properties of the dispersionless limit impact the nature and the existence of integrable deformations.

These are results of a joint work with Paolo Lorenzoni. (Received August 14, 2018)

1143-35-246 **Benjamin Seibold***, Department of Mathematics, 1805 N. Broad Street, Philadelphia, PA 19022. *The Curious Life of Jamitons.*

Initially homogeneous vehicular traffic flow can become inhomogeneous even in the absence of obstacles. In this phantom traffic jam phenomenon, small perturbations grow into traffic waves, called jamitons. We demonstrate that both phenomena can be captured via rather innocent-looking systems of hyperbolic balance laws, that turn out to exhibit a rich structure of nonlinear phenomena. We present what is understood about the dynamics of jamitons, as well as highlight several open question. (Received August 15, 2018)

1143-35-253 **Jingwei Hu*** (jingweihu@purdue.edu). *A particle method for the Landau equation.* Preliminary report.

The Landau equation describes the collisional process in plasmas. Due to the high dimensionality of the collision operator, the mesh (Eulerian) based deterministic method is computationally expensive. In this work, we introduce a particle (Lagrangian) method for the Landau operator which avoids the curse of dimensionality. Joint work with J. Carrillo, T. Ding, M. Levy, and L. Wang. (Received August 15, 2018)

1143-35-264 **Fei Wang*** (fwang256@umd.edu), College Park, MD 20740, Peoples Rep of China, and **Igor Kukavica** and **Vlad Vicol**. *The van Dommelen and Shen singularity in the Prandtl equations.*

In 1980, van Dommelen and Shen provided a numerical simulation that predicted the spontaneous generation of a singularity in the Prandtl boundary layer equations from a smooth initial datum, for a nontrivial Euler background. In this paper we prove this numerical conjecture by rigorously establishing the finite time blowup of the boundary layer thickness. (Received August 15, 2018)

1143-35-267 **Antoine Mellet***, Department of Mathematics, College Park, MD 20742. *Neumann boundary conditions for fractional diffusion equations.*

We will discuss the role of Neumann boundary conditions for fractional diffusion equations. While such conditions are well understood for the usual Laplace operator, we will see that there are many ways of extending such a notion to fractional Laplace operators. We will discuss several such extensions, but our focus will be on studying a (new?) formulation which we will rigorously derive as the singular limit of a microscopic model describing particles being reflected by the boundary according to so-called Maxwell's reflections. (Received August 16, 2018)

1143-35-272 **Inwon Kim** and **Olga Turanova*** (turanova@math.ucla.edu). *The incompressible limit of a tumor growth model.*

This talk concerns a PDE system that models tumor growth. We show that the incompressible, or stiff pressure, limit of this system yields a novel free boundary problem. We will also discuss connections to other well-known classes of PDEs, including the porous medium equation and the Hele-Shaw problem. (Received August 16, 2018)

1143-35-273 **Vincent Calvez**, **Christopher Henderson**, **Sepideh Mirrahimi** and **Olga Turanova*** (turanova@math.ucla.edu). *Front propagation in a nonlocal reaction-diffusion equation.*

We consider a reaction-diffusion equation with a nonlocal reaction term that arises as a model in evolutionary ecology. We study asymptotic behavior for solutions of this PDE. (Received August 16, 2018)

1143-35-279 **Blair Davey*** (bdavey@ccny.cuny.edu) and **Jenn-Nan Wang**. *On Landis' conjecture in the plane.*

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. (Received August 16, 2018)

1143-35-292 **Wei Li**, **Yang Yang*** (yangy5@msu.edu) and **Yimin Zhong**. *Fluorescence Ultrasound Modulated Optical Tomography in the Diffusive Regime.*

Fluorescence optical tomography (FOT) is an imaging technology that localizes fluorescent targets in tissues. FOT is unstable and of poor resolution in highly scattering media, where the propagation of multiply-scattered light is governed by the smoothing diffusion equation. We study a hybrid imaging modality called fluorescent ultrasound-modulated optical tomography (fUMOT), which combines FOT with acoustic modulation to produce high-resolution images of optical properties in the diffusive regime. The principle of fUMOT is to perform multiple measurements of photon currents at the boundary as the optical properties undergo a series of perturbations by acoustic radiation, in which way internal information of the optical field is obtained. We set up a mathematical model for fUMOT, prove well-posedness for certain choices of parameters, and present reconstruction algorithms and numerical experiments for the well-posed cases. This is joint work with Wei Li and Yimin Zhong. (Received August 17, 2018)

1143-35-293 **Maarten de Hoop**, **Gunther Uhlmann** and **Yiran Wang*** (yrwang.math@gmail.com). *Nonlinear interaction of waves in elastodynamics and inverse problems.*

We consider nonlinear elastic wave equations generalizing Gol'dberg's five constants model. We analyze the nonlinear interaction of two distorted plane waves and characterize the possible nonlinear responses. Using the boundary measurements of the nonlinear responses, we solve the inverse problem of determining elastic parameters from the displacement-to-traction map. (Received August 17, 2018)

1143-35-297 **Mark Allen*** (allen@mathematics.byu.edu) and **Henrik Shahgholian** (henriksh@kth.se). *Boundary Harnack Principle for supersolutions.*

We present a Boundary Harnack Principle for supersolutions to the Laplace operator on domains with Lipschitz boundaries. We show that the allowed behavior of the right hand side is determined by the Lipschitz constant of the boundary. The method also applies to second order elliptic operators in divergence form. This result may be applied to study the obstacle problem at the fixed boundary when the fixed boundary is Lipschitz. (Received August 17, 2018)

1143-35-302 **Russell Schwab*** (rschwab@math.msu.edu), **Hector Chang Lara** and **Nestor Guillen**. *Some free boundary evolutions that are equivalent to parabolic integro-differential equations.*

We give a description of various work about elliptic operators that satisfy the global comparison property, their representations via integro-differential operators, and how they relate to some free boundary evolutions. The global comparison property is simply the requirement that an operator acts on functions in its domain in a way that preserves the ordering of any two functions that are globally ordered and their graphs touch at a point (when the operator is evaluated at this point of contact of the two functions). This is a nonlocal generalization of the comparison property enjoyed by operators like the Laplacian (or general second order non-divergence elliptic operators). It turns out that these operators can be characterized, even in the nonlinear and nonlocal setting, as an appropriate min-max over linear integro-differential operators. Furthermore, it turns out that many free boundary problems, such as those related to Hele-Shaw flow can be completely characterized by an evolution involving operators that fall into the scope of the nonlinear, nonlocal representation by integro-differential operators. We will outline this correspondence in this brief overview. (Received August 17, 2018)

1143-35-315 **Jiaqi Liu*** (jliu@math.toronto.edu), **Robert Jenkins**, **Peter Perry** and **Catherine Sulem**. *Inverse scattering transform with arbitrary spectral singularities.*

For the AKNS system Xin Zhou in his dissertation developed an inverse scattering mechanism to deal with non-generic initial data that allow arbitrary number of spectral singularities. In this talk, we give a self-contained and constructive characterization of the scattering data and discuss its applications to the global well-posedness problem to the dnls equation. This is joint work with R. Jenkins, P.Perry and C. Sulem. (Received August 17, 2018)

1143-35-318 **Robert Jenkins**, **Jiaqi Liu** and **Peter Perry*** (peter.perry@uky.edu), Department of Mathematics, University of Kentucky, Lexington, KY 40506-0027, and **Catherine Sulem**. *Soliton Resolution for the Derivative Nonlinear Schrödinger Equation (Part I).*

This talk concerns joint work with Robert Jenkins, Jiaqi Liu and Catherine Sulem on the soliton resolution conjecture for the Derivative Nonlinear Schrodinger Equation (DNLS), a completely integrable dispersive nonlinear equation in one space and one time dimension. It is the first of two talks to be given in sequence by Peter Perry and Robert Jenkins. The relevant papers will appear in *Communications in PDE* and *Communications in Mathematical Physics*.

In the first talk, we'll discuss the complete integrability of the DNLS and the analysis of direct and inverse scattering maps in the presence of finitely many solitons. By posing the Riemann-Hilbert problem that defines the inverse scattering map, we will set the stage for a steepest descent analysis of large-time asymptotics to be described in greater detail in Robert Jenkins' talk.

In a related talk, Jiaqi Liu will describe more recent work on global well-posedness for DNLS with arbitrary spectral singularities. (Received August 17, 2018)

1143-35-322 **Barbara Prinari*** (bprinari@uccs.edu), Department of Mathematics, 1420 Austin Bluffs Pkwy, University of Colorado Colorado Springs, Colorado Springs, CO 80918. *Inverse scattering transform and soliton solutions for certain matrix nonlinear Schrödinger equations.*

We will discuss the Inverse Scattering Transform (IST) for two novel reductions of the matrix nonlinear Schrödinger equation which are integrable, and which are the analog of the modified Manakov system with mixed signs of the nonlinear coefficients, i.e., a nonlinearity in the norm which is of Minkowski type, instead of Euclidean type. We will also classify one soliton solutions, discuss regularity conditions and investigate special bound states and two soliton solutions. (Received August 17, 2018)

1143-35-324 **Jing Tian*** (jtian@towson.edu), 7800 York Rd, towson, MD 21252. *On the Navier-Stokes equations for turbulent channel flows in a particular function class.* Preliminary report.

To understand the connection for fluid flows described by Navier-Stokes equations and by Navier-Stokes-alpha, we restrict our consideration to channel flows having special function forms prescribed as a function class called $\mathcal{P}$. This function class $\mathcal{P}$ was inspired by the concept of regular part of the weak attractor of the 3D NSE as well as by that of the sigma weak attractor. In this study, we study the properties of the solutions of the Navier-Stokes equations in this particular function class. We have explored the non-stationary solutions for the Navier-Stokes equations and Navier-Stokes-alpha model having particular function forms. In particular, the term of sum of pressure and potential can be shown to be harmonic in the space variable. (Received August 17, 2018)

1143-35-328 **William M Feldman*** (feldman@math.uchicago.edu), Department of Mathematics, 5734 S. University Ave, Chicago, IL 60637. *Facet formation in quasi-static motion of contact lines.*

I will introduce a simple free boundary problem modeling quasi-static contact line motion. In this model I will explain how the formation of facets is related to the continuity properties of the pinning interval with respect to the normal direction. (Received August 17, 2018)

1143-35-329 **William M Feldman*** (feldman@math.uchicago.edu), 5734 S University Ave, Department of Mathematics, Chicago, IL 60637. *Shapes of local minimizers for the Alt-Caffarelli functional in inhomogeneous media.*

I will explain how to classify the macroscopic shapes of local minimizers to the Alt-Caffarelli functional with a periodic inhomogeneity. This is related to pinning and hysteresis phenomena for contact line motion in inhomogeneous environments. (Received August 17, 2018)

1143-35-336 **Maria Soria*** (maria.soriac@math.utexas.edu), 3479 Lake Austin Blvd., Apt B, Austin, TX. *A stability argument for transmission problems and $C^{1,\alpha}$ regularity.*

The transmission problem we are going to deal with consists in finding a pair of functions (u, v), defined in $(D, \mathcal{C}D)$, respectively, where $D, \mathcal{C}D \subset \mathbb{R}^n$ are domains separated by a $C^{1,\alpha}$ interface, for some $0 < \alpha < 1$. For this to be a genuine transmission problem, we impose along ∂D the compatibility condition, $\partial_\nu u - \partial_\nu v = g$, where ν is the interior normal vector to D, and $g > 0$ is a C^α function. Our goal is to study the regularity of solutions up to the boundary. If the interface is flat, then we can prove that u and v are $C^{1,\alpha}$, by using a reflection method. If the interface is nearly flat, we can show that the solution to the flat transmission problem is *close* to the one of the curved problem. Then, by an iteration procedure, we finally prove that the latter is $C^{1,\alpha}$ as well. These results are part of my PhD dissertation and they are joint work with L. A. Caffarelli and P. R. Stinga. (Received August 18, 2018)

1143-35-337 **Fernando Charro***, Department of Mathematics, 1150 F/AB, 656 W. Kirby, Detroit, MI 48202. *On a nonlocal Monge-Ampere equation.*

In this talk we will review the classical local Monge-Ampere equation and some of its applications to optimal transport and differential geometry. Then, we will consider a nonlocal analogue of the Monge-Ampere operator, introduced in a joint work with Luis Caffarelli. (Received August 18, 2018)

1143-35-346 **Andrea Giorgini*** (agiorgin@iu.edu), Rawles Hall, 831 East 3rd. Street, Bloomington, IN 47405-3171. *Uniqueness results for Navier-Stokes-Cahn-Hilliard equations.*

In the diffuse interface theory the motion of two contiguous incompressible and viscous fluids is described by the so-called model H. The system consists of the Navier–Stokes equations for the velocity of the mixture, which are coupled with the Cahn–Hilliard equation for the difference of fluids concentrations. In this talk we will discuss some uniqueness results. (Received August 18, 2018)

1143-35-347 **Yuanzhen Shao*** (yshao@georgiasouthern.edu) and **Patrick Guidotti**. *Wellposedness of a Nonlocal Nonlinear Diffusion Equation of Image Processing.*

In this talk, we will establish the wellposedness of a degenerate regularization of the well-known Perona-Malik equation in noise reduction for discontinuous initial data. We will also show the (exponential) asymptotic stability of stationary solutions. (Received August 18, 2018)

1143-35-358 **Xiaoqian Xu*** (xxu@math.cmu.edu), Pittsburgh, PA 15232. *Suppression of chemotactic explosion by mixing.*

Chemotaxis plays a crucial role in a variety of processes in biology and ecology. One of the most studied PDE models of chemotaxis is given by Keller-Segel equation, which describes a population density of bacteria or mold which attract chemically to substance they secrete. However, solution of Keller-Segel equation can exhibit dramatic collapsing behavior. In other words, there exist initial data leading to finite time blow up. In this talk, we will discuss the possible effects resulting from interaction of chemotactic and fluid transport processes, namely we will consider the Keller-Segel equation with additional advection term modeling ambient fluid flow. We will prove that the presence of fluid can prevent the singularity formation. We will discuss several classes of flows that have the explosion arresting property. (Received August 18, 2018)

1143-35-362 **Ru-Yu Lai*** (rylai@umn.edu), 206 Church St. SE, Minneapolis, MN 55455, and **Yi-Hsuan Lin** (yihsuanlin3@gmail.com), P.O. Box 35 (MaD), University of Jyvaskyla, 40014 Jyvaskyla, Finland. *Global uniqueness for the semilinear fractional Schrödinger equation.*

We study global uniqueness in an inverse problem for the fractional semilinear Schrödinger equation $(-\Delta)^s u + q(x, u) = 0$ with $s \in (0, 1)$. We show that an unknown function $q(x, u)$ can be uniquely determined by the Cauchy data set. In particular, this result holds for any space dimension greater than or equal to 2. Moreover, we demonstrate the comparison principle and provide a L^∞ estimate for this nonlocal equation under appropriate regularity assumptions. (Received August 19, 2018)

1143-35-380 **Mary Vaughan*** (maryo@iastate.edu) and **Pablo Raúl Stinga**. *Fractional derivatives in one-sided weighted Sobolev spaces.*

Marchaud fractional derivatives can be defined in the most general way in the distributional sense. We start from this point and then show that the usual pointwise formulas for these operators indeed hold for functions in more general classes. The classes we consider are weighted Sobolev spaces with one-sided Sawyer weights which capture the one-sided nature of fractional derivatives. The pointwise and norm limits as the orders of the derivatives converge to an integer are also analyzed. (Received August 19, 2018)

1143-35-384 **Dumitru Trucu*** (trucu@maths.dundee.ac.uk), Division of Mathematics, University of Dundee, Dundee, DD1 4HN, United Kingdom. *Multiscale Dynamics of Bulk and Leading Edge in Cancer Invasion.*

One common aspect of all cancer progressions is the secretion of matrix degrading enzymes (MDEs) by the cancer cells that modify or destroy various components of extracellular matrix (ECM) and support local cancer cell invasion. In conjunction with MDEs activities, increased cancer cell motility is caused by changes in cell-adhesion properties that further exacerbates the invasion process. Despite recent mathematical modelling advances, the understanding of the biologically multiscale process of cancer invasion remains an open question. In this work we introduce a novel multiscale moving boundary approach for cancer invasion that accounts for cell-adhesion in the context of the multiphase nature of the ECM dynamics. Distinguishing here between the fibres component and the rest of the ECM components and incorporating their multiscale dynamics within the new modelling approach, this framework connects the tissue-scale macro-dynamics with both the proteolytic cell-scale dynamics occurring at the tumour invasive edge and the micro-scale ECM fibres dynamic degradation and realignment occurring inside the tumour domain. The presentation of the new modelling framework, will be accompanied by details of the computational approach and a discussion of the numerical simulation results. (Received August 19, 2018)

1143-35-397 **Agnid Banerjee**, **Mariana Smit Vega Garcia*** (mariana.smitvegagarcia@wwu.edu) and **Andrew K Zeller**. *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 in De Silva and Savin. As an application, we show that the free boundary near a regular point of the parabolic thin obstacle problem with zero obstacle is C^∞ regular in space and time. (Received August 19, 2018)

1143-35-425 **Nestor Guillen*** (nguillen@math.umass.edu), nguillen@math.umass.edu. *Nonlocal operators and spatial dependence.*

In this talk I will present work regarding the structure of integro-differential elliptic operators which are translation invariant and those which change continuously with translations. In work with Russell Schwab, it is shown such operators admit a representation through a min-max formula involving Levy operators, the operators themselves being translation invariant or having "regular" coefficients reflecting the spatial dependence of the original operator. The relevance of such characterizations to comparison principles for viscosity solutions will be discussed, particularly with regards to recent work with Chenchen Mou and Andrzej Swiech. (Received August 20, 2018)

1143-35-428 **Animesh Biswas***, 396 Carver Hall, Department of Mathematics, Ames, IA 50011, **Marta De León-Contreras**, Departmento de Matemáticas, Facultad de Ciencias, 28049 Madrid, Spain, and **Pablo Raúl Stinga**, 396 Carver Hall, Department of Mathematics, Ames, IA 50011. *Extension Problem and Harnack Inequality For Master Equations.*

We analyze regularity properties for fractional powers of parabolic operators in divergence form in bounded domains. These equations are fundamental in continuous time random walk models and appear as the generalized master equation. Some other applications include the parabolic Signorini problem and the phenomenon of osmosis in heterogeneous media. These problems are nonlocal in nature. They are studied by using a localization procedure in the spirit of the extension problem of Luis Caffarelli and Luis Silvestre. Indeed, we develop a parabolic method of semigroups that allows us to prove an extension problem of parabolic type. As a consequence, we obtain parabolic Harnack estimates, both in the interior and up to the boundary. These results are completely novel for generalized master equations.

This is joint work with Marta de León-Contreras (Universidad Autónoma de Madrid, Spain) and Pablo Raúl Stinga (Iowa State University). (Received August 20, 2018)

1143-35-429 **Nestor Guillen***, nguillen@math.umass.edu, and **Maria Gualdani**. *On the Landau equation: A_p weights and a conditional L^∞ estimate.*

The Landau equation with Coulomb potential is a model in plasma physics which features transport, diffusion, and reaction effects. In joint work with Maria Gualdani we provide a new conditional L^∞ estimate for homogeneous solutions of this equation. Our result backs the intuition that the strength of the dissipative effect of the equation is at least comparable to the reaction effect that could drive it to blow up. The result is based on the observation that the coefficients arising in the equation are controlled by A_p weights, combined with

a an argument in the the style of De Giorgi-Nash-Moser theory which ultimately yields a (conditional) L^∞) regularization rate of order $t^{-(1+s)}$ for valid for any small $s > 0$. (Received August 20, 2018)

1143-35-451 **Junshan Lin*** (jzl0097@auburn.edu), Department of Mathematics and Statistics, Auburn University, Auburn, AL 36830. *Scattering Resonances Through Small Holes: Perfect Conductors and Plasmonic Metals.*

The so-called extraordinary optical transmission (EOT) through metallic nanoholes has triggered extensive research in modern plasmonics. The mechanisms contributing to the EOT phenomenon can be complicated due to the multiscale nature of the underlying structure. In this talk, I will focus on one mechanism induced by resonances. Rigorous mathematical analysis and numerical approaches will be presented to study the scattering resonances for two-dimensional structures. Both the perfect electric conductors and plasmonic metals will be discussed. (Received August 20, 2018)

1143-35-455 **Robert Buckingham***, buckinrt@uc.edu. *Large-order asymptotics for multiple pole solitons of the focusing NLS equation.*

We analyze the large-order behavior of multiple-pole solitons of the focusing NLS equation using the nonlinear steepest-descent method for Riemann-Hilbert problems. For moderate values of the pole order we obtain exact solutions, revealing highly oscillatory and quiescent regions. We compute the boundary of the quiescent regions exactly and prove the asymptotic limit of the solitons is zero in these regions. In a scaled neighborhood of the central peak we prove that the solitons converge to functions satisfying the second member of the Painleve-III hierarchy in the sense of Sakka. This function is a generalization of a function recently identified by Suleimanov in the context of geometric optics and by Bilman, Ling, and Miller in the context of rogue wave solutions to the focusing NLS equation. This is joint work with Deniz Bilman. (Received August 20, 2018)

1143-35-467 **Zaher Hani*** (zhani@umich.edu), Ann Arbor, MI 48109, and **Marcel Guadia**, **Emanuele Haus**, **Michela Procesi** and **Alberto Maspero**. *Strong transverse instability and growth of Sobolev norms near quasiperiodic finite-gap tori for the 2D cubic NLS equation.*

We consider the defocusing cubic nonlinear Schrödinger equation (NLS) on the two-dimensional torus. The equation admits a special family of invariant quasiperiodic tori called finite-gap solutions. These are inherited from the integrable 1D model (cubic NLS on the circle) by considering solutions that depend only on one variable. We study the long-time stability of such invariant tori for the 2D NLS model and show that, under certain assumptions and over sufficiently long timescales, they exhibit a strong form of *transverse instability* in Sobolev spaces $H^s(\mathbb{T}^2)$ $(0 < s < 1)$. More precisely, we construct solutions of the 2D cubic NLS that start arbitrarily close to such invariant tori in the H^s topology and whose H^s norm can grow by any given factor. This work is partly motivated by the problem of infinite energy cascade for 2D NLS, and seems to be the first instance where (unstable) long-time nonlinear dynamics near (linearly stable) quasiperiodic tori is studied and constructed. (Received August 20, 2018)

1143-35-471 **Robert Jenkins***, bobjen@rams.colostate.edu, and **Jiaqi Liu**, **Peter Perry** and **Catherine Sulem**. *Soliton Resolution for the Derivative Nonlinear Schrödinger Equation (Part II).*

This talk concerns joint work with Jiaqi Liu, Peter Perry, and Catherine Sulem on the soliton resolution conjecture for the Derivative Nonlinear Schrodinger Equation (DNLS), a completely integrable dispersive nonlinear equation in one space and one time dimension. This is the second of two talks to be given in sequence by Peter Perry and Robert Jenkins. The relevant papers will appear in *Communications in PDE* and *Communications in Mathematical Physics*.

In the first talk, Peter Perry will discuss the complete integrability of the DNLS and the analysis of direct and inverse scattering maps in the presence of finitely many solitons. In this talk we will describe the steepest descent analysis of the Riemann-Hilbert problem that defines the inverse scattering map in the large-time asymptotics regime. The result of this analysis is a soliton resolution result for generic solutions of DNLS.

In a related talk, Jiaqi Liu will describe more recent work on global well-posedness for DNLS with arbitrary spectral singularities. (Received August 20, 2018)

1143-35-474 **Stephen Philip Cameron*** (scameron@math.uchicago.edu). *Lipschitz regularization for bounded fractional mean curvature flow.* Preliminary report.

The s-perimeter of a set E is given by the $\dot{W}^{s,1}$ norm of its characteristic function for $s \in (0, 1)$. The first variation of this functional gives the s-mean curvature H_s, the fractional, nonlocal analog of typical mean curvature. We show that if your initial surface is bounded between two hyperplanes, then after evolving for a fixed finite time

under fractional mean curvature flow the surface becomes a Lipschitz graph. The proof is inherently nonlocal in nature, and in fact the theorem is false for classical mean curvature flow. (Received August 20, 2018)

1143-35-480 **Seongmin Jeon** and **Arshak Petrosyan***, Department of Mathematics, Purdue University, 150 N University St, West Lafayette, IN 47907. *Almost minimizers for the thin obstacle problem.*

We consider almost minimizers for the thin obstacle problem with zero thin obstacle and establish their $C^{1,\alpha}$ regularity on the either side of the thin manifold, the optimal growth away from the free boundary, as well as the $C^{1,\alpha}$ regularity of the regular part of the free boundary. The analysis of the free boundary is based on a successful adaptation of energy methods such as a one-parameter family of Weiss-type monotonicity formulas, Almgren-type frequency formula, and the epiperimetric inequality for the solutions of the thin obstacle problem. (Received August 20, 2018)

1143-35-489 **Emanuel G Indrei*** (eindrei@purdue.edu). *The geometry of the free boundary near the fixed boundary generated by a fully nonlinear uniformly elliptic operator.*

The dynamics of how the free boundary intersects the fixed boundary has been the object of study in the classical dam problem which is a mathematical model describing the filtration of water through a porous medium split into a wet and dry part. By localizing around a point at the intersection of free and fixed boundary, one is led to the following problem

$$\begin{cases} F(D^2u) = \chi_\Omega & \text{in } B_1^+ \\ u = 0 & \text{on } B_1' \end{cases}$$

where $\Omega = \big(\{u \neq 0\} \cup \{\nabla u \neq 0\}\big) \cap \{x_n > 0\} \subset \mathbb{R}^n_+$, $B_1' = \{x_n = 0\} \cap \overline{B_1^+}$, and F is a C^1 fully nonlinear uniformly elliptic operator. In this context, the free boundary is $\Gamma = \mathbb{R}^n_+ \cap \partial\Omega$ and tangential touch means that on a small enough scale, the free boundary is trapped below any cone with opening strictly less than π: for any $\epsilon > 0$ there exists $\rho_\epsilon > 0$ such that

$$\Gamma \cap B^+_{\rho_\epsilon} \subset B^+_{\rho_\epsilon} \setminus \mathcal{C}_\epsilon,$$

where $\mathcal{C}_\epsilon := \{x_n > \epsilon|x'|\}$, $x' = (x_1, \dots, x_{n-1})$. This talk focuses on the regularity problem of the free boundary in higher dimensions. (Received August 20, 2018)

1143-35-490 **Giusy Mazzone*** (giusy.mazzone@vanderbilt.edu), Department of Mathematics, Vanderbilt University, 1326 Stevenson Center, Nashville, TN 37240, **Jan Prüss** (jan.pruess@mathematik.uni-halle.de), Martin-Luther-Universität Halle-Wittenberg, Institut für Mathematik, Theodor-Lieser-Strasse 5, D-06120 Halle, Germany, and **Gieri Simonett** (gieri.simonett@vanderbilt.edu), Department of Mathematics, Vanderbilt University, 1326 Stevenson Center, Nashville, TN 37240. *On the inertial motion of a fluid-filled rigid body with partial-slip boundary conditions.*

We consider the inertial motion of a system constituted by a rigid body with an interior cavity completely filled with a viscous incompressible fluid. Partial-slip boundary conditions are imposed on the cavity surface. In the case of no-slip boundary conditions, it has been proved that the fluid has a stabilizing effect on the motion of the rigid body. Every weak solution à la Leray-Hopf to the equations of motion converges to an equilibrium at an exponential rate in the L_q topology for every fluid-solid configurations. The same stabilizing effect can also be observed in the case of partial-slip. We determine the critical spaces for the governing evolution equation, and use parabolic regularization in time-weighted spaces to establish regularity of solutions and their convergence to equilibria. Equilibria are characterized by having the fluid at a relative rest with respect to the solid, and the fluid-solid system moving as a whole rigid body, with a constant angular velocity. A nonlinear stability analysis shows that equilibria associated with the largest moment of inertia of the system fluid-filled rigid body are asymptotically (exponentially) stable, whereas all other equilibria are normally hyperbolic and unstable in an appropriate topology. (Received August 20, 2018)

1143-35-492 **Vincent R Martinez***, CUNY-Hunter College, Department of Mathematics and Statistics, 695 Park Ave, New York, NY 10065. *Unique Ergodicity for the damped-driven stochastic KdV equation.* Preliminary report.

In their 1967 seminal paper, Foias and Prodi defined a notion of finitely many degrees of freedom in the context of the two-dimensional incompressible Navier-Stokes equations (NSE). In particular, they proved that if a sufficiently large spectral projection of the difference of two solutions converge to zero asymptotically in time, then the corresponding complementary projection of their difference must also converge to 0 in the infinite-time limit. In other words, the high modes are eventually enslaved by the low modes. One may thus define the number of degrees of freedom of the flow to be the smallest number of modes needed to guarantee this convergence. This

property has since led to several developments in the understanding of the long-time behavior of solutions to the NSE, for instance, in the context of turbulence, but also to data assimilation, and the existence of determining forms. In this talk, we will discuss this asymptotic enslavement property as it regards the issue of uniqueness of invariant measures the damped-driven stochastic KdV equation, of which the undamped, deterministic analog is a classical model for shallow water waves. This is joint work with Nathan Glatt-Holtz (Tulane University) and Geordie Richards (Utah State University). (Received August 20, 2018)

1143-35-500 **Yernat Assylbekov** and **Ting Zhou*** (t.zhou@northeastern.edu). *Direct and Inverse problems for the Nonlinear Time-Harmonic Maxwell Equations in Kerr-Type Media.*

In this work, we consider an inverse boundary value problem of electromagnetism in a nonlinear Kerr medium. We show the unique determination of the electromagnetic ma- terial parameters and the nonlinear susceptibility parameters of the medium by making electromagnetic measurements on the boundary. We are interested in the case of the time-harmonic Maxwell equations. This is a joint work with Dr. Yernat M. Assylbekov. (Received August 21, 2018)

1143-35-503 **Anna L Mazzucato***, Penn State University, University Park, PA. *Irregular transport and well-posedness of the continuity equation.*

I will discuss geometric properties of non-Lipschitz flows (so-called regular Lagrangian flows) and how irregular transport affects well-posedness of the continuity equation. (Received August 21, 2018)

1143-35-514 **Huy Nguyen***, 151 Thayer Street, PROVIDENCE, RI 02912, and **Benoit Pausader** (benoit.pausader@math.brown.edu), 151 Thayer Street, PROVIDENCE, RI 02912. *On the one-phase Muskat problem.* Preliminary report.

The one-phase Muskat problem models the dynamics of an interface between vacuum and a fluid in porous medium. We will discuss results on well-posedness and maximum principles for this problem in all dimensions and in domains with general geometry. (Received August 21, 2018)

1143-35-520 **Cecilia F Mondaini*** (cfreiremondaini@tulane.edu), Mathematics Department, 424 Gibson Hall, Tulane University, New Orleans, LA 70118. *Space-time discrete numerical schemes for a feedback-control data assimilation algorithm.*

We consider a feedback-control (nudging) approach for data assimilation that works for a general class of dissipative dynamical systems and observables. As a model example, we consider the 2D incompressible Navier-Stokes equations (NSE). Our purpose is to present an estimate of the error between a numerical approximation of the solution to the nudging equation and a reference solution of the 2D NSE, representing the truth. We consider a spatial discretization given by the Postprocessing Galerkin method and two types of implicit Euler schemes for the time discretization: fully implicit and semi-implicit. Our results show that the time-discrete schemes are unconditionally stable and the error estimates are uniform in time. This is based on joint works with H. Ibdah (Texas A&M) and E. S. Titi (Texas A&M). (Received August 21, 2018)

1143-35-523 **Alexey Cheskidov*** (acheskid@uic.edu), 322 SEO, 851 S. Morgan Street, Chicago, IL 60605. *Regularity, uniqueness, and energy balance for the Navier-Stokes equations: the effect of intermittency.*

Intermittent flows, possessing more intense energy flux, exhibit deviations from Kolmogorov's scaling laws, which can be measured in numerical simulations and experiments. I will rigorously define the spectrum of intermittency dimensions (as a function of the Holder exponent) and discuss how it affects regularity properties of solutions to the Navier-Stokes equations (NSE) and their ability to satisfy the energy equality. In particular, I will present new Onsager's spaces for the NSE and compare intermittent flows used for recent non-uniqueness constructions for the NSE in various dimensions. (Received August 21, 2018)

1143-35-525 **Mihaela Ignatova*** (ignatova@temple.edu) and **Peter Constantin** (const@math.princeton.edu). *Electrodiffusion of ions in fluids.*

The electrodiffusion of ions in fluids is governed by the Nernst-Planck-Navier-Stokes system. We prove global existence and stability results for large data, in two dimensions, with Dirichlet boundary conditions for the Navier-Stokes and Poisson equations, and blocking (vanishing normal flux) or selective (Dirichlet) boundary conditions for the ionic concentrations, for arbitrary Reynolds number, voltages, ionic valences, and species diffusivities. The proofs follow from a remarkable structure resulting in the decay of the sum of relative entropies of the ionic concentrations and the kinetic energy of the fluid. This is joint work with Peter Constantin. (Received August 21, 2018)

1143-35-533 **Eduardo Teixeira*** (eduardo.teixeira@ucf.edu), University of Central Florida, Department of Mathematics, 4393 Andromeda Loop N., Orlando, FL 32816. *On a new class of variable diffusibility elliptic operators.*

Motivated by the theory of free boundary problems in rough media, we introduce a new class of non-divergence form elliptic operators whose degree of degeneracy/singularity chances accordantly to a prescribed law. Such an endeavor parallels the by now well established minimization theory of functionals satisfying θ-growth condition, which in particular encompasses the theory of $p(x)$-laplacian. Under rather general conditions, we prove viscosity solutions to variable exponent fully nonlinear elliptic equations are locally of class $C^{\{1,\alpha\}}$; sharp estimates are also derived.

This is in part a joint work with Edgard Pimentel and his group at PUC-Rio. (Received August 21, 2018)

1143-35-538 **Diana T White*** (dtwhite@clarkson.edu), 8 Clarkson Avenue, Potsdam, NY 13699, **Florence Hubert**, Institute of Mathematics, 39, rue Frédéric Joliot-Curie, 13453 Marseille, Provence, France, and **Stephane Honore**, 264 Rue Saint Pierre, 13005 Marseille, Provence, France. *Modeling microtubule dynamics: applications to cancer chemotherapy treatments.*

Questions regarding how microtubule targeting agents (MTAs), used in the treatment of a variety of cancers, alter microtubule (MT) dynamics have been investigated experimentally and theoretically. It has been well established that MTAs exert their cytotoxic effect on MTs by suppressing MT dynamic instability. However, at low non-cytotoxic levels, more interesting dynamics have been observed, such as an increase in MT dynamic instability. Also, it has recently been discovered that the end-binding (EB) family of tip tracking proteins sensitize the action of MTAs on MT dynamics.

Here, we propose a novel modelling approach, based on the work of Hinow et al. [*], to describe MT dynamic instability in the presence of EBs. In particular, we develop an integro-PDE model for MTs, that takes into account large and fast shortening events that can be observed in such systems. For EBs, we introduce a pair of ODEs to describe the binding and unbinding of EBs with growing MT ends. Simulation results illustrate that our model accurately describes MT dynamics for varying EB concentrations. Further, we show how our model can be used to suggest mechanisms for how EBs work to sensitize the action of MTAs on MT dynamic instability. [*] Hinow et al. Physical Review E. 2009 (Received August 21, 2018)

1143-35-541 **Thomas Trogdon*** (ttrogdon@math.uci.edu), University of California, Irvine, Rowland Hall, Irvine, CA 92697-3875. *The construction and evaluation of shock wave solutions to the KdV equation and a linear KdV-like equation.*

We consider the problem of computing the inverse scattering transform for the KdV equation on $\mathbb{R}$ when the initial data $q_0(x)$ satisfies $\lim_{x\to+\infty} q_0(x) \neq \lim_{x\to-\infty} q_0(x)$. We build on the work of Cohen and Kappeler (1985) and Andreiev et al. (2016). In particular, we demonstrate how the use of both left and right reflection coefficients is necessary, in contrast to decaying initial data. Properties of this solution motivate a linearization that shares non-trivial structure with its nonlinear counterpart. This is joint work with Deniz Bilman, Dave Smith and Vishal Vasan. (Received August 21, 2018)

1143-35-542 **Stephen Anco*** (sanco@brocku.ca), Brock University, St Catharines, ON L2S3A1, Canada. *A family of U(1)-invariant integrable peakon equations related to the NLS hierarchy.* Preliminary report.

I will report on a family of U(1)-invariant integrable peakon equations that come from the Hirota hierarchy which sits inside the NLS hierarchy. One of the U(1)-invariant peakon equations is of NLS type, while another one is of Hirota type. Interesting features of these peakon equations will be presented. (Received August 21, 2018)

1143-35-547 **William Feldman** and **Charles K Smart*** (smart@math.uchicago.edu). *A free boundary problem with facets.*

We study a free boundary problem on the lattice whose scaling limit is a harmonic free boundary problem with a discontinuous Hamiltonian. We find an explicit formula for the Hamiltonian, prove the solutions are unique, and prove that the limiting free boundary has a facets in every rational direction. Our choice of problem presents difficulties that require the development of a new uniqueness proof for certain free boundary problems. The problem is motivated by physical experiments involving liquid drops on patterned solid surfaces. (Received August 21, 2018)

1143-35-548 **Michael Winkler** (michael.winkler@math.uni-paderborn.de), 80305 Paderborn, Germany, and **Nancy Rodriguez*** (rodrign@colorado.edu), Boulder, CO 80305. *On the global existence and qualitative behavior of solutions to a model for urban crime.*

We consider the no-flux initial-boundary value problem for the cross-diffusive evolution system which was introduced to describe the dynamics of urban crime. In bounded intervals I will first discuss the existence of global classical solutions for all reasonably regular non-negative initial data. Next I will address the issue of determining the qualitative behavior of solutions. Finally, I will conclude with some numerical simulations exploring possible effects that may arise when considering large cross diffusion terms not covered by our qualitative analysis. (Received August 21, 2018)

1143-35-558 **Sergey Dyachenko**, **Dmitry Zakharov*** (dvzakharov@gmail.com) and **Vladimir Zakharov**. *A generalization of the inverse spectral transform and bounded, non-vanishing solutions of the KdV equation.*

There are two classical methods for constructing solutions of the Korteweg-de Vries (KdV) equation. The inverse scattering method (ISM) is used in the rapidly decaying case, and relates the initial conditions to the spectral data of the associated linear Schroedinger operator. The finite-gap method, on the other hand, produces solutions that are periodic or quasi-periodic.

It has long been understood that the two methods should be related, but a precise description of such a relation was lacking. A key difference between the two methods is that the finite-gap method is symmetric with respect to spatial involution, while the ISM is not.

We present a generalization of the inverse scattering method for the one-dimensional Schroedinger equation that is symmetric with respect to spatial involution. This method specializes to both the classical ISM and to the finite-gap method. The corresponding solutions of the KdV equation are bounded, but not rapidly decaying at infinity. (Received August 21, 2018)

1143-35-564 **Joel Jacob Klipfel*** (jjkl223@g.uky.edu), Department of Mathematics, 719 Patterson Office Tower, Lexington, KY 40506-0027, and **Peter A Perry** and **Yilun Wu**. *Direct Scattering Map for the Intermediate Long Wave Equation.* Preliminary report.

In the 1970's and 1980's, Kodama, Ablowitz and Satsuma, together with Santini, Ablowitz and Fokas, developed the formal inverse scattering theory of the Intermediate Long Wave (ILW) equation and explored its connections with the Benjamin-Ono (BO) and KdV equations. The ILW equation

$$u_t + \frac{1}{\delta}u_x + 2uu_x + Tu_{xx} = 0,$$

models the behavior of long internal gravitational waves in stratified fluids of depth $0 < \delta < \infty$, where T is a singular operator which dependes on the depth δ. In the limit $\delta \to 0$, the ILW reduces to the Korteweg de Vries (KdV) equation, and in the limit $\delta \to \infty$, the ILW (at least formally) reduces to the Benjamin-Ono (BO) equation.

While the KdV equation is very well understood, a rigorous analysis of inverse scattering for the ILW equation remains to be accomplished. There is currently no rigorous proof that the inverse scattering procedure outlined by Kodama *et al.* solves the ILW, even for small data. In this talk, I present a progress report on joint work with Peter Perry, Yilun Wu, and myself on studying the direct scattering map for the ILW as a first step to a rigorous analysis of the inverse scattering method. (Received August 21, 2018)

1143-35-575 **Lihe Wang*** (lwang.iowa@gmail.com), Department of Mathematics 15 MLH, The University of Iowa, Iowa city, IA 52242-1419. *Rigidity theorem with capacity.*

We prove a rigidity theorem using a capacity condition on sets in R^n. (Received August 22, 2018)

1143-35-579 **Alexey Cheskidov*** (acheskid@uic.edu), 322 SEO, 851 S. Morgan Street, Chicago, IL 60607. *Onsager's conjecture for the Navier-Stokes equations.*

Recent conditions implying energy equality and regularity will be discussed. We will also examine the effect of hyper-dissipation. (Received August 22, 2018)

37 ► Dynamical systems and ergodic theory

1143-37-176 **Nathan Glatt-Holtz** and **Vincent R Martinez*** (vincent.martinez@hunter.cuny.edu), Department of Mathematics and Statistics, Room 919/944 East, 695 Park Ave, New York, NY 10065, and **Geordie Richards**. *Unique ergodicity for the damped, stochastically-driven Korteweg de Vries equation.* Preliminary report.

In their 1967 seminal paper, Foias and Prodi captured precisely a notion of finitely many degrees of freedom in the context of the two-dimensional (2D) incompressible Navier-Stokes equations (NSE). In particular, they proved that if a sufficiently large spectral projection of the difference of two solutions converge to 0 asymptotically in time, then the corresponding complementary projection of their difference must also converge to 0 in the infinite-time limit. In other words, the high modes are "eventually enslaved" by the low modes. One could thus define the number of degrees of freedom of the flow to be the smallest number of modes needed to guarantee this convergence for a given flow, insofar as it is represented by a solution to the NSE. This property has since led to several developments in the understanding and application of the long-time behavior of solutions to the NSE, for instance, in the context of turbulence, data assimilation, and the existence of determining forms. In this talk, we will discuss this asymptotic enslavement property as it regards the issue of uniqueness of invariant measures for stochastically forced equations, particularly the damped-driven, stochastically forced KdV equation. (Received August 10, 2018)

1143-37-263 **Roy Goodman*** (goodman@njit.edu), New Jersey Institute of Technology, Newark, NJ 07102. *NLS Bifurcations on the bowtie combinatorial graph and the dumbbell metric graph.*

We consider the bifurcations of standing wave solutions to the nonlinear Schrödinger equation (NLS) posed on a quantum graph consisting of two loops connected by a single edge, the so-called dumbbell, recently studied by Marzuola and Pelinovsky. The authors of that study found the ground state undergoes two bifurcations, first a symmetry-breaking, and the second which they call a symmetry-preserving bifurcation. We clarify the type of the symmetry-preserving bifurcation, showing it to be transcritical. We then reduce the question, and show that the phenomena described in that paper can be reproduced in a simple discrete self-trapping equation on a combinatorial graph of bowtie shape. This allows for complete analysis both by geometric methods and by parameterizing the full solution space. We then expand the question, and describe the bifurcations of *all* the standing waves of this system, which can be classified into three families, and of which there exists a countably infinite set. We highlight the numerical package we have been creating that was used to do the computations in this work. (Received August 15, 2018)

1143-37-291 **P. J. Morrison*** (morrison@physics.utexas.edu), 2515 Speedway Stop C1600, Austin, TX 78712–106. *Metriplectic Dynamics and Reduction.*

Metriplectic dynamical systems [1-2] possess Hamiltonian and dissipative vector fields, where the dissipation obeys fundamental yet dynamical properties of thermodynamics, viz. conservation of energy and entropy production. This formalism will be reviewed and examples will be given. The notion of metriplectic reduction will be introduced [3], whereby larger systems with symmetry are reduced to metriplectic form.

[1] P. J. Morrison, "A Paradigm for Joined Hamiltonian and Dissipative Systems," Physica D **18**, 410–419 (1986).
[2] A. M. Bloch, P. J. Morrison, and T. S. Ratiu, "Gradient Flows in the Normal and Kaehler Metrics and Triple Bracket Generated Metriplectic Systems," in Recent Trends in Dynamical Systems, eds. A. Johann et al., Springer Proceedings in Mathematics & Statistics 35, DOI 10.1007/978-3-0348-041-6-15, (2013) pp. 371–415.
[3] M. Materassi and P. J. Morrison, "Metriplectic Torque for Rotation Control of a Rigid Body,"Journal Cybernetics and Physics, Accepted (2018). arXiv:1807.01168 (Received August 17, 2018)

1143-37-396 **Wencai Liu*** (liuwencai1226@gmail.com), 410 P, Rowland Hall, IRVINE, CA 92697. *Anderson localization for high dimensional quasi-periodic operators with long-range interactions.*

We study the long-range quasi-periodic operators on $\ell^2(\mathbb{Z}^d)$:

$$H(x)(n,n') = S^{\phi}(n,n') + \lambda v(x + n \otimes \omega)\delta_{nn'}, \quad (n,n') \in \mathbb{Z}^{2d},$$

where S^{ϕ} is a Töplitz operator satisfying

$$|S^{\phi}(n,n')| \leq Ce^{-\rho|n-n'|},$$

$$n \otimes \omega := (n_1\omega_{11}, \cdots, n_1\omega_{b_1 1}, \cdots, n_d\omega_{1d}, \cdots, n_d\omega_{b_d d}),$$

and v is a real analytic function on b-dimensional torus where $b = \sum_{i=1}^{d} b_i$, and establish Anderson localization and related estimates.

If $S^{\phi}(n,n')=1$ for $|n-n'|=1$ and $S^{\phi}(n,n')=0$, the above operator reduces to a discrete Schrödinger operator. In this case, the Anderson localization for large λ was proved by Bourgain-Goldstein ($d=1, b=2$), Bourgain ($d=1, b\geq 3$), Bourgain-Goldstein-Schlag ($b=d=2$) and Bourgain ($b=d\geq 3$). The general b, d and long-range case is particularly important because it appears as Aubry-dual of general quasiperiodic Schrödinger operators with analytic potentials. (Received August 19, 2018)

1143-37-433 **Mojtaba Moniri*** (mojtaba.moniri@normandale.edu) and **Saman Moniri** (moniri@umich.edu). *A Hitherto Already-bifurcated Impression Resolved.*

We describe the misbehavior of an iterative computer calculation, and how more correct outputs can be obtained via other algorithms. The logistic map with parameter $r\in(0,4]$ is defined on $[0,1]$ as $f_r(x)=rx(1-x)$. Although most parameters $r\in(3.570,4]$ lead to a chaotic orbit for an arbitrary $x_0\in(0,1)$, there are windows of periodicity there. Calculations involving Gröbner bases show the first onset of 5-cycles rounded up to be 3.7382 with first 5 to 10 bifurcation rounded down at 3.7411. For $r=3.74$ (resp. $r=3.742$), the existence of a 5- (resp. 10-) cycle can also be proved using Brouwer's fixed point theorem. Initial tries to calculate the orbit for 3.74 directly lead to a wrong impression of 10-periodicity. The exact rational values have rapidly growing numerators, that of the 26^{th} term has more than 134 million digits. The round-off errors due to the limitations of the floating point reals have significant effects. Gröbner bases also provide a way to further approximate the attracting limiting cycle and discover the repelling 5-cycle. Such indirect computer-assisted proofs are of philosophical interest too. (Received August 20, 2018)

1143-37-491 **Tomoki Ohsawa*** (tomoki@utdallas.edu), 800 W Campbell Rd, Richardson, TX 75080. *The Lie–Poisson dynamics of N point vortices.*

We show that the symplectic reduction of the dynamics of N point vortices on the plane by the special Euclidean group $\mathsf{SE}(2)$ yields a Lie–Poisson equation for relative configurations of the vortices. Specifically, we combine symplectic reduction by stages with a dual pair associated with the reduction by rotations to show that the $\mathsf{SE}(2)$-reduced space with non-zero angular impulse is a coadjoint orbit. (Received August 20, 2018)

1143-37-499 **Kiattisak Prathom*** (kp525914@ohio.edu) and **Todd Young**. *Stability Regions of Cell Cycle Model with Negative Feedback.* Preliminary report.

We study a simple model of many cells in a bioreactor in which cells in one phase of the cycle called signaling region may effect the growth rate of other cells in another phase called responsive region. The relation between cells in both phases is called feedback function. For negative feedback, the model predicted that temporal clusters would be formed by cohorts of cells. This model was motivated by yeast autonomous oscillation experiments.

This talk focuses on regions of stability in parameter space of "k-cyclic" periodic solution corresponding to clustered configurations. We discover that regions of stability are the same as "isosequential regions", triangular regions whose vertices are points where certain events in the solution occur simultaneously. To deal with the problems about stability of isosequential regions, we analyze all eigenvalues of DF where F is a map representing each position of all cohorts in the cycle after the time required for the last position k-th cohort to reach the end point of the cycle. Here F is a factor of the Poincaré map. (Received August 21, 2018)

39 ► Difference and functional equations

1143-39-563 **Irina Nenciu***, Department of Mathematics, Statistics, and Computer Science, 851 S Morgan St, Chicago, IL 60607. *On an a-priori bound in Riemann-Hilbert problems.* Preliminary report.

We will discuss certain a-priori bounds for the inverse of $I-C_w$ which allow us to proceed with the needed deformations for the KdV Riemann-Hilbert problem in the collisionless shock region. This work is part of a joint project with P. Deift. (Received August 21, 2018)

41 ► Approximations and expansions

1143-41-79 **Rayan Saab*** (rsaab@ucsd.edu) and **Thang Huynh**. *New and Improved Binary Embeddings of Data (and Quantization for Compressed Sensing with Structured Random Matrices).*

We discuss two related problems that arise in the acquisition and processing of high-dimensional data. First, we consider distance-preserving fast binary embeddings. Here we propose fast methods to replace points from

a subset of $\mathbb{R}^N$ with points in a lower-dimensional cube $\{\pm 1\}^m$, which we endow with an appropriate function to approximate Euclidean distances in the original space. Second, we consider a problem in the quantization (i.e., digitization) of compressed sensing measurements. Here, we deal with measurements arising from the so-called bounded orthonormal systems and partial circulant ensembles, which arise naturally in compressed sensing applications. In both these problems we show state-of-the art error bounds, and to our knowledge, some of our results are the first of their kind. This is joint work with Thang Huynh. (Received July 31, 2018)

1143-41-340 **Steven Damelin***, 416 4th Street, Ann Arbor, MI 48104, and **Kai Diethelm**, **David Ragozin** and **Charles Fefferman**. *Approximate and exact alignment of data, extensions and interpolation in R^D.*

Suppose we are given two sets of data in a containing Euclidean space R^D. The data sets are indexed by the same set, and we know that pairwise Euclidean distances between corresponding points are equal in the two data sets. Can this correspondence be extended to an isometry of space? In this form, the question is long known to be yes. We study a related question fundamental in data analysis. Here, the known points are samples from a larger, unknown set say a smooth manifold in a containing Euclidean space R^D and we seek to know what can be said about the manifold itself. This is referred to as the problem of manifold hypothesis. A typical example might be a problem of DNA interfaces or multiple view image recognition with noise. The problem can be formulated so that we demand that the pairwise distances between corresponding points should be close in some metric inherited from a group action for example an orthogonal or projective action. As it turns out the problem relates to Whitney extensions, interpolation in R^D and bounds for Hilbert transforms. For practical algorithms there is a natural deep learning framework for both labelled and unlabeled data. We will discuss new results and pose several open problems for future research. (Received August 18, 2018)

1143-41-363 **Nir Sharon*** (nir.sharon@math.tau.ac.il), , Israel. *Estimation problems over groups in a noisy environment.*

We discuss the approach of solving an approximation problem modeled with group action using low order statistics. We further show the relation of this method with solutions based on variants features. We demonstrate the strength of our approach on the application of estimating the 3D structure of a molecule from its (very) noisy 2D projection images, as appear in single-particle cryo-electron microscopy (cryo-EM). (Received August 19, 2018)

1143-41-443 **Hrushikesh N Mhaskar*** (hrushikesh.mhaskar@cgu.edu), 1237 N. Dartmouth Ave, Claremont Graduate University, Claremont Graduate University (Claremont, CA, Claremont, CA 91711. *Beyond super-resolution.* Preliminary report.

The problem of super-resolution in general terms is to recuperate a finitely supported measure μ given finitely many of its coefficients $\hat{\mu}(k)$ with respect to some orthonormal system in the case when the number of coefficients required is substantially smaller than a power of the minimal separation among the points in the support of μ. In this paper, we consider the more severe problem of recuperating μ approximately without any assumption on μ beyond having a finite total variation. In particular, the minimal separation of the support of μ is 0. A variant of this problem is of interest in machine learning as well as the inverse problem of de-convolution. We define an appropriate notion of a distance between the target measure and its recuperated version, give an explicit expression for the recuperation operator, and estimate the distance between μ and its approximation. We show that these estimates are the best possible in many different ways. In particular, we offer one explanation as to why an approximation of a finitely supported measure is bounded from below if the amount of information is smaller than what is demanded in the super-resolution problem. (Received August 20, 2018)

1143-41-539 **Bingying Lu*** (bylu@umich.edu), 530 Church St, Ann Arbor, MI 48109, and **Peter D Miller** (millerpd@umich.edu), 530 Church St, Ann Arbor, MI 48109. *The semi-classical sine-Gordon equation, universality at the gradient catastrophe and Painlevé-I equation.*

We consider a class of solutions with pure impulse initial data below critical value such that within small time only librational-type waves are generated and the solutions should decay when $|x| \to \infty$. In a neighbourhood of a certain gradient catastrophe point that contains both modulated plane waves and localized structures, the asymptotic behaviour of the solutions can be universally described by analyzing a Riemann-Hilbert problem related to Painlevé I equation Tritronquée solutions. It is a well-known fact that the solution to Painlevé equations have poles. In fact we show the locations of the poles are directly linked to where the "spikes" happen. In suitable scaling limit, we are able describe the first correction of the solution (compared to before breaking happens) using Painlevé I Tritronquée solution away from the "spikes", and then modify the Riemann-Hilbert problem to describe the "spike" shapes. Notice that this result is universal in the sense that the local

asymptotics is not sensitive to the initial condition as long as it falls into a large class. Our technique is the Deift-Zhou steepest descent method related to an approach of Bertola and Tovbis to universality for the focusing nonlinear Schrödinger equation. (Received August 21, 2018)

42 ► Fourier analysis

1143-42-24 **Alexander I. Aptekarev**, **Sergey A. Denisov** and **Maxim L. Yattselev***, Department of Mathematical Sciences, IUPUI, 402 North Blackford Street, Indianapolis, IN 46202. *Self-adjoint Jacobi matrices on trees and multiple orthogonal polynomials.*

We consider a set of measures on the real line and the corresponding system of multiple orthogonal polynomials (MOPs) of the first and second type. Under some very mild assumptions, which are satisfied by Angelesco systems, we define self-adjoint Jacobi matrices on certain rooted trees. We express their Green's functions and the matrix elements in terms of MOPs. This provides a generalization of the well-known connection between the theory of polynomials orthogonal on the real line and Jacobi matrices to higher dimension. (Received June 15, 2018)

43 ► Abstract harmonic analysis

1143-43-268 **Chunping Xie*** (xie@msoe.edu), 1025 N Broadway, Milwaukee, Milwaukee, WI 53202. *A_∞ Weight Extrapolation.* Preliminary report.

In this paper, we generalize the extrapolation theorem from A_p weights to A_∞ weights on Weighted Morrey space by using the Rubio de Francia algorithm. (Received August 16, 2018)

44 ► Integral transforms, operational calculus

1143-44-317 **Yang Zhang*** (zhan1891@purdue.edu). *Artifacts in the Inversion of the Broken Ray Transform in the Plane.*

We study the integral transform over a general family of broken rays in $\mathbb{R}^2$. One example of the broken rays is the family of rays reflected from a curved boundary once. There is a natural notion of conjugate points for broken rays. If there are conjugate points, we show that the singularities conormal to the broken rays cannot be recovered from local data and therefore artifacts arise in the reconstruction. As for global data, more singularities might be recoverable. We apply these conclusions to two examples, the V-line transform and the parallel ray transform. In each example, a detailed discussion of the local and global recovery of singularities is given and we perform numerical experiments to illustrate the results. (Received August 17, 2018)

46 ► Functional analysis

1143-46-136 **Daniel Spector***, dspector@math.nctu.edu.tw. *An Optimal Sobolev Embedding for L^1.* Preliminary report.

In this talk we discuss a recent result obtained by the author, the following optimal Lorentz space estimate for the Riesz potential acting on curl-free vectors: There is a constant $C = C(\alpha, d) > 0$ such that

$$\|I_\alpha F\|_{L^{d/(d-\alpha),1}(\mathbb{R}^d;\mathbb{R}^d)} \leq C\|F\|_{L^1(\mathbb{R}^d;\mathbb{R}^d)}$$

for all fields $F \in L^1(\mathbb{R}^d;\mathbb{R}^d)$ such that $\operatorname{curl} F = 0$ in the sense of distributions. This is the best possible estimate on this scale of spaces and completes the picture in the regime $p = 1$ of the well-established results for $p > 1$. (Received August 06, 2018)

47 ► Operator theory

1143-47-132 **Jake Fillman***, Mathematics (MC0123), 225 Stanger Street, Blacksburg, VA 24061, and **Rui Han**. *Discrete Bethe–Sommerfeld conjecture for square, triangular, and hexagonal lattices.*

We will discuss versions of the Bethe–Sommerfeld conjecture on the triangular lattice, the hexagonal lattice, and the square lattice with next-nearest-neighbor interactions. In each case, we prove bounds on the number of gaps

that may be opened in the spectrum in the perturbative regime as well as conditions on the period lattice that reduce the number of spectral gaps. We also exhibit examples to show that these bounds are sharp. (Received August 06, 2018)

1143-47-323 **Jacob Christiansen**, **Benjamin Eichinger** and **Tom VandenBoom*** (thomas.vandenboom@yale.edu). *A Magic Formula for Almost-Periodic CMV Matrices.* Preliminary report.

We prove that any absolutely continuous, almost-periodic CMV matrix with finite-gap type spectrum E is unitary equivalent to an operator Möbius transformation of a periodic (up to a phase) CMV matrix. Such operators have previously been related to bases of orthogonal rational functions. When suitably defined, these operators satisfy a Magic Formula analogous to that of Damanik-Killip-Simon precisely when the corresponding almost-periodic CMV matrices lie in the isospectral torus for E. (Received August 17, 2018)

1143-47-335 **Martin Gebert***, UC Davis, 1 Shields Ave, Davis, CA 95616. *A lower Wegner estimate and bounds on the spectral shift function for continuum random Schrödinger operators.*

In this talk we prove a strictly positive, locally uniform lower bound on the density of states (DOS) of continuum random Schrödinger operators on the entire spectrum, i.e. we show that the DOS does not have a zero within the spectrum. This follows from a lower Wegner estimate for finite-volume continuum random Schrödinger operators. We assume throughout iid random variables and the single-site distribution having a Lebesgue density bounded from below on its support. The main mathematical novelty are pointwise-in-energy bounds on the expectation of the spectral shift function at all energies for these operators where we mainly focus on perturbations corresponding to a change from Dirichlet to Neumann boundary conditions along the boundary of a cube. We show that the bound scales with the area of the hypersurface where the boundary conditions are changed. (Received August 18, 2018)

1143-47-355 **Rodrigo Matos*** (matosrod@msu.edu), 619 Red Cedar Road, C531, East Lansing, MI 48824, and **Jeffrey Schenker**. *Localization for the Hubbard model in the Hartree approximation via fractional moments.*

We are interested in localization for systems of infinitely many interacting particles. Using the fractional moment method it is shown that, within the Hartree approximation for the random Hubbard Hamiltonian, fermions at positive temperature exhibit localization, suitably defined as exponential decay of eigenfunction correlators, in the regime of large disorder and weak interaction. (Received August 18, 2018)

1143-47-393 **Simon Becker** and **Rui Han*** (rhan2@uci.edu), Skiles Building, Office 226, Georgia Institute of Technology, Atlanta, GA 30332, and **Svetlana Jitomirskaya**. *Cantor spectrum of graphene in magnetic fields.*

In this talk, we present a full analysis of the spectrum of graphene in magnetic fields with constant flux through every hexagonal comb of the graphene structure. In particular, we provide a rigorous foundation for self-similarity by showing that for irrational flux quanta, the electron spectrum of graphene is a Cantor set. (Received August 19, 2018)

1143-47-395 **Svetlana Jitomirskaya** and **Fan Yang*** (ffyangmath@gmail.com), Skiles Building, Office 226, Atlanta, GA 30332. *Spectral transition line in phase for the almost Mathieu operator.*

In this presentation, we will talk about the spectral transition line in phase for the almost Mathieu operator in the positive Lyapunov exponent regime. We show both pure point spectrum and purely singular continuous spectrum occur for dense subsets of phases on this transition line. (Received August 19, 2018)

1143-47-545 **Jeffrey Schenker**, **F Zak Tilocco*** (tiloccof@msu.edu) and **Shiwen Zhang**. *Diffusion in the Mean for a Periodic Schrödinger Equation Perturbed by a Fluctuating Potential.*

We consider the solution to a tight-binding, periodic Schrödinger equation with a random potential evolving stochastically in time. If the potential evolves according to a stationary Markov process we obtain a positive, finite diffusion constant for the evolution of the solution. More generally, we show that the square amplitude of the wave packet, after diffusive rescaling, converges to a solution of the heat equation. This work generalizes the previous results of Y. Kang and J. Schenker on the free Laplace and J. Schenker on the Anderson model (Joint work with J. Schenker and S. Zhang). (Received August 21, 2018)

49 ► Calculus of variations and optimal control; optimization

1143-49-15 **Ugur G. Abdulla**, **Vladislav Bukshtynov** and **Saleheh Seif*** (sseif2014@my.fit.edu), 316 Georgetown ave, Melbourne, FL 32901. *Breast Cancer Detection via Electrical Impedance Tomography and Optimal Control Theory for Systems with Distributed Parameters.*

Ugur G. Abdulla, Vladislav Bukshtynov and Saleheh Seif

We analyze the inverse problem of breast cancer detection through Electrical Impedance Tomography (EIT). Inverse EIT problem consists in recovering electrical conductivity tensor and potential within the body based on the measurement of the boundary voltages on the electrodes for given electrode current. We consider inverse EIT problem as an optimal control problem for elliptic PDE. Electrical conductivity and boundary voltages are control parameters and the cost functional is L_2 norm declination of the boundary electrode current from given current pattern. We prove the existence of optimal control and Frechet differentiability in the Banach space of bounded measurable matrix functions, and derive the optimality condition. The discretization of the optimal control problem through finite differences is implemented and the convergence of the sequence of discrete optimal control problems to continuous optimal control problem is analyzed. We pursue numerical analysis by implementing projective gradient method in Banach spaces, re-parametrization, Tikhonov regularization and sensitivity analysis with respect to relative size and locations of cancerous tumors. (Received May 26, 2018)

1143-49-406 **Marta Farré Puiggalí*** (mfarrepu@umich.edu), 2074 East Hall, 530 Church Street, Ann Arbor, MI 48109. *Applications of the inverse problem to the stabilization of controlled Lagrangian systems.*

The inverse problem of the calculus of variations consists in determining whether or not a given system of second order differential equations is equivalent to some regular Lagrangian system. I will explain how to apply some results of the inverse problem to the stabilization of controlled Lagrangian systems. (Received August 20, 2018)

1143-49-519 **Domenico D'Alessandro*** (daless@iastate.edu), Department of Mathematics, Iowa State University, 440 Carver Hall, Ames, IA 50011. *Geometric Optimal Control of a Class of Quantum Systems.*

In the control of finite dimensional quantum systems, a very common class of time optimal problems is amenable of explicit solutions. These are called K-P problems. The K-P structure refers to an underlying Cartan-type K-P decomposition of the Lie algebra su(n) such that only the operators corresponding to the P part of the decomposition appear in the Schrodinger equation of the system. The time optimal control problem is equivalent to finding appropriate sub-Riemannian geodesics. We describe the case of a two level quantum system (qubit) and use it to illustrate the general theory. In particular, we explicitly derive the minimum time trajectories between any two states for this system. This analysis also reveals some general features of the optimal synthesis such as: the cut locus, the geometry of the set of reachable states at each time and the sub-Riemannian diameter. Furthermore, such an analysis leads to the general consideration of the role of symmetries in optimal control problems. The explicit nature of the solution of the optimal control problem provided lends itself to generalizations to other systems of interest in applications. We shall in particular illustrate the case of N qubits controlled in parallel in minimum time. (Received August 21, 2018)

51 ► Geometry

1143-51-47 **Michael Gerard Ruddy*** (mgruddy@ncsu.edu), **Irina Kogan** and **Cynthia Vinzant**. *Signatures of Algebraic Curves.* Preliminary report.

For the action of G on the plane, the group equivalence problem for curves can be stated as: given two curves, decide if they are related by an element of G. The signature method to answer the local group equivalence problem for smooth curves and its application to image science has been extensively studied. However, computing an implicit equation of a signature curve is a challenging problem. In this talk we consider signatures for algebraic curves and show that the degree of the polynomial vanishing on the signature can be predicted without computing the polynomial explicitly. Additionally, we express the degree of the signature polynomial for a generic curve in terms of the curve's degree for the Euclidean, affine, and projective actions. We present some interesting examples including the signature polynomial for Fermat curves. (Received July 12, 2018)

1143-51-49 **Elsa Ghandour*** (elsa.ghandour@hotmail.com), , France. *3-dimensional Ricci solitons under biconformal deformations.*

Biconformal deformations in the presence of a conformal foliation by curves are exploited to study equivalence between 3-dimensional Ricci solitons. We describe a 1-parameter family of soliton metrics which interpolates between hyperbolic 3-space, the product of the hyperbolic plane with the real line and the geometry Sol. Each member of the family is a biconformal deformation with respect to the foliation of $\mathbb{R}^3$ of parallel lines. We also describe a family of solitons containing the geometry Nil which collapses to $\mathbb{R}^2$ endowed with the Gaussian soliton structure. (Received July 19, 2018)

52 ► Convex and discrete geometry

1143-52-276 **Frédéric Bihan** and **Ivan Soprunov*** (i.soprunov@csuohio.edu), Department of Mathematics, Cleveland State University, Cleveland, OH 44115. *Strict monotonicity of the mixed volume.*

The Bernstein-Kushnirenko-Khovanskii (BKK) theorem gives an upper bound for the number of isolated solutions to a Laurent polynomial system in terms of the mixed volume of the Newton polytopes of the system. It also provides a criterion for when this bound is met. By definition, the mixed volume $V(P_1,\dots,P_n)$ is the polarization of the Euclidean volume form; in particular $V(P,\dots,P) = \mathrm{vol}(P)$. Moreover, the mixed volume is monotone with respect to the inclusion, that is $V(P_1,\dots,P_n) \le V(Q_1,\dots,Q_n)$, whenever $P_i \subseteq Q_i$ for $1 \le i \le n$. Our main result is a criterion for when this inequality is strict. In particular, if polytopes $P_1,\dots,P_n$ are contained in an n-dimensional polytope Q we show that $V(P_1,\dots,P_n) < \mathrm{vol}(Q)$ if and only if Q has a face of dimension $k < d$ which is touched by at most k of the P_i. As an application of this criterion we obtain a simple test which detects when a system with the same Newton polytope does not meet the BKK bound. The test requires comparing the ranks of certain submatrices of the coefficient matrix and the exponent matrix of the system, which is computationally more efficient than the BKK criterion. (Received August 16, 2018)

53 ► Differential geometry

1143-53-11 **Adela Mihai***, Bd. Lacul Tei 122-124, 020396 Bucharest, Romania. *Recent Results in the Geometry of Einstein Spaces.* Preliminary report.

Given a compact C^∞-differentiable manifold M, $\dim M = n$, the following question arises (René Thom, Strasbourg Math. Library, 1958):

Are there any best (or nicest, or distinguished) Riemannian structures on M ?

A good candidate for such a privileged metric on a given manifold is an *Einstein* metric, if one considers the *best metrics* those of constant sectional curvature. More precisely, if the dimension of the manifold is greater than 2, a good generalization of the concept of constant sectional curvature might be the notion of *constant Ricci curvature.*

A Riemannian manifold (M, g) of dimension $n \ge 3$ is called an *Einstein space* if $Ric = \lambda \cdot id$, where trivially $\lambda = \kappa$, with k the (normalized) *scalar curvature*; in this case one easily proves that $\lambda = \kappa = constant$.

Singer and Thorpe (1969) discovered a symmetry of sectional curvatures which characterizes 4-dimensional Einstein spaces. Later, this result was generalized by B.Y. Chen e.a. [Proc. AMS, 2000] to Einstein spaces of even dimensions $n = 2k \ge 4$. The present author and U. Simon [Colloq. Math., 2018] established curvature symmetries for Einstein spaces of arbitrary dimension $n \ge 4$. (Received May 19, 2018)

1143-53-18 **Ramesh Sharma*** (rsharma@newhaven.edu), 300 Boston Post rd., West Haven, CT. *Some results on Lagrangian Submanifolds Of Nearly Kaehler 6-sphere.* Preliminary report.

Recently, it has been shown by Sharma, Deshmukh and Al-Solamy that a unit tangent vector field ξ on a Lagrangian manifold M of the nearly Kaehler unit 6-sphere $S^6(1)$ induces an almost contact metric structure called the canonical almost contact structure on M. We prove: (1) Let the canonical almost contact structure be normal. Then the second fundamental form of M annihilates ξ (hence Chen's equality is satisfied) if and only if the sectional curvature of M with respect to plane sections containg ξ equals 1. If, in addition, the second fundamental form is parallel along ξ and M is not cosymplectic, then it is locally totally geodesic unit 3-sphere. (2) If the canonical almost contact metric structure is quasi-Sasakian, then it is α-Sasakian which becomes Sasakian when the second fundamental form annihilates ξ. (Received June 05, 2018)

1143-53-34 **Timothy James Buttsworth*** (timothy.buttsworth@uq.net.au). *The Dirichlet Problem for Cohomogeneity One Einstein Metrics.*

Einstein metrics are of fundamental interest in geometry. In the cohomogeneity one setting, the problem of finding an Einstein metric is equivalent to solving a system of ODEs, describing the evolution of a family of submanifolds. In this talk, I describe how Schauder degree theory can be used to solve the Dirichlet problem for this system. This result contributes to the well-known and difficult question of understanding boundary-value problems for Einstein metrics. (Received July 03, 2018)

1143-53-35 **Paul Baird**, **Ye-Lin Ou*** (yelin.ou@tamuc.edu) and **Elsa Ghandour**. *Some recent work on biharmonic conformal maps between Riemannian manifolds.*

Biharmonic maps are generalizations of harmonic maps and biharmonic functions, and they include biharmonic submenisolds as special cases. These maps are maps between Riemannian manifolds that are critical points of the bienergy functional, they are solutions of a system of 4th order PDEs. This talk will report some recent work on biharmonic conformal immersions, biharmonic conformal submersions, biharmonic conformal maps between manifolds of the same dimension, and their relations to the maps between manifolds that preserve solutions of bi-Laplace equations and their links to Yamabe-type equations. (Received July 04, 2018)

1143-53-73 **Hemangi M. Shah*** (hemangimshah@hri.res.in), Chhatnag Road, Jhunsi, Allahabad, UP 211019, India. *Geometry of Asymptotically harmonic manifolds with minimal horospheres.*

(M^n, g) be a complete Riemannian manifold without conjugate points. We show that if M is also simply connected, then M is flat, provided that M is also asymptotically harmonic manifold with minimal horospheres (AHM). The (first order) flatness of M is shown by using the strongest criterion: $\{e_i\}$ be an orthonormal basis of T_pM and $\{b_{e_i}\}$ be the corresponding Busemann functions on M. Then, (1) The vector space $V = span\{b_v | v \in T_pM\}$ is finite dimensional and dim V = dim $M = n$. (2) $\{\nabla b_{e_i}(p)\}$ is a global parallel orthonormal basis of T_pM for any $p \in M$. Thus, M is a parallizable manifold. And (3)$F : M \to R^n$ defined by $F(x) = (b_{e_1}(x), b_{e_2}(x), \cdots, b_{e_n}(x))$, is an isometry and therefore, M is flat. Consequently, AH manifolds can have either polynomial or exponential volume growth, generalizing the corresponding result for harmonic manifolds. In case of harmonic manifold with minimal horospheres (HM), the (second order) flatness was proved by Ranjan and Shah by showing that $span\{b_v^2 | v \in T_pM\}$ is finite dimensional. (Received July 29, 2018)

1143-53-80 **Ion Mihai*** (imihai@fmi.unibuc.ro), Faculty of Mathematics and Computer Science, Str. Academiei 14, 010014 Bucharest, Romania. *Statistical Manifolds and Their Submanifolds. Results on Chen-like Invariants.* Preliminary report.

Statistical manifolds were introduced by S. Amari [Springer, 1985]. They generalize the Hessian manifolds. The geometry of statistical manifolds and their submanifolds is an actual topic of research in pure and applied mathematics.

M.E. Aydin, A. Mihai and the present author [Filomat, 2015] obtained geometric inequalities for the scalar curvature and Ricci curvature associated to the dual connections for submanifolds in statistical manifolds of constant curvature.

The same authors [Bull. Math. Sci., 2017] proved a generalized Wintgen inequality for such submanifolds.

Recently, in co-operation with A. Mihai [Mathematics, 2018], we established a Euler inequality and a Chen-Ricci inequality for submanifolds in Hessian manifolds of constant Hessian curvature.

We shall continue the study of Chen-like invariants on such submanifolds. (Received July 31, 2018)

1143-53-83 **David E. Blair*** (blaird@msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Whitney spheres in complex and contact geometry.*

We begin with the question that since Gromov (1985) proved that the sphere S^n can not be embedded in $\mathbb{C}^n$ as a Lagrangian submanifold, what is the next best thing? The answer is the Whitney sphere and we will discuss its characterization as such; this was a result of Professor Bang-Yen Chen together with V. Borrelli and J. M. Morvan (1995). In a related vein Professor Chen introduced the notion of a Lagrangian H-umbilical submanifold and proved classification results in complex space forms.

We will also discuss contact geometry for two reasons. First Prof. Chen uses Legendre curves in S^3 in his construction of Lagrangian H-umbilical submanifolds (1997). Secondly we define a contact Whitney sphere as an embedded sphere in the contact manifold $\mathbb{R}^{2n+1}$ and present a characterization corresponding to the Borrelli-Chen-Morvan result as given in my joint work with A. Carriazo (2000). (Received July 31, 2018)

1143-53-125 **Marilena Moruz** and **Luc Vrancken*** (luc.vrancken@univ-valenciennes.fr), Universite Polytechnique de Haut de France, Campus du Mont Houy, 59313 Valenciennes, Nord, France. *Warped product hypersurfaces.*

Classical examples of warped product hypersurfaces in a real space form are the rotational hypersurfaces. In this talk we show that in some sense the reverse statement is also true, i.e. let $M = I \times_f N(\tilde{c})$ be a warped product manifold of an interval with a real space form and assume that M is contained as a hypersurface in a real space form. Then either M is itself a space of constant sectional curvature or M is a rotational hypersurface in the sense of Dajczer and Do Carmo. (Received August 06, 2018)

1143-53-126 **M. P. Dussan**, **A. P. Franco Filho** and **M. A. Magid*** (mmagid@wellesley.edu). *Isotropic surfaces of the de Sitter space* $\mathbb{S}^3_1(1) \subset \mathbb{R}^4_1$.

We present a method of describing all timelike surfaces in $\mathbb{S}^3_1(1)$ using null coordinates (u, v) and the complex variable $w = u + iv$. Using stereographic projection we identify the Grassmannian of spacelike planes in $\mathbb{R}^4_1$ with a quadric in complex projective space. We give necessary and sufficient conditions for lifting our isotropic surface in $\mathbb{S}^3_1(1)$ into the complex quadric in terms of three complex valued functions. We recover the surface as the real part of this lifting. We also obtain a system of differential equations in terms of the complex functions which characterize minimal surfaces. In the case where the functions are holomorphic we can solve the system explicitly. (Received August 06, 2018)

1143-53-141 **Shihshu Walter Wei*** (wwei@ou.edu), 601 Elm Ave # 423, Department of Mathematics, University of Oklahoma, Norman, OK 73019. *Average methods in Warped product manifolds, geometric function and mapping theory.*

We will describe the background and the current work of Warped product manifolds, geometric function and mapping theory through the development of average methods and applications. (Received August 07, 2018)

1143-53-153 **Oscar J. Garay*** (oscarj.garay@ehu.es), Department of Mathematics., Faculty of Science and Technology., University of the Basque Country, 48080 Bilbao, Vizcaya, Spain. *Binormal evolution surfaces swept out by elastica-like extremals.*

The *localized induction equation* (LIE), also known as Da Rios' equation, describes the evolution of a vortex filament in incompressible fluids. Motivated by LIE, in this talk we analyze the evolution, in pseudo-riemannian 3-space forms, of extremal curves for energy functionals depending on the Frenet curvatures. We show that they evolve under naturally associated binormal flows with curvature dependent velocity.

Using basic results of the theory of submanifolds to study the geometry of this family of binormal evolution surfaces (BES), many interesting facts can be derived. Moreover, by choosing a suitable geodesic coordinate system, they can be expressed, usually, in terms of the Frenet curvatures of the evolving curves. Some of them are discussed in this talk, for instance: the geometric construction of binormal evolution surfaces; and the connection between travelling wave solutions of the Gauss-Codazzi equations and the *generalized Kirchhoff centerlines*.

Finally, we particularize our findings to three significant choices of the curvature energy. Binormal evolution of their extremals will give rise, respectively, to *Hasimoto surfaces*, *Hopf tubes*, and surfaces with constant mean curvature (*CMC surfaces*). (Received August 08, 2018)

1143-53-168 **Alfonso Carriazo*** (carriazo@us.es), Department of Geometry and Topology, Faculty of Mathematics, c/ Tarfia s/n, University of Seville, 41012 Seville, Spain. *Slant submanifolds in semi-Riemannian manifolds.*

In this talk we will review the main definitions about slant submanifolds in some different ambient manifolds, as well as the latest developments about this kind of submanifolds when we try to translate them to semi-Riemannian environments. (Received August 09, 2018)

1143-53-193 **Yun Myung Oh*** (ohy@andrews.edu), 4260 Administration Dr., Department of Mathematics, Berrien Springs, MI 49104. *Rectifying submanifolds in pseudo-Euclidean spaces and rectifying curves in Minkowski Space* $\mathbb{E}^4_1$.

The idea of rectifying submanifold was introduced by Bang-Yen Chen and he classified the rectifying submanifolds in Euclidean m-space $\mathbb{E}^m$ in 2016. It is natural to investigate the space-like rectifying submanifold in pseudo-Euclidean space $\mathbb{E}^m_i$ and in this talk, we will see that every proper rectifying pseudo-Riemannian submanifold in $\mathbb{E}^m_i$ is N-submanifold. The complete classification of proper rectifying submanifolds in $\mathbb{E}^m_i$ will be presented. Also, we investigate curvature functions for a unit speed rectifying time-like curve in Minkowski space at the end. (Received August 13, 2018)

1143-53-201 **Leonard M. Giugiuc** and **Bogdan D. Suceavă*** (bsuceava@fullerton.edu), 800 N. State College Blvd., Department of Mathematics, 154 McCarthy Hall, Fullerton, CA 92834-6850. *Strictly Convex Hypersurfaces Satisfying Weingarten-Type Inequalities.*

Linear Weingarten surfaces in three-dimensional ambient space satisfy a relation between mean curvature and Gaussian curvature: $aH^2+bK = c$. We investigate whether for hypersurfaces invariant to inversions of dimensions 3 and 4 there are curvature inequalities similar to the classical Weingarten condition. We also consider the globalization of these pointwise inequalities. This question is suggested by the investigations of Bang-Yen Chen's fundamental inequalities, as we reflect on the geometric interpretations of these relations. (Received August 13, 2018)

1143-53-218 **Ivan Contreras***, Department of Mathematics and Statistics, Amherst College, and **Rui Fernandes**, Department of Mathematics, University of Illinois, Urbana-Champaign. *Genus integration of Lie algebroids and abelianization.*

Lie algebroids are natural objects in Poisson geometry, e.g. the cotangent bundle T^*M of a Poisson manifold is equipped with a Lie algebroid structure. In this work we study the existence of an abelian integration of the abelianization of Lie algebroids. We prove that the obstructions of such integration are given by the so-called extended monodromy groups. We also show that the abelianization can be constructed geometrically, in terms of homology equivalence. (Received August 14, 2018)

1143-53-219 **Ivan Contreras***, Department of Mathematics and Statistics, Amherst College, and **Nicolas Martinez Alba**, Department of Mathematics, Universidad Nacional de Colombia. *Poly-Poisson geometry and field theories.*

Poly-Poisson geometry can be traced back to de-Donder and Weyl in 1930's. This approach leads to a poly-symplectic formulation of Lagrangian field theories, with several applications to mechanics. In this talk we address the problem of integration of poly-Poisson manifolds via Lagrangian field theories with boundary, which is a natural extension of the Poisson sigma model. (Received August 14, 2018)

1143-53-224 **Mark Levi*** (levi.psu@gmail.com), Mathematics Department, Penn State University, University Park, PA 16802. *Gaussian curvature, gyroscopic effects and the Jacobi fields.*

I will describe a surprising connection between the Gaussian curvature with the gyroscopic effect, and will explain this connection via Jacobi fields. (Received August 14, 2018)

1143-53-260 **Ivko M Dimitric*** (ivko@psu.edu), 2201 University Dr, PSU-Fayette, Lemont Furnace, PA 15456, and **Mirjana Djoric**. *A study of CR-submanifolds of Chen-type two in complex space forms.* Preliminary report.

We undertake a study of CR-submanifolds of non-flat complex space forms $\mathbb{C}Q^m(4c)$, $c = \pm 1$, which are of Chen 2-type via the standard embeddings by projectors. This means that the position vector of such submanifolds via these embeddings can be written as the sum of two vector eigenfunctions of the Laplacian (up to a translation). We characterize totally real submanifolds of 2-type which are assumed to be mass-symmetric or minimal as well as Lagrangian submanifolds with parallel mean curvature vector. We also prove some non-existence results for certain families of CR-submanifolds of complex space forms. For example, there exist no holomorphic submanifolds of the complex hyperbolic space which are of 2-type. We further show that there exist no ruled hypersurfaces in $\mathbb{C}Q(4c)$ of Chen-type two and comment on possible further research in this direction. (Received August 15, 2018)

1143-53-265 **Joeri Van der Veken*** (joeri.vanderveken@kuleuven.be), KU Leuven - Department of Mathematics, Celestijnenlaan 200B - Box 2400, 3001 Leuven, Belgium. *Lagrangian submanifolds of the complex quadric.*

The complex quadric Q^n is the complex hypersurface of complex $(n+1)$-dimensional projective space given in homogeneous coordinates by the equation $z_0^2+z_1^2+\ldots+z_{n+1}^2 = 0$. This manifold inherits a Kähler structure from the complex projective space, carries a family of non-integrable almost product structures and its curvature can be relatively easily described in terms of these two. Moreover, Q^n is the natural target space when considering the Gauss map of a hypersurface of a round sphere. In fact, such Gauss maps are related to minimal Lagrangian submanifolds of Q^n. We will discuss this relation – in particular for isoparametric hypersurfaces of spheres – and then study minimal Lagrangian submanifolds of Q^n, obtaining examples and some classifications, such as that of minimal Lagrangian submanifolds of Q^n with constant sectional curvature. (Received August 16, 2018)

1143-53-296 **Andrzej Derdzinski***, andrzej@math.ohio-state.edu. *Harmonic curvature and real algebraic geometry.* Preliminary report.

We present a step towards a classification of compact Riemannian four-manifolds, the curvature tensor of which is harmonic as a 2-form valued in 2-forms or, equivalently, the Ricci tensor of which satisfies the Codazzi equation. Specifically, this talk describes a reduction of the above classification question to a problem in real algebraic geometry, and outlines work in progress on the latter problem, joint with Paolo Piccione. (Received August 17, 2018)

1143-53-316 **David Martin de Diego*** (david.martin@icmat.es), ICMAT, Campus de Cantoblanco, UAM, C/ Nicolas Cabrera, 15, 28049 Madrid, Spain, and **Rodrigo Takuro Martin de Almagro**. *Variational order for forced Lagrangian discrete dynamics.*

In this talk, we will discuss how to derive the equations of motion for forced mechanical systems in a purely variational setting, both in the context of Lagrangian or Hamiltonian mechanics, by duplicating the variables of the system. Moreover, we show that this construction is useful to design high-order integrators for forced Lagrangian systems and, more importantly, we give a characterization of the order of a method applied to a forced system using the corresponding variational order of the duplicated one. (Received August 17, 2018)

1143-53-468 **Jordan Watts*** (jordan.watts@cmich.edu), Department of Mathematics, Central Michigan University, Mount Pleasant, MI 48859, and **Jean-Pierre Magnot**. *Classifying Spaces of Diffeological Groups.*

Fix an irrational number A, and consider the action of the group of pairs of integers on the real line defined as follows: the pair (m, n) sends a point x to $x + m + nA$. Since the orbits of this action are dense, the quotient topology on the orbit space is trivial and continuous real-valued functions are constant. Can we give the space any type of useful "smooth" group structure?

The answer is "yes": its natural diffeological group structure. It turns out this group is not just some pathological example, but has many interesting associated structures, and is of interest to many areas of mathematics. In particular, it shows up in geometric quantisation and the integration of certain Lie algebroids as the structure group of certain principal bundles, the main topic of this talk.

We will perform Milnor's construction in the realm of diffeology to obtain a diffeological classifying space for a diffeological group G, such as the irrational torus. After mentioning a few hoped-for properties, we then construct a connection 1-form on the G-bundle $EG \to BG$, which will naturally pull back to a connection 1-form on sufficiently nice principal G-bundles. We then look at what this can tell us about irrational torus bundles. (Received August 20, 2018)

1143-53-556 **Ekaterina Shemyakova*** (ekaterina.shemyakova@utoledo.edu), Department of Mathematics and Statistics, University of Toledo, Toledo, OH. *Obstructions to factorizations of differential operators on the algebra of densities on the line.*

Algebra of densities was introduced in 2004 by H.Khudaverdian and Th.Voronov in connection with Batalin-Vilkovisky geometry. It is a commutative algebra with unity and invariant scalar product naturally associated with every manifold (and containing the algebra of functions). It gives a convenient framework to consider differential operators acting on densities of different weights simultaneously. We shall show that factorization of differential operators acting on densities on the line is different from what we know for the classical case, where factorizations always exist and their structure is known due to Frobenius theorem. We explicitly describe the obstruction to factorization of generalized Sturm-Liouville operator in terms of a solution of the corresponding classical Sturm-Liouville equation.

(based on joint work with Th.Voronov) (Received August 21, 2018)

55 ► Algebraic topology

1143-55-20 **Montek Singh Gill*** (montekg@umich.edu). *Stable operads and spectral chains.*

Let $\mathcal{EZ}$ denote the Eilenberg-Zilber operad. McClure and Smith have constructed a small combinatorial E_∞ operad $\mathcal{MS}$ which embeds into $\mathcal{EZ}$ via an inclusion $\mathcal{MS} \to \mathcal{EZ}$. Both $\mathcal{EZ}$ and $\mathcal{MS}$ act naturally on the normalized cochains $\mathrm{N}^\bullet(X)$ of a simplicial set X. I will discuss a notion of suspension of operads, and the fact that $\mathcal{EZ}$ and $\mathcal{MS}$ admit stabilization maps $\Sigma\mathcal{EZ} \to \mathcal{EZ}$ and $\Sigma\mathcal{MS} \to \mathcal{MS}$. I will discuss a notion of a stable operad, and will discuss stable analogues $\mathcal{EZ}_{\mathrm{st}}$ and $\mathcal{MS}_{\mathrm{st}}$ of the Eilenberg-Zilber and McClure-Smith operads. I will then discuss some applications of these concepts, including a convenient notion of spectral chains. (Received June 12, 2018)

1143-55-21 **Ruian Chen*** (ruchen@umich.edu), 530 Church St., East Hall 2096, Ann Arbor, CA 48109-1043. *Constructible sheaves of spectra.*

In this talk, I will present the theory of Kan's combinatorial spectra and their sheaves. I show that the category of Kan spectral sheaves has co-localization, which allows constructions analogous to those in abelian sheaf theory, from sheafification to the six-functor formalism, on the levels of both the strict and derived categories. I will also explore the notions of E_∞-ring spectra and E_∞-ring spectral sheaves in the context of simplicial Kan spectral sheaves. Some of this this is joint work with Igor Kriz and Aleš Pultr. (Received June 12, 2018)

1143-55-32 **Yunze Lu*** (yunze@umich.edu). *$RO(G)$-graded coefficients of D_{2p}-equivariant cohomology.*

Let G be the dihedral group with $2p$ elements when p is a prime number. In this talk I will give an equivariant CW structure for real representation spheres of G and use that to compute the $RO(G)$-graded coefficients of equivariant cohomology with constant coefficients. If time permits, I will also explain the modifications needed for the Burnside ring case. (Received July 01, 2018)

1143-55-41 **XiaoLin Danny Shi*** (dannyshi@math.harvard.edu). *Real Orientations of Lubin–Tate spectra.*

We show that Lubin–Tate spectra at the prime 2 are Real oriented and Real Landweber exact. The proof is by application of the Goerss–Hopkins–Miller theorem to algebras with involution. For each height n, we compute the entire homotopy fixed point spectral sequence for E_n with its C_2-action given by the formal inverse. We study, as the height varies, the Hurewicz images of the stable homotopy groups of spheres in the homotopy of these C_2-fixed points. (Received July 08, 2018)

1143-55-105 **Marco Vergura*** (mvergura@uwo.ca). *Localization theory in an ∞-topos.*

Inspired by recent work [CORS18] in homotopy type theory, we develop the theory of *reflective subfibrations* of an ∞-topos $\mathcal{E}$. A reflective subfibration L of $\mathcal{E}$ is a pullback-compatible assignment of a reflective subcategory $\mathcal{D}_X \subseteq \mathcal{E}_{/X}$ with reflector L_X, for every $X \in \mathcal{E}$. Reflective subfibrations abound in homotopy theory, albeit often disguised, e.g., as stable factorization systems. Our work may thus lead to new insights on classically studied localizations. The added properties of a reflective *subfibration* L with respect to a mere reflective *subcategory* are crucial for most of our results. For example, we can prove that *L-local maps* (i.e., those $p \in \mathcal{E}_{/X}$ such that $L_X(p) \simeq p$) admit a classifying map. The existence of such a classifying map is a powerful tool we exploit to prove many results, including our main one, the existence of a reflective subfibration L' whose local objects are exactly those with L-local diagonal map.

References

[CORS18] J. D. Christensen, M. Opie, E. Rijke, and L. Scoccola, *Localization in Homotopy Type Theory*, arXiv e-prints (2018), arXiv:1807.04155.

(Received August 03, 2018)

1143-55-111 **J.D. Quigley***, 255 Hurley Hall, Notre Dame, IN 46556. *The parametrized Tate construction.*

The parametrized Tate construction is an equivariant enhancement of the classical Tate construction. I will define this construction and outline some applications to C_2-equivariant Mahowald invariants, blueshift for Real oriented spectra (joint work with Guchuan Li and Vitaly Lorman), and Real cyclotomic spectra (work-in-progress with Jay Shah). (Received August 04, 2018)

1143-55-112 **Kyle M Ormsby*** (ormsbyk@reed.edu), 3203 SE Woodstock Blvd, Portland, OR 97202. *Towards the η-periodic motivic sphere.* Preliminary report.

In motivic homotopy theory, the Hopf map η is non-nilpotent, supplying a first example of exotic behavior in the homotopy theory of smooth schemes. We study the η-periodic (or η-inverted) motivic sphere spectrum via the slice spectral sequence and (co)operations for "very effective" Hermitian K-theory. (Received August 04, 2018)

1143-55-115 **Bhargav Bhatt**, **Dustin Clausen** and **Akhil Mathew*** (amathew@math.uchicago.edu). *$K(1)$-local Algebraic K-theory.*

Let R be a ring. We consider the algebraic K-theory $K(R)$ of R, and then localize at $K(1)$ (mod p topological K-theory) at the prime p; explicitly this corresponds to inverting a Bott type element, and was first considered by Thomason for $\mathbb{Z}[1/p]$-algebras. We show that the $K(1)$-localization of $K(R)$ agrees with that of $K(R[1/p])$. Our method relies on the cyclotomic trace and the connection between TC and p-adic cohomology developed by Bhatt, Morrow, and Scholze. (Received August 04, 2018)

1143-55-130 **Piotr Pstragowski*** (pstragowski.piotr@gmail.com). *Synthetic spectra and the cellular motivic category.*

To any Adams-type homology theory we associate a notion of a synthetic spectrum, this is a spherical sheaf on the site of finite spectra with projective E-homology. We show that the ∞-category $\mathcal{S}yn_E$ of synthetic spectra based on E is symmetric monoidal, stable, and that it is in a precise sense a deformation of Hovey's stable homotopy theory of E_*E-comodules whose generic fibre is the ∞-category of spectra. It follows that the Adams spectral sequence in $\mathcal{S}yn_E$ interpolates between the topological and algebraic Adams spectral sequences.

We then describe a symmetric monoidal functor $\Theta_* : \mathcal{S}p_{\mathbb{C}} \to \mathcal{S}yn^{ev}_{MU}$ from the ∞-category of cellular motivic spectra over Spec($\mathbb{C}$) into an even variant of synthetic spectra based on MU and show that Θ induces an equivalence between the ∞-categories of p-complete objects for all primes p. This establishes a purely topological model for the p-complete cellular motivic category and gives a conceptual explanation of the "$C\tau$-philosophy" of Gheorghe, Isaksen, Wang and Xu. (Received August 06, 2018)

1143-55-131 **Andrew Blumberg**, **Teena Gerhardt*** (teena@math.msu.edu), **Michael Hill** and **Tyler Lawson**. *Hochschild homology for Green functors.*

Hochschild homology of a ring has a topological analogue for ring spectra, topological Hochschild homology (THH), which plays an essential role in the trace method approach to algebraic K-theory. For a C_n-equivariant ring spectrum, one can define C_n-relative THH. This leads to the question: What is the algebraic analogue of C_n-relative THH? In this talk, I will define twisted Hochschild homology for Green functors, which allows us to describe this algebraic analogue. This also leads to a theory of Witt vectors for Green functors, as well as an algebraic analogue of TR-theory. (Received August 06, 2018)

1143-55-134 **Foling Zou*** (zoufoling@uchicago.edu). *Equivariant factorization homology.* Preliminary report.

In this talk I will first discuss the two sided bar construction used by Andrade, Kupers, and Miller to define factorization homology. Factorization homology was first proposed by Ayala, Francis, and Lurie in algebraic topology. Then I will explain how to adapt this approach to the equivariant setting. (Received August 12, 2018)

1143-55-204 **Gabriel C Drummond-Cole** and **Philip Hackney*** (philip.hackney@louisiana.edu). *Dwyer–Kan homotopy theory for cyclic operads.*

Cyclic operads, introduced by Getzler–Kapranov, are operads with extra symmetries which allow one to exchange 'inputs' and 'outputs'. Many familiar operads admit a cyclic structure, for instance the associative, Lie and commutative operads, the A_∞ operad, and the framed little disks operads. We aim to study the homotopy theory for colored (i.e., multi-sorted) cyclic operads.

The Bergner model structure on categories enriched in simplicial sets admits an extension to the Cisinski–Moerdijk model structure on (colored) operads enriched in simplicial sets. The first is a model for $(\infty, 1)$-categories, while the second is a model for ∞-operads. The weak equivalences in both are called Dwyer–Kan equivalences, that is, maps which are locally Kan equivalences of simplicial sets and which induce equivalences on the underlying categories of components. We show that there is a corresponding model structure for the category of cyclic operads enriched in simplicial sets. (Received August 13, 2018)

1143-55-213 **Eduardo Fischer*** (edufisch@indiana.edu), 831 E 3rd St, Bloomington, IN 47401. *A criterion for weak equivalency of self-maps of complex cobordism.*

Let MUR be the complex cobordism spectrum with coefficients in R, $R \in \mathbb{Q}$. We give a criterion in terms of the formal coordinate for a self-map of MUR to be a weak equivalence. (Received August 13, 2018)

1143-55-448 **M A Mandell*** (mmandell@indiana.edu). *E_2 Structures and Derived Koszul Duality in String Topology.*

We construct an equivalence of E_2 algebras between two models for the Thom spectrum of the free loop space that are related by derived Koszul duality. To do this, we describe the functoriality and invariance properties of topological Hochschild cohomology. Joint work with Andrew Blumberg. (Received August 20, 2018)

1143-55-458 **Ugur Yigit*** (uyigit@ur.rochester.edu), Department of Mathematics, University of Rochester, Hylan 713, ROCHESTER, NY 14627. . Preliminary report.

In this talk, we calculate $RO(C_2)$-graded cohomology of C_2-equivariant Eilenberg-Mac Lane spaces. Then, I will describe C_2-equivariant lambda algebra. These are used to give the relation between equivariant lambda algebra and equivariant Adams resolution and equivariant unstable Adams spectral sequence, which are defined in author's dissertation. (Received August 20, 2018)

1143-55-568 **Calvin D Woo*** (calwoo@iu.edu), 831 E 3rd Street, Rawles Hall, Bloomington, IN 47405. *On a candidate for a relative log THH.*

In contract to the localization sequences for algebraic K-theory constructed by Quillen, the localization sequences of Hesselholt-Madsen/Blumberg-Mandell for THH involved a mysterious term connected to logarithmic differentials. However, it can be questioned whether there is a geometric picture underlying the sequence. Crystalline cohomology's connection to THH leads one to conjecture extra structures on the logarithmic term that gives it an algebro-geometric meaning.

In this talk I will sketch out a candidate for a relative log THH by a construction in analogy to classical Mokrane-Hyodo-Steenbrink complexes equipped with monodromy operators. (Received August 21, 2018)

57 ► Manifolds and cell complexes

1143-57-570 **Andrew Putman*** (andyp@nd.edu), Department of Mathematics, University of Notre Dame, 255 Hurley Hall, Notre Dame, IN 46556. *The mapping class group of a surface.*

The mapping class group of a surface plays an important role in many areas of mathematics, including topology, algebraic geometry, and dynamics. One of its appealing features is that its study requires a healthy balance between concrete (often visual) geometric arguments and sophisticated abstract machinery. I will give an introduction to this group, with a focus on its algebraic topology and finiteness properties. (Received August 21, 2018)

58 ► Global analysis, analysis on manifolds

1143-58-82 **Oscar E. Fernandez*** (ofernand@wellesley.edu), Department of Mathematics, 106 Central St, SCI 366, Wellesley, MA 02481. *The Quantum Mechanics of a Molecular "Nanocar".*

Recent experiments on molecular machines synthesized in labs have yielded a variety of "nanovehicles." Some of these, when deposited on surface and set into motion via an STM tip, have been observed to roll. In this talk I will discuss my collaboration with a chemist to formulate a mathematical model of a "molecular wheelbarrow"–a two-wheeled nanoscale molecular machine–synthesized recently. The model is a nonholonomic system (briefly, a system with non-integrable velocity constraints), for which no general quantization procedure exists. Nonetheless, I will discuss how we successfully embedded the system in a Hamiltonian one and then quantized the result using geometric quantization and other tools. One can then extract from the result the quantum mechanics of the molecular wheelbarrow, and I will overview the explicit formulae for the quantized energy spectrum we derived. Finally, I will discuss the four additional variants of our model we studied. Some of these ignore the model's nonholonomic constraints. As we will see, these variants have different quantum energy spectra, indicating that in such systems one should not ignore the nonholonomic constraints, since they alter in a non-trivial way the energy spectrum of the molecule. (Received July 31, 2018)

1143-58-430 **Steven B Damelin**, **David L Ragozin*** (dlragozin@comcast.net) and **Michael Werman**. *The metric structure of the space of G-equivalence classes of labelled points in Euclidean space for various subgroups, G, of affine transformations.*

We show how to realize the space of all G-equivalence classes, or G-orbits, of $n >= 1$ labelled points in R^k as a metric space with a computable metric for various groups $G \subseteq Aff(k) = GL(k) \ltimes R^k$, including the motion group and similarity group. A labelled n-point image is any $n \times k$ matrix $Y = [\mathbf{y}_1 \dots \mathbf{y}_n]^T \in M(n,k)$ with each $\mathbf{y}_i^T$ considered as the image, on the film hyperplane $(R^k)^T$ of a camera, of the ith labelled point on some object in R^{k+1}. When the camera moves via $(A, \mathbf{y}) \in G$ through the hyperplane, the new labelled image will be $Y \mapsto Y(A,\mathbf{u})^{-1} = YA^{-1} - \mathbf{1}_n(A^{-1}\mathbf{y})^T$ with $\mathbf{1}_n = [1 \dots 1]^T \in R^n$,

For any $X \in M(n,k)$ let $X_{norm} = X - \frac{1}{n}\mathbf{1}_n\mathbf{1}_n^T X$. Then our main result is

Theorem. The $G = SO(k) \ltimes R^k$ orbits of $Y, Z \in M(n,k)$ are equal if and only if the k-eigenvalues of $A = Y_{norm}^T Y_{norm}$ and $B = Z_{norm}^T Z_{norm}$ listed in non-increasing order are equal and the orthogonal eigenspaces for the each distinct eigenvalue are equal. (Received August 21, 2018)

1143-58-510 **Alexander Tovbis*** (alexander.tovbis@ucf.edu), Department of Mathematics, UCF, Orlando, 32816. *Towards kinetic equation for soliton and breather gases for the focusing Nonlinear Schroedinger equation.* Preliminary report.

Kinetic equation for a soliton gas for the Korteweg - de Vries equation was first proposed by V. Zakharov and later derived by G. El using the thermodynamic limit of the KdV-Whitham equations. Later, G. El and A. Kamchatnov proposed kinetic equation for the soliton gas for the focusing Nonlinear Schroedinger (fNLS) equation using physical reasoning.

In this talk, we consider the large N limit of nonlinear N-phase wave solutions to the fNLS equation subject to a certain scaling of the corresponding bands and gaps. In this limit, we obtain integral equations for the scaled wavenumbers and frequences and, as a consequence, derive the kinetic equation for soliton and breather gases, which takes into account soliton-soliton and soliton-background interactions. Our approach can be used to derive kinetic equation for the soliton gas on the background of any finite gap solution. (Received August 21, 2018)

1143-58-557 **Xiangjin Xu*** (xxu@math.binghamton.edu), Department of Mathematical Sciences, Binghamton university-SUNY, Binghamton, NY 13902-6000. *Sharp Li-Yau type gradient estimates and new heat kernel estimates on negative curved manifolds.* Preliminary report.

In this talk, based some new sharp Li-Yau type gradient estimates and new parabolic Harnack inequalities, both in local and global version, for the positive solution of the heat equations on a complete manifold with negative Ricci curvature lower bound, we obtain some new sharp Gaussian type lower bound and upper bound of the heat kernel on such manifolds, which are new even for the manifold with nonnegative Ricci curvature. We also achieve an upper bound of $\mu_(M) \geq 0$, the greatest lower bound of the L^2-spectrum of the Laplacian on a complete noncompact manifold, At the end, we discuss some open questions related to the sharp Li-Yau type estimates. (Received August 21, 2018)

60 ► Probability theory and stochastic processes

1143-60-8 **Samy Tindel*** (stindel@purdue.edu), Department of Mathematics, 150 N. University Street, West Lafayette, IN 47907, and **Yanghui Liu** (liu2048@purdue.edu), Department of Mathematics, 150 N. University Street, West Lafayette, IN 47907. *Some limit theorems obtained by rough paths techniques.* Preliminary report.

In this talk we focus on a series of results concerning p-variation limits, as well as Itô type formulas in law for Gaussian processes. This line of research has been quite active in the recent past in the stochastic analysis community. Most of the techniques involve integration by parts, Stein's method, and other Malliavin calculus tools. This yields a series of limitations on the nature of the results, as well as the dimension of the Gaussian process at stake. Our aim is to show how those questions can possibly be handled in a more natural way thanks to rough path type techniques. More specifically we will show how to transfer limits taken on a Gaussian signature to limits involving controlled processes, by means of the typical expansions of the rough paths theory. Applications of this rather simple trick include the aforementioned p-variations and Itô type formulas, as well as central limit theorems for numerical schemes. (Received April 30, 2018)

1143-60-16 **Snigdha Panigrahi** (snigdha@stanford.edu), Department of Statistics, Stanford University, Stanford,, CA 94305-4065, **Parthanil Roy** (parthanil.roy@gmail.com), Stat-Math Unit, Indian Statistical Institute, Bangalore 560059, India, and **Yimin Xiao*** (xiao@stt.msu.edu), Department of Statistics and Probability, Michigan State University, East Lansing, MI 48824. *Maximal Moments and Uniform Modulus of Continuity for Stable Random Fields.* Preliminary report.

Sample functions of self-similar stable random fields have interesting analytic and geometric properties which are more difficult to study compared with their Gaussian counterparts. In particular, many questions regarding regularity properties (e.g., uniform modulus of continuity, modulus of nondifferentiability) remain unsolved.

In this talk, we present some recent results on regularity properties of self-similar stable random fields. Based on the seminal works of Rosinski (1995, 2000) and Samorodnitsky (2004), we derive sharp results on the rate of growth of the maximal moments for many stationary symmetric stable random fields. As applications, we establish upper bounds for the uniform modulus of continuity of stable random fields with stationary increments. (Received May 26, 2018)

1143-60-28 **Joel A. Tropp*** (jtropp@cms.caltech.edu), 1200 E. California Blvd., MC 305-16, Pasadena, CA 91125, and **Samet Oymak** (oymak@ece.ucr.edu), Suite 343 Winston Chung Hall, 900 University Ave., Riverside, CA 92521. *Universality laws in geometric random matrix theory.*

A basic problem in geometry is to understand the probability that a uniformly random subspace of a given codimension intersects a fixed convex set. The hitting probability exhibits a phase transition as the codimension of the subspace increases. That is, the probability changes rapidly from one to zero when the codimension reaches the "statistical dimension," a geometric invariant of the convex set.

The focus of this talk is a new universality law in random matrix theory connected to this geometric problem. For a fixed convex set, the location of the phase transition is universal over a large class of random subspaces that are constructed as the kernels of random matrices. (Received June 25, 2018)

1143-60-30 **Zuopeng Fu*** (fuzg@mail.uc.edu) and **Yizao Wang**. *A family of manifold-indexed fractional stable processes.* Preliminary report.

A new family of fractional stable processes was introduced. They are presented as special examples of a family of set-indexed stable processes, including the Gaussian case, which can be viewed as natural extensions of self-similar stable processes with stationary increments indexed by $\mathbb{R}_+$. A limit theorem is established for the general set-indexed stable processes, and a few other related examples are discussed. (Received June 28, 2018)

1143-60-48 **Shui Feng*** (shuifeng@mcmaster.ca), 1280 Main Street West, Hamilton, Ontario L8S 4K1, Canada. *Asymptotic Behaviour of Homozygosity.*

Taking a random sample from a population consisting of individuals of countable number of types. The probability that all individuals in the sample are of the same type is called the homozygosity. This talk will provide a brief survey on the asymptotic behaviour of the homozygosity when the proportions of types follow the Poisson-Dirichlet distribution. These include the law of large numbers, the fluctuation theorems, and large deviations. (Received July 13, 2018)

1143-60-62 **Ahmad Reza Soltani*** (asoltanir@yahoo.com), PO Box 5969 Khaldiya, Department of Statistics and Operations Resea, College of Science , Safat 13060, Kuwait. *A Pivot Function and Its Limiting Distribution: An Application For the Martingale Central Limit Theorem in Testing Hypothesis and Constructing Confidence Regions.*

A pivot function which is in terms of the sample and the underlying population distribution is introduced. Then, the martingale central limit theorem is applied to prove that its limiting distribution is the standard normal. Interestingly, this result provides a unified procedure that can easily be applied for the purpose of parametric and non-parametric inference. (Received July 24, 2018)

1143-60-66 **Erkan Nane*** (ezn0001@auburn.edu), 221 Parker Hall, Auburn, AL 36849. *Fractional Cauchy problems on compact manifolds.*

We investigate anomalous diffusion on compact Riemannian manifolds, modeled by time-changed Brownian motions. These stochastic processes are governed by equations involving the Laplace-Beltrami operator and a time-fractional derivative of order $\beta \in (0, 1)$. We also consider time dependent random fields that can be viewed as random fields on randomly varying manifolds. We discuss time fractional Cauchy problems on the sphere as an example. Some of these random fields on the sphere exhibit a kind of "long range dependence".

The results presented are our recent joint work with Mirko D'ovidio. (Received July 25, 2018)

1143-60-67 **Zaoli Chen** (zc288@cornell.edu) and **Gennady Samorodnitsky*** (gs18@cornell.edu). *Infinitely divisible random fields with long range dependence.*

It has been established now that long range dependence of stationary infinitely processes is strongly related to ergodic-theoretical properties of the shift operatior acting on its L'evy measure. We discuss one case in which these ideas can can be extended to stationary infinitely divisible random fields. (Received July 26, 2018)

1143-60-109 **Kazuo Yamazaki***, Department of Mathematics, University of Rochester, Rochester, NY 14627. *Some results concerning the fluid dynamics PDE forced by random noise.* Preliminary report.

I will discuss some recent developments in the directions of research on fluid dynamics PDE forced by random noise in which I was involved. The systems of equations to be discussed should include Navier-Stokes equations, magnetohydrodynamics system, Hall-magnetohydrodynamics system, potentially KPZ equations and more. The directions of research to be discussed may include well-posedness in case the noise is white in time, Markov selections, ergodicity, and the well-posedness in case the noise is white in both space and time which requires

techniques from theories of rough path, regularity structures or paraproduct distributions. (Received August 03, 2018)

1143-60-128 **Kathryn Stewart*** (kal150@case.edu), Department of Mathematics, Case Western Reserve University, 231 Yost Hall, Cleveland, OH 44106. *Truncations of Haar distributed random matrices.*

In this talk I will give an overview on truncations, that is, principal submatrices, of an $n \times n$ random Haar distributed matrix. I will discuss a result of T. Jiang showing that the entries of an $m \times m$ square truncation of a random matrix from the orthogonal group are approximately jointly Gaussian when $m = o(\sqrt{n})$. I will further discuss how this result holds in the non-square case as long as the total number of entries in the submatrix is $o(n)$. I will also consider limiting spectral measures for square truncations of random matrices from the unitary group in joint work with E. Meckes. (Received August 06, 2018)

1143-60-157 **Rafal Kulik*** (rkulik@uottawa.ca), 585 King Edward Ave., Ottawa, Ontario K1N6N5, Canada. *Change-Point Problem For Long Memory Stochastic Volatility Models.*

In this talk we consider change-point problems for long memory stochastic volatility models. We show that the limiting behavior for the CUSUM test statistics may not be affected by long memory, unlike the Wilcoxon test statistic which is typically influenced by long range dependence. We compare our results to subordinated long memory Gaussian processes. Theoretical properties are accompanied by simulation studies.

This is joint work with Annika Betken (Bochum). (Received August 08, 2018)

1143-60-163 **Roman Vershynin*** (rvershyn@uci.edu), Department of Mathematics, University of California, Irvine, Irvine, CA 92697, and **Pierre Baldi** (pfbaldi@ics.uci.edu), Department of Computer Science, Irvine, CA 92697. *Invertibility of random tensors.*

Invertibility of random matrices is now sufficiently well understood. Extending this theory to random tensors is challenging. Our initial advances on the invertibility problem for random tensors are motivated by questions about Boolean functions. A "smooth" Boolean function is obtained by taking the sign of some polynomial of low degree in n variables. Such functions are called polynomial threshold functions, and they are widely used in machine learning as classification devices. An old question of M. Saks is - how many polynomial threshold functions of a given degree are there? Answering this question, we find a tight asymptotic bound on this number. Invertibility result on random tensors plays a key role in the argument. (Received August 08, 2018)

1143-60-169 **Shuyang Bai*** (bsy9142@uga.edu), **Takashi Owada** and **Yizao Wang**. *A non-central limit theorem on heavy-tailed chaos.* Preliminary report.

We introduce the partial-sum limit theorems for a class of stationary sequences exhibiting both heavy tails and long-range dependence. The stationary sequences are constructed using heavy-tailed multiple stochastic integrals and conservative null dynamical systems. The limits are represented by multiple stables integrals, where the integrands involve the local times of the intersections of stationary stable regenerative sets. This is a joint work with Takashi Owada and Yizao Wang. (Received August 09, 2018)

1143-60-214 **Hoi H. Nguyen***, 231 W. 18th Ave., Columbus, OH 43210. *A universality result for the cokernel of random integral matrices.*

For a random matrix of entries sampled independently from a fairly general distribution in Z we discuss the probability that the cokernel is isomorphic to a given finite abelian group, or when it is cyclic. We will show that these statistics are asymptotically universal, given by precise formulas involving zeta values, and agree with distributions defined by Cohen and Lenstra.

Based on joint work with M. M. Wood. (Received August 13, 2018)

1143-60-215 **Zhigang Bao**, **Xiucai Ding** and **Ke Wang*** (kewang@ust.hk), Department of Mathematics, HKUST, Clear Water Bay, Kowloon, 999077, Hong Kong. *Limiting distribution of outlier singular vectors of low-rank matrices with additive random noise.*

In this talk, we consider the matrix model Y=S+X where S is a low-rank deterministic matrix, representing the signal, and X is a random noise. It is a central task in high dimensional data analysis to understand how the spectral properties of S are altered with a small random perturbation. We give a precise description of the limiting distribution of the angles between the outlier singular vectors of Y with their counterparts, the leading singular vectors of S. It turns out that the limiting distribution depends on the structure of S and the distribution of X, and thus is non-universal. This talk is based on a joint work with Zhigang Bao and Xiucai Ding. (Received August 14, 2018)

1143-60-228 **Kyle Luh**, Harvard University, and **Sean O'Rourke***, Department of Mathematics, University of Colorado Boulder, Campus Box 395, Boulder, CO 80309-0395. *Optimal delocalization bounds for eigenvectors of independent-entry random matrices.*

Intuitively, one expects the unit eigenvectors of a large-dimensional random matrix to behave like random vectors uniformly distributed on the unit sphere. This instinctive idea can be heuristically justified by quantifying various properties of the eigenvectors. In this talk, I will focus on some specific delocalization properties of the eigenvectors of independent-entry matrices, which match corresponding properties of uniformly distributed unit vectors. As an application, I will also consider normal vectors to random hyperplanes. (Received August 14, 2018)

1143-60-232 **Shunlong Luo**, **Jie Shen*** (j52shen@uwaterloo.ca) and **Yi Shen**. *Noether Theorem for random locations.*

We propose a unified framework for random locations exhibiting some probabilistic symmetries. A theorem of Noether's type is proved, which gives rise to a conservation law describing the change of the density function of a random location as the interval of interest changes. We also discuss the boundary and near boundary behaviour of the distribution of the random locations. (Received August 14, 2018)

1143-60-250 **Farzad Sabzikar*** (sabzikar@iastate.edu), 2218 Snedecor Hall, AMES, IA 50011, and **Mark Meerschaert** and **Ian McLeod**. *Semi-long range dependence.*

A popular model of long range dependence involves a correlation function that falls off like a power law. This class includes fractional Brownian motion, fractional Gaussian noise, and fractional ARIMA time series. We present a novel modification of these models that involves tempering the power law correlation function with an exponential. This results in a tempered fractional Brownian motion, tempered fractional Gaussian noise, and tempered fractional ARIMA time series. Several applications will be presented to illustrate the mathematical advantages, statistical advantages, and practical utility of the new model. (Received August 15, 2018)

1143-60-261 **Alfred Olivier Hero***, 1301 Beal Ave, Ann Arbor, MI 48105. *Continuum limits for shortest paths.*

Many applications involve computing shortest paths over the nodes of a graph relative to a measure of pairwise node dissimilarity. When the node attributes are real valued random vectors and the dissimilarity is an increasing function of Euclidean distance these shortest paths can have continuum limits as the number of nodes approaches infinity. Such continuum limits can lead to low complexity continuous diffusion approximations to the combinatorial shortest path problem. This work is joint with Sung Jin Hwang and Steven Damelin and was supported in part by NSF Grant CCF-1217880 and ARO grant W911NF-15-1-0479. (Received August 15, 2018)

1143-60-286 **Olivier Durieu** and **Yizao Wang*** (yizao.wang@uc.edu), Department of Mathematical Sciences, University of Cincinnati, 2815 Commons Way, Cincinnati, OH 45221. *A family of random sup-measures with long-range dependence.*

A family of self-similar and translation-invariant random sup-measures with long-range dependence are investigated. They are shown to arise as the limit of the empirical random sup-measure of a stationary heavy-tailed process, inspired by an infinite urn scheme, where same values are repeated at several random locations. The random sup-measure reflects the long-range dependence nature of the original process, and in particular characterizes how locations of extremes appear as long-range clusters represented by random closed sets. A limit theorem for the corresponding point-process convergence is established. (Received August 16, 2018)

1143-60-325 **Yanghui Liu*** (liu2048@purdue.edu). *LAN property for SDEs with additive fractional noise and continuous time observation.*

The Local Asymptotic Normality property (LAN) is a fundamental concept in asymptotic theory of statistics, which was developed by Le Cam, 1960. The main application of the LAN property is that if LAN holds true it provides a (usually sharp) asymptotic lower bound for the risk with respect to a loss function. In this talk, we consider a stochastic differential equation with additive fractional noise with Hurst parameter $H > 1/2$, and a non-linear drift depending on an unknown parameter, and we show the LAN property of this parametric model when the solution is observed continuously on the time interval. (Received August 17, 2018)

1143-60-333 **Daniel Mckenzie***, Department of mathematics, University of Georgia, Athens, GA 30602, and **Steven Damelin**. *Shortest path distances and semi-supervised learning.* Preliminary report.

In many situations, one is given a set of data points $\mathcal{X} \subset \mathbb{R}^d$ and one seeks to sort these points into clusters, $C_1, \ldots, C_k$. These clusters could be full dimensional (for example, drawn from a Gaussian distribution) or they could be supported on a low dimensional submanifold. Many algorithms for this task, for example spectral clustering approaches or ISOMAP, take as input a distance matrix D, where D_{ij} is the distance between $\mathbf{x}_i$ and $\mathbf{x}_j$. However, the Euclidean metric is frequently an unsatisfactory distance measure. Ideally, one would like a metric that "squeezes" points in the same cluster together while "pulling" points in different clusters apart. To this end, many authors have introduced data-dependent metrics such as density based metrics, shortest paths metrics or the longest-leg path distance. In this talk we will present some recent work on shortest paths metrics for the semi-supervised case. That is, when one is given a small subset of points $\mathcal{Y} \subset \mathcal{X}$ for which the true cluster membership is known. (Received August 18, 2018)

1143-60-343 **Stilian A Stoev*** (sstoev@umich.edu), Ann Arbor, MI 48109, **Jinqi Shen** (jqshen@umich.edu), Ann Arbor, MI 48109, and **Tailen Hsing** (thsing@umich.edu), Ann Arbor, MI 48109. *Intrinsic Random Tangent Fields.* Preliminary report.

Consider a random field $X = \{X(t),\ t \in \mathbb{R}^d\}$ with continuous paths. The process X is said to have a tangent field $Y_z = \{Y_z(t), \mathbb{R}^d\}$ at $z \in \mathbb{R}^d$, if

$$\{X(ht + z) - X(z))/a(h),\ t \in \mathbb{R}^d\} \Rightarrow \{Y_z(t),\ t \in \mathbb{R}^d\}, \quad \text{as } h \to 0,$$

for some $a(h) \downarrow 0$, where $\Rightarrow$ denotes convergence in distribution in the space of continuous functions endowed with the local uniform topology.

In a seminal paper Falconer (2002) characterized the structure of the tangent process of a random field. Specifically, he showed that the tangent filed Y_z must be self-similar and with stationary increments, for almost all $z \in \mathbb{R}^d$ (for which it is defined). The stationarity of increments property is most delicate to prove and most surprising.

We discuss an alternative proof of Falconer's characterization, based on Lusin's and Egorov's theorems. Our approach applies to the characterization of tangent objects corresponding to general k-th order local increments of the field X. This leads us to an extension of Falconer's characterization to the case of tangents of intrinsic random functions.

(This is a joint work in progress with Jinqi Shen and Tailen Hsing.) (Received August 18, 2018)

1143-60-438 **Tetiana Shcherbyna*** (tshcherbyna@princeton.edu). *Local regime of 1d random band matrices.*

Random band matrices (RBM) are natural intermediate models to study eigenvalue statistics and quantum propagation in disordered systems, since they interpolate between mean-field type Wigner matrices and random Schrodinger operators. In particular, RBM can be used to model the Anderson metal-insulator phase transition (crossover) even in 1d. In this talk we will discuss some recent progress in application of the supersymmetric method (SUSY) and transfer matrix approach to the analysis of local spectral characteristics of some specific types of RBM. (Received August 20, 2018)

1143-60-453 **Jinqi Shen*** (jqshen@umich.edu), 311 West Hall, 1085 South University, Ann Arbor, MI 48109, and **Hsing Tailen**. *Hurst Function Estimation.*

Since the introduction by Mandelbrot and Van Ness (1968), fractional Brownian motion (fBm) has been widely used to model data that exhibit long-range dependence and scaling phenomena. Multi-fractional Brownian motion (mBm) has been proposed to be an extension of fBm allowing nonstationary increments, which has a function related to locations called Hurst function characterizing the path smoothness locally.

Our paper considers a wide range of issues concerning the estimation of the Hurst function of a mBm when the process is observed on a regular grid. A theoretical lower bound for the minimax risk of this inference problem is established for a wide class of smooth Hurst functions. We also propose a new nonparametric estimator and show that it is rate optimal. Implementation issues of the estimator including how to overcome the presence of a nuisance parameter and choose the tuning parameter from data have also been be considered.

(This is a joint work with Tailen Hsing.)

References:

Mandelbrot, B. B. and Van Ness, J. W. (1968). Fractional Brownian motions, fractional noises and applications. SIAM Rev. 10 422-437. (Received August 20, 2018)

1143-60-460 **Frederi Viens*** (viens@msu.edu), East Lansing, MI 48824. *Generalized methods of moments for parameter estimation in long-memory and other Gaussian processes.*

We consider the class of all stationary Gaussian processes. When the spectral density is parametrically explicit, we defined a GMM estimator that satisfies consistency and asymptotic normality, using the Breuer-Major theorem which applies to long-memory processes. This result is applied to the joint estimation of the three parameters of a stationary Ornstein-Uhlenbeck (fOU) process driven by a fractional Brownian motion. The asymptotic normality of its GMM estimator applies for any $H \in (0, 1)$. For general processes observed at fixed discrete times, no matter what the memory length, we use state-of-the-art Malliavin calculus tools to prove Berry-Esseen-type and other speeds of convergence in total variation, for estimators based on power variations. This is joint work with Luis Barboza (U. Costa Rica), Khalifa es-Sebaiy (U. Kuwait), and Soukaina Douissi (U. Cadi Ayyad, Morocco). (Received August 20, 2018)

1143-60-463 **Samuel Cohn** and **Gautam Iyer***, Dept. of Math. Sci, WEH #6113, Carnegie Mellon University, Pittsburgh, PA 15206, and **Robert L Pego** and **James Nolen**. *Anomalous diffusion in one and two dimensional combs.*

We study the effective behavior of a Brownian motion in both one and two dimensional comb like domains. This problem arises in a variety of physical situations such as transport in tissues, and linear porous media. We show convergence to a limiting process when when both the spacing between the teeth, and the probability of entering a tooth vanish at the same rate. This limiting process exhibits an anomalous diffusive behavior, and can be described as a Brownian motion time-changed by the local time of an independent sticky Brownian motion. At the PDE level, this leads to equations that have fractional time derivatives and are similar to the Bassett differential equation. (Received August 20, 2018)

1143-60-476 **Jeffrey Schenker*** (schenke6@msu.edu), **Zak Tilocco**, **Alejandro Becerra** and **Tait Weicht**. *How big is a lattice point?*

A lattice random walk may be approximated over long time scales by Brownian motion. Suppose we wish to compute the probability for a random walk to hit a particular point over a given time. It is natural to approximate this hitting probability by the probability for Brownian motion to hit a ball over the same time. But how big of a ball should we use? In $d = 1$ this problem is trivial and in $d \geq 3$ it is not difficult. However, in two dimensions the problem is subtle because the probability for Brownian motion to eventually hit any disk is one, regardless of the radius.

Borrowing ideas from spectral theory and the physics of renormalization, we show how to use the singular part of lattice Green's functions to compute an "effective Brownian radius" for a lattice point, which can be used to obtain the best approximation of random walk hitting probabilities. We apply this technique to a variety of 2D lattices, as well as to various directed random walks, obtaining for each an "effective Brownian radius" for a point. I will close the talk with some conjectures about the numerical error in this approximation. (Joint work with A. Becerra, Z. Tilocco, and T. Weicht.) (Received August 20, 2018)

1143-60-482 **Anna Lytova** and **Konstantin Tikhomirov*** (ktikhomirov6@gatech.edu). *No-gaps delocalization of eigenvectors of non-Hermitian random matrices.*

A random vector has the no-gaps delocalization property if every subset of coordinates of a sufficiently large cardinality carries a non-negligible part of its mass. In this work, we study no-gaps delocalization for eigenvectors of non-Hermitian random matrices. (Received August 21, 2018)

1143-60-487 **Megan McCormick Stone*** (mmccormick@math.arizona.edu). *Eigenvalue Densities for the Hermitian Two-Matrix Model.*

The two-matrix model consists of pairs of Hermitian matrices equipped with a joint probability distribution. This distribution contains an interaction term which is scaled by a coupling constant, τ. A result of Goulden, Guay-Paquet, and Novak provides an expansion for the interaction term in a neighborhood of $\tau = 0$. The expansion involves monotone double Hurwitz numbers, which count a collection of ramified coverings of the two-sphere. Using this expansion, and its connection to monotone Hurwitz numbers, this talk provides a variational problem which describes the joint eigenvalue densities for the two-matrix model up to order τ^2. (Received August 20, 2018)

1143-60-496 **Alisa Knizel**, **Leo Petrov** and **Axel Saenz*** (ais6a@virginia.edu), Axel Saenz, 141 Cabell Drive, Kerchof Hall, P.O. Box 400137, Charlottesville, VA 22904. *Generalizations of TASEP in discrete and continuous inhomogeneous space.*

We investigate a rich new class of exactly solvable particle systems generalizing the Totally Asymmetric Simple Exclusion Process (TASEP). Our particle systems evolve in discrete or continuous space, and can be thought

of as new exactly solvable examples of tandem queues, directed first- or last-passage percolation models, or Robinson-Schensted-Knuth type systems with random input. One of the features of the particle systems we consider is the presence of spatial inhomogeneity which can lead to formation of traffic jams.

For systems with special step-like initial data we find explicit limit shapes, describe their hydrodynamic evolution, and obtain asymptotic fluctuation results which put our generalized TASEPs into the Kardar-Parisi-Zhang universality class. At a critical scaling around a traffic jam in the continuous space TASEP we observe deformations of the Tracy-Widom distribution and the extended Airy kernel. A homogeneous version of our discrete space system is a one-parameter deformation of the geometric last-passage percolation, and we obtain a corresponding extension of the limit shape parabola from the seminal work of K. Johansson in 2000. (Received August 20, 2018)

1143-60-513 **Jinho Baik**, **Ji Oon Lee** and **Hao Wu*** (lingluan@umich.edu), Office 4072, 530 Church St, Ann Arbor, MI 48109. *Ferromagnetic to paramagnetic transition in spherical spin glass.*

We consider the spherical spin glass model defined by a combination of the pure 2-spin spherical Sherrington-Kirkpatrick Hamiltonian and the ferromagnetic Curie-Weiss Hamiltonian. In the large system limit, there is a two-dimensional phase diagram with respect to the temperature and the coupling strength. The phase diagram is divided into three regimes; ferromagnetic, paramagnetic, and spin glass regimes. The fluctuations of the free energy are known in each regime. In this talk, we will focus on the transition between the ferromagnetic regime and the paramagnetic regime in a critical scale. It turns out that the fluctuations of the free energy in this transition regime are governed by the joint distribution of the linear statistics and the largest eigenvalue of the disorder. (Received August 21, 2018)

1143-60-532 **Manuel de Leon*** (mdeleon@icmat.es), ICMAT, c/ Nicolás Cabrera 13-15, 28003 Madrid, Spain. *Geometry and dynamics.*

In this talk, we will discuss how different background geometries produce completely different dynamics. More precisely, we show how symplectic and cosymplectic geometries produce the Hamilton equations for a given Hamiltonian function, but dissipative Hamiltonian equations needs to use contact geometry. (Received August 21, 2018)

1143-60-540 **Nicholas Cook*** (nickcook@math.ucla.edu). *Large deviations for subgraph counts in sparse Erdős–Rényi graphs.*

Let A be the adjacency matrix of an Erdős–Rényi graph G on N vertices with expected edge density p. That is, A is a random $N \times N$ symmetric matrix with zeros on the diagonal and iid Bernoulli(p) entries above the diagonal. We focus on the sparse regime where $p \sim N^{-c}$ for a fixed constant $c \in (0,1)$ as $N \to \infty$. We determine the asymptotic rate function for deviations of the kth moment of A above a fixed multiple of its expectation, for each $k \geq 3$, assuming $c < 1/2$ when $k \geq 4$ and $c < 1/3$ when $k = 3$. The case $k = 3$ gives the sharp upper tail for triangle counts in G, extending a previous result of Eldan holding for $c < 1/18$. We also obtain results for large deviations of general subgraph counts in G (for narrower ranges of c), as well as for a general class of spectral statistics of A that includes the Perron–Frobenius eigenvalue. (Received August 21, 2018)

1143-60-549 **Charles K Smart*** (smart@math.uchicago.edu). *The Abelian sandpile and circle packings.*

We discuss some recent progress understanding the scaling limit of the Abelian sandpile. (Received August 21, 2018)

1143-60-560 **Jun Yin***, 520 Portola Plaza, Los Angeles, CA 90095, and **Horng-Tzer Yau**, **Paul Bourgade** and **Fan Yang**. *Universality and Delocalization for Random Band Matrices.*

Consider $N \times N$ symmetric one-dimensional random band matrices with general distribution of the entries and band width $W \gg N^{3/4+\epsilon}$ for any $\epsilon > 0$.

In the bulk of the spectrum and in the large N limit, we obtain the following results.

1. The semicircle law holds up to the scale $N^{-1+\epsilon}$ for any $\epsilon > 0$.

2. The eigenvalues locally converge to the point process given by the Gaussian orthogonal ensemble at any fixed energy.

3. All eigenvectors are delocalized, meaning their L_∞ norms are all simultaneously bounded by $N^{-1/2+\epsilon}$ (after normalization in L_2) with overwhelming probability, for any $\epsilon > 0$.

4. Quantum unique ergodicity holds, in the sense that the local L_2 mass of eigenvectors becomes equidistributed with overwhelming probability.

For general distribution, the previous best result requires $W = \Omega(N)$. (Received August 21, 2018)

62 ► Statistics

1143-62-13 **Linda A Ness*** (nesslinda@gmail.com). *Exploiting Mathematical Representation Theorems to Characterize Patterns in Data.* Preliminary report.

When confronted with real world data one often does not know what statistical model would appropriately model the data. Furthermore, different patterns may be observed over different time intervals or different localities. However, it is possible to exploit several representation theorems from mathematics to automatically detect patterns at different scales. I'll illustrate two of these techniques: one relying on a little known representation theorem for a very large class of statistical distributions applicable to all data sets on which an ordered set of binary feature functions have been defined and the other relying on application of the Singular Value Decomposition Theorem to local neighborhood systems. The techniques will be illustrated on several different types of data sets including time-series data, binary feature data, three dimensional image data and social network data.

The work with these representations began as a collaboration with D. Bassu, P.W. Jones, and David Shallcross. Recently the second representation was used to obtain heuristic characterizations of local intrinsic dimension, in collaboration with F. P. Medina, M. Weber, and K. Yacoubou Djima. (Received May 23, 2018)

1143-62-119 **Vladas Pipiras*** (pipiras@email.unc.edu), Department of Statistics & OR, CB# 3260, Hanes Hall, UNC-CH, Chapel Hill, NC 27599, **Changryong Baek** (crbaek@skku.edu), Dept. of Statistics, Sungkyunkwan University, 25-2, Sungkyunkwan-ro, Jongno-gu, Seoul, 110-745, South Korea, and **Stefanos Kechagias** (stefanos.kechagias@sas.com), SAS Institute, 100 SAS Campus Drive, Cary, NC 27513. *Asymptotics of bivariate local Whittle estimators with applications to fractal connectivity.*

Several methodological and numerical issues behind the local Whittle estimation of long and short memory in bivariate stationary time series with possible fractional cointegration are reexamined. These issues include the asymptotic normality for all model parameters, local Whittle plots for phase parameter and fractal connectivity, and others. For fractal connectivity, in particular, it is advocated to work with a model parametrization for which the model parameters associated with this phenomenon are identifiable and could be tested naturally within the local Whittle estimation framework. A simulation study and data applications are also considered. (Received August 04, 2018)

1143-62-229 **Afonso Bandeira**, **Ben Blum-Smith** and **Joe Kileel*** (jkileel@math.princeton.edu), Princeton University, Applied and Computational Mathematics, Princeton, NJ 08544, and **Amelia Perry**, **Jonathan Weed** and **Alexander Wein**. *Statistical Learning Under Group Actions With Applications to Cryo-Electron Microscopy.*

In many problems in computer vision, robotics and image/signal processing, we wish to recover latent variables from observations suffering unknown shifts or rotations. One example is cryo-electron microscopy (cryo-EM), where the challenge is to estimate the 3D structure of a protein from many, very noisy 2D images taken at unknown viewing directions.

In this talk, I will place cryo-EM reconstruction inside a mathematical framework for statistical learning under group actions. The main result is a tight relation between sample complexity for statistical learning under group actions and the invariant theory of the underlying symmetry group. On the algebra side, this motivates apparently new questions in invariant theory, to which we offer partial algorithmic answers in general. For the cryo-EM case, we contribute a novel *ab initio* 3D reconstruction algorithm, which is both sample and computationally efficient, at least under model assumptions.

Based on joint work with Afonso Bandeira, Ben Blum-Smith, Amelia Perry, Jonathan Weed and Alexander Wein, as well as ongoing work. (Received August 14, 2018)

1143-62-233 **Alfred Olivier Hero*** (hero@umich.edu), 1301 Beal Ave, Ann Arbor, MI 48105. *Reconstructing multimodal genomic networks.* Preliminary report.

We propose a mathematical model for inferring the topology of a latent network representing multiple modality genomic measurements. This model is applicable to multiple platform assays such as HiC and RNA-seq that are often used to simultaneously probe spatial and functional structure of gene organization. (Received August 14, 2018)

1143-62-354 **Adam Gustafson**, **Ariel Herbert-Voss**, **Matthew Hirn*** (mhirn@msu.edu), **Frederick McCollum**, **Kitty Mohammed**, **Hariharan Narayanan** and **Jason Xu**. *Fitting smooth functions to high dimensional data.*

Given high dimensional data points and corresponding scalar function values, a fundamental problem in both interpolation algorithms and machine learning is how to efficiently fit an optimal function to the given data. The

nature of such algorithms depends upon the function class from which the interpolating or regression function is drawn, with popular examples including reproducing kernel Hilbert spaces and neural networks. Such function classes, though, only implicitly specify the smoothness of the function, whereas in certain applications (such as those arising out of physics) it can be desirable to specify smoothness properties directly. A simple example that has received some attention in the machine learning community is Lipchitz functions; however, specifying higher order smoothness constraints significantly complicates matters. In this talk we provide provably efficient algorithms for fitting functions with Lipschitz gradients, i.e. $C^{1,1}$ functions, to data, in both the noiseless and noisy data settings. In the former case, the algorithm will guarantee perfect interpolation, while in the latter case we provide statistical guarantees relating the empirical risk to the true risk. (Received August 18, 2018)

1143-62-551 **Rida Benhaddou*** (benhaddo@ohio.edu), Department of Mathematics, Morton Hall 321, Ohio University, Athens, OH 45701. *Laplace deconvolution with dependent errors: a minimax study.*

We investigate the problem of estimating a function f based on observations from its noisy convolution when the noise exhibits long-range dependence. We consider both Gaussian and sub-Gaussian errors. We construct an adaptive estimator based on the kernel method, with the optimal selection of the bandwidths performed via Lepski's Method. We derive a minimax lower bound for the L2-risk when f belongs to a Sobolev ball and show that such estimator attains optimal or near-optimal rates that deteriorate as the long-range dependence worsens. We carry out a limited simulations study which con rms our conclusions from theoretical results. (Received August 21, 2018)

65 ► Numerical analysis

1143-65-5 **Di Liu*** (liudi1@msu.edu), D217 Wells Hall, 619 Red Cedar Rd, East Lansing, MI 48824. *Multiscale Modeling and Computation of Optically Manipulated Nano Devices.*

We present a multiscale modeling and computational scheme for optical- mechanical responses of nanostructures. To balance accuracy and complexity, we adopt the semi-classical approach that the EM field is described classically by the Maxwell equations, and the charged particles follow the Schroidnger equations quantum mechanically. We further simplify the model with the Ehrenfest molecular dynamics to determine the motion of the nuclei, and use the Time- Dependent Current Density Functional Theory (TD-CDFT) to calculate the excitation of the electrons. This leads to a system of coupled equations that computes the electromagnetic field, the nuclear positions, and the electronic current and charge densities simultaneously. In the regime of linear responses, the resonant frequencies initiating the out-of-equilibrium optical-mechanical responses can be formulated as an eigenvalue problem. The isomerization of Azobenzene is presented as a numerical example. (Received March 12, 2018)

1143-65-22 **Chi Yeung Lam*** (lamchiye@msu.edu). *A ray-based IPDG method for high-frequency time-domain acoustic wave propagation in inhomogeneous media.*

The numerical approximation of high-frequency wave propagation in inhomogeneous media is a challenging problem. In particular, computing high-frequency solutions by direct simulations requires several points per wavelength for stability and usually requires many points per wavelength for a satisfactory accuracy. In this paper, we propose a new method for the acoustic wave equation in inhomogeneous media in the time domain to achieve superior accuracy and stability without using a large number of unknowns. The method is based on a discontinuous Galerkin discretization together with carefully chosen basis functions. To obtain the basis functions, we use the idea from geometrical optics and construct the basis functions by using the leading order term in the asymptotic expansion. Also, we use a wavefront tracking method and a dimension reduction procedure to obtain dominant rays in each cell. We show numerically that the accuracy of the numerical solutions computed by our method is significantly higher than that computed by the IPDG method using polynomials. Moreover, the relative errors of our method grow only moderately as the frequency increases. This is a joint work with Prof. Eric T. Chung (CUHK) and Prof. Jianliang Qian (Michigan State University). (Received August 08, 2018)

1143-65-43 **Sean P Carney*** (scarney@math.utexas.edu), **Bjorn Engquist** and **Milica Taskovic**. *Numerical methods for reducing the boundary error in numerical homogenization.* Preliminary report.

In the numerical homogenization of multiscale elliptic operators, one often needs to take an average of the solution to a microscale problem. Both the boundary conditions and domain size of the microscale problem play

an important role in the accuracy of the homogenization procedure. In particular, imposing naive boundary conditions leads to a $\mathcal{O}(\epsilon/\eta)$ error in the computation, where ϵ is the characteristic size of the microscopic fluctuations in the heterogeneous media, and η is the size of the microscopic domain. This so-called "cell resonance" error can dominate discretization error and pollute the entire homogenization scheme. We present below a procedure that reduces this cell resonsance error to $\mathcal{O}(\epsilon/\eta)^r$, where r can be made arbitrarily large through the use of special averaging kernels. We present a theorem for the one-dimensional case and perform a variety of numerical experiments in two-dimensions to showcase the utility of the approach in more general settings. (Received July 09, 2018)

1143-65-45 **Lulu Tian** and **Yang Yang*** (yyang7@mtu.edu). *On the blow-up time of local discontinuous Galerkin methods for chemotaxis model.*

In this talk, we apply local discontinuous Galerkin (LDG) method to solve Keller-Segel (KS) chemotaxis model. The KS chemotaxis model may exhibit blow-up patterns (δ-singularities) with certain initial conditions, and is not easy to approximate numerically. Especially, the exact blow-up time is very difficult to estimate. We will construct a strategy to compute the numerical blow-up time and theoretically prove that the $\liminf$ of the constructed numerical blow-up time is exactly the true one. Some numerical experiments will be given to demonstrate the convergence of the numerical blow-up time defined in this paper. (Received July 11, 2018)

1143-65-50 **H Zhao** and **Y Zhong*** (yiminz@uci.edu). *A hybrid adaptive phase space method for reflection traveltime tomography.*

We present a hybrid imaging method for a challenging travel time tomography problem which includes both unknown medium and unknown scatterers in a bounded domain. The goal is to recover both the medium and the boundary of the scatterers from the scattering relation data on the domain boundary. Our method is composed of three steps: 1) preprocess the data to classify them into three different categories of measurements corresponding to non-broken rays, broken-once rays, and others, respectively, 2) use the the non-broken ray data and an effective data-driven layer stripping strategy–an optimization based iterative imaging method–to recover the medium velocity outside the convex hull of the scatterers, and 3) use selected broken-once ray data to recover the boundary of the scatterers–a direct imaging method. By numerical tests, we show that our hybrid method can recover both the unknown medium and the not-too-concave scatterers efficiently and robustly. (Received July 20, 2018)

1143-65-57 **Jingmei Qiu** (jingqiu@udel.edu) and **Xiaofeng Cai*** (xcai@udel.edu). *A high order non-splitting conservative semi-Lagrangian Discontinuous Galerkin Method for two-dimemsional transport simulations.*

In this talk, we will introduce a high order non-splitting conservative semi-Lagrangian (SL) discontinuous Galerkin (DG) method for the two-dimensional transport simulations. The proposed method relies on a characteristic Galerkin weak formulation and a high order characteristics tracing mechanism. Unlike many existing SL methods, the high order accuracy and mass conservation of the method are realized in a non-splitting manner. Thus, the detrimental splitting error, which could significantly contaminate long term transport simulations, will be not incurred. One key ingredient in the scheme formulation is the use of Green's theorem which allows us to convert volume integrals into a set of line integrals. The resulting line integrals are much easier to approximate with high order accuracy, hence facilitating the implementation. To assess the numerical performance, we benchmark the proposed SLDG schemes for simulating several transport problems, the nonlinear Vlasov-Poisson system, incompressible Euler equations and the Vlasov Guiding center model. The efficiency and efficacy of the proposed scheme are numerically verified when compared with other prominent transport solvers such as the Eulerian DG methods combined with Runge-Kutta time integrators. (Received July 23, 2018)

1143-65-59 **Joshua Buli** and **Yulong Xing*** (xing.205@osu.edu). *Discontinuous Galerkin Method for the Aw-Rascle Traffic Flow Model on Networks.*

In this presentation, we consider the second-order Aw-Rascle (AR) model for traffic flow on a network, and propose a discontinuous Galerkin (DG) method for solving the AR system with appropriate coupling conditions at the junctions. The Lax-Friedrichs flux is employed in the proposed method. Coupling conditions are also required at the junctions of the network for the problem to be well-posed. As the choice of coupling conditions is not unique, we test different coupling conditions at the junctions. Numerical examples are provided to demonstrate the high-order accuracy, and comparison of results between the first-order Lighthill-Whitham-Richards traffic model and the second-order AR model. (Received July 23, 2018)

1143-65-60 **Sander Rhebergen*** (srheberg@uwaterloo.ca) and **Garth Wells**. *Preconditioning for hybridizable discontinuous Galerkin methods: the Stokes problem.*

In [1,2] we introduced a hybridizable discontinuous Galerkin (HDG) method for the Stokes and Navier–Stokes problem. Our method results in an approximate velocity field that is pointwise divergence-free and $H(\mathrm{div})$-conforming. Furthermore, our HDG method is pressure-robust, and for the Navier–Stokes equations, locally conservative and energy stable. In this talk we will introduce optimal preconditioners for the (statically condensed) linear systems arising from our HDG discretization of the Stokes problem [3].

[1] S. Rhebergen and G.N. Wells, Analysis of a hybridized/interface stabilized finite element method for the Stokes equations. SIAM J. Numer. Anal., Vol. 55/4, pp. 1982-2003, 2017.

[2] S. Rhebergen and G.N. Wells, A hybridizable discontinuous Galerkin method for the Navier–Stokes equations with pointwise divergence-free velocity field. J. Sci. Comput., 2018.

[3] S. Rhebergen and G.N. Wells, Preconditioning of a hybridized discontinuous Galerkin finite element method for the Stokes equations. J. Sci. Comput., 2018. (Received July 23, 2018)

1143-65-65 **Michael Neilan*** (neilan@pitt.edu), **Johnny Guzman** and **Guosheng Fu**. *Exact smooth piecewise polynomial sequences on Alfeld splits.*

We develop exact polynomial sequences on Alfeld splits in any spatial dimension and any polynomial degree. An Alfeld split of a tetrahedron is obtained by connecting the vertices of an n-simplex with its barycenter. We show that, on these triangulations, the kernel of the exterior derivative has enhanced smoothness. Byproducts of this theory include characterizations of discrete divergence-free subspaces for the Stokes problem, commutative projections, and simple formulas for the dimensions of smooth polynomial spaces. (Received July 25, 2018)

1143-65-87 **Guosheng Fu***, guosheng_fu@brown.edu, and **Chi-Wang Shu**. *A new class of energy-conserving discontinuous Galerkin methods for waves equations.*

We present a new class of energy-conserving discontinuous Galerkin methods on unstructured meshes for wave equations. Details of the derivation for the model scalar advection equation in one dimension will be presented. The optimal convergence of the method and a superior performance of the method in terms dispersion analysis will be discussed. Extensions to other wave equations including aeroacoustics, electromagnetism, elastodynamics, and nonlinear dispersive waves (KdV equation) will be briefly covered. (Received August 01, 2018)

1143-65-88 **Thomas L Lewis*** (tllewis3@uncg.edu). *Approximating Positone Boundary Value Problems with Multiple Solutions.*

In this talk we introduce the class of positone boundary value problems and the analytic issues that must be addressed when using an approximation method. Positone boundary value problems are semilinear elliptic PDEs that arise in mathematical biology and the theory of nonlinear heat generation. Under certain conditions, the problems may have multiple positive solutions or even nonexistence of a positive solution. We will discuss new analytic techniques for proving admissibility, stability, and convergence of finite difference methods for approximating sublinear positone problems. The admissibility and stability results will be based on adapting the method of sub- and supersolutions typically used to analyze the underlying PDEs. Since most known approximation methods for positone boundary value problems rely upon shooting techniques, they are restricted to one-dimensional problems and/or radial solutions. The new tools will serve as a foundation for approximating positone boundary value problems in higher dimensions and on more general domains. (Received August 01, 2018)

1143-65-90 **Benjamin W Ong*** (ongbw@mtu.edu), 1400 Townsend Drive, Department of Mathematical Sciences, Houghton, MI , and **Felix Kwok**. *Waveform Relaxation with Adaptive Pipelining.*

The development of waveform relaxation methods has enjoyed recent activity due to its flexibility in the choice of spatial and temporal grids and integrators, and the capability for space-time parallelism, where multiple waveform iterates can be simultaneously computed in a pipeline fashion. In this work, we are interested in adaptively choosing the number of waveform iterates that are computed in a pipeline parallel fashion at each time step. We provide some numerical evidence that supports one's intuition about the proposed Waveform Relaxation method with Adaptive Pipelining (WRAP), followed by an analysis of the convergence and # of iterations for the WRAP method applied to the homogeneous heat equation. (Received August 01, 2018)

1143-65-99 **Xiaoming Zheng*** (zheng1x@cmich.edu), PE201E, Mathematics Department, Central Michigan University, Mount Pleasant, MI 48858, and **John Lowengrub**. *An interface-fitted adaptive mesh method for free interface problems.*

This work presents a novel two-dimensional interface-fitted adaptive mesh method to solve elliptic problems of jump conditions across the interface, and its application in free interface problems with surface tension. The

interface-fitted mesh is achieved by two operations: (i) the projection of mesh nodes onto the interface and (ii) the insertion of mesh nodes right on the interface. The interface-fitting technique is combined with an existing adaptive mesh approach which uses addition/subtraction and displacement of mesh nodes. We develop a simple piecewise linear finite element method built on this interface-fitted mesh and prove its almost optimal convergence for elliptic problems with jump conditions across the interface. Applications to two free interface problems, a sheared drop in Stokes flow and the growth of a solid tumor, are presented. In these applications, the interface surface tension serves as the jump condition or the Dirichlet boundary condition of the pressure, and the pressure is solved with the interface-fitted finite element method developed in this work. This is a joint work with John Lowengrub of University of California at Irvine. (Received August 02, 2018)

1143-65-101 **Jue Yan*** (jyan@iastate.edu), 396 Carver Hall, Department of Math, Iowa State University, Ames, IA 50010. *Positivity preserving high order direct Discontinuous Galerkin methods for Keller-Segel chemotaxis equations.* Preliminary report.

We develop a new direct discontinuous Galerkin (DDG) method to solve Keller-Segel Chemotaxis equations. One unique feature of our method is that we introduce no extra variables to approximate the gradient of the chemical concentration and solve the system directly with DDG method. We obtain optimal (k+1)th order convergence with kth degree piecewise polynomials approximations, even on random none uniform meshes. Furthermore, we prove the cell density solution is maintained positive at all time levels with at least third order of accuracy. Cell density blow up phenomena is captured well. (Received August 03, 2018)

1143-65-106 **Dong Lu**, **Shanqin Chen** and **Yong-Tao Zhang*** (yzhang10@nd.edu), Dept. of Applied and Comp. Math. and Stat., University of Notre Dame, Notre Dame, IN 46556. *Sparse grid WENO schemes for high spatial dimension convection-diffusion and hyperbolic equations.*

In recent years, sparse grid techniques have been used broadly as an efficient approximation tool for high-dimensional problems. In this talk, I will present our results on designing sparse grid weighted essentially non-oscillatory (WENO) schemes for solving high spatial dimension convection-diffusion and hyperbolic PDEs. Our goal is to apply sparse grid techniques in high order schemes to achieve more efficient computations. A challenge is how to design the schemes on sparse grids such that comparable high order accuracy of the schemes in smooth regions of the solutions can still be achieved as that for computations on regular single grids. For problems with discontinuous solutions, additional challenge is that essentially non-oscillatory stability in non-smooth regions of the solutions needs to be preserved in the sparse grid schemes. We apply sparse-grid combination approach to overcome these difficulties. To deal with discontinuous solutions, we apply WENO interpolation for the prolongation part in sparse-grid combination techniques. Both 2D and 3D examples are presented to show that significant computational times are saved, while both accuracy and stability of the original schemes are maintained for numerical simulations on sparse grids. (Received August 03, 2018)

1143-65-140 **Lewei Zhao*** (fp5042@wayne.edu), **Hao Pan** and **Zhimin Zhang**. *Some New Developments of Polynomial Preserving Recovery on Hexagon Pattern.*

Polynomial Preserving Recovery (PPR) is a very popular post-processing techniques for finite element methods. In this work, we propose and analyze an effective linear element PPR on a new pattern so called Hexagon. By giving an interior estimates for discrete Green function and expansion analysis for the superconvergence theory , we prove that liner element PPR on this new pattern can reach $O(h^4|\ln h|)$ superconvergence for recovering gradient of possion problems in 2-d. This research is working with Hao Pan and Zhimin Zhang. (Received August 07, 2018)

1143-65-142 **Xiaoming He*** (hex@mst.edu), 400 W. 12th St., Rolla, MO 65401. *Non-iterative multi-physics domain decomposition method for coupled free flow and porous media flow problem.*

The Stokes-Darcy and Navier-Stokes-Darcy model have attracted significant attention in the past ten years since they arise in many applications involving with coupled free flow and porous media flow such as surface water flows, groundwater flows in karst aquifers, petroleum extraction and industrial filtration. They have higher fidelity than either the Darcy or Navier-Stokes systems on their own, but coupling the two constituent models leads to a very complex system. This presentation discusses a series of works for the non-iterative multi-physics domain decomposition method to solve this type of problems, including both the algorithm development and analysis. The key idea is to decouple the free and porous media flow through Robin type boundary conditions which arise from the three interface conditions. Optimal convergence is proved for the k-step back backward differentiation scheme with k less than or equal to 5. Computational results are presented to illustrate the features of the proposed method. (Received August 07, 2018)

1143-65-146 **Hae-Soo Oh*** (hso@uncc.edu), Dept. of Mathematics and Statistics, University of North Carolina at Charlotte, Charlotte, NC, **Seokchan Kim** (sckim@changwon.ac.kr), Dept. of Mathematics, Changwon National University, Changwon, 51140, South Korea, and **Birce Palta** (pbirce@uncc.edu), Dept. of Mathematics and Statistics, University of North Carolina at Charlotte, Charlotte, NC 28223. *Extracting Stress Intensity Factors in the fourth-order partial differential equations on cracked two dimensional domains.*

We drive a formula extracting stress intensity factors λ_1^1, λ_1^2 (related to the Mode I and Mode II of the plate bending problems) of the forth-order partial differential equations $\Delta^2 u = f$ on the cracked two-dimensional domains with clamped as well as natural boundary conditions. The formula needs to use the true solution that is unknown. Thus, the unknown true solution can be replaced by iteratively improved approximate solutions $U_h^{(n)}$, which is the sum of the solution of a forth-order problem with no singularities and the linear combination of singular functions and estimated stress intensity factors. We prove this iteration method converges. Various numerical experiments that support the extraction formula are performed. (Received August 07, 2018)

1143-65-150 **Tong Sun*** (tsun@bgsu.edu), 6841 Reflections Dr., Maumee, OH 43537. *Numerical smoothness and error analysis for numerical solutions of parabolic PDEs.*

In the past work on numerical PDEs, it is found that certain smoothness properties of numerical solutions (numerical smoothness) are necessary for optimal rate convergence. Moreover, for nonlinear hyperbolic conservation laws, numerical smoothness has been used to obtain error estimates which are optimal in terms of convergence rate, and also optimal in error propagation. The dual optimality in this sense is the key to make an error estimate practically useful. This talk is to show some progresses of using numerical smoothness toward the error analysis for finite element solutions of parabolic problems. (Received August 07, 2018)

1143-65-162 **Sheng Zhang*** (szhang@wayne.edu). *Stability of discontinuous Galerkin methods for geometrically rigid shells.* Preliminary report.

Geometrically rigid shells have greater strength, but may also be unstable, or even sensitive. For such shells, the stability of interior penalty discontinuous Galerkin methods may not be assured by a sufficiently big penalty constant. We identify a condition on the finite element mesh that assures the stability, thus optimal order of accuracy in the energy norm. The condition requires that the shell elements are relatively shallow. (Received August 08, 2018)

1143-65-207 **Fanchen He*** (wzfche@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *Recovery-based discontinuous Galerkin method for the Cahn-Hilliard equation.* Preliminary report.

Handling high-order derivatives, say, the diffusion terms in the Navier-Stokes equations, with discontinuous Galerkin (DG) method is a nontrivial task, because the numerical solutions are represented by discontinuous piecewise polynomials of degree p. In 2005, a novel recovery-based discontinuous Galerkin method (RDG) was introduced by van Leer and Nomura for diffusion, where a polynomial of degree $2p + 1$ is reconstructed on the two adjacent elements. It achieved a surprising order of accuracy of $3p + 1$ for odd p and $3p + 2$ for even p in terms of cell-average error for the heat equation. Here we illustrate how to apply the idea of recovery to solving partial differential equations with high-order derivatives. We developed a RDG method for the Cahn-Hilliard equation. To enable analysis of RDG schemes designed for non-linear problems, we suggested a new way to analyze the accuracy of RDG schemes via Taylor expansion. The new form of analysis explains the accuracy of the RDG scheme developed for the Cahn-Hilliard equation in one space dimension. Numerical experiments show that the new RDG scheme has property of superconvergence. Furthermore, it's demonstrated that the new RDG scheme is more accurate than the established local discontinuous Galerkin (LDG) approach. (Received August 13, 2018)

1143-65-208 **Weifeng Qiu** and **Ke Shi*** (kshi@odu.edu), Old Dominion University, Norfolk, VA 23529. *Structure-preserving finite element methods for stationary incompressible magnetohydrodynamics.*

Magnetohydrodynamics (MHD) models have various important applications in liquid metal industry, controlled fusion and astronomy etc. There have been extensive discussions on numerical methods for MHD models. However, due to the complicated nonlinear coupling and rich structures of MHD systems, the numerical simulation still remains a challenging and active research area. In this talk We discuss three finite element schemes for stationary magnetohydrodynamics (MHD) systems. In all cases, the schemes provide optimal convergence for the primary unknowns under minimal regularity assumptions for the exact solution. (Received August 13, 2018)

1143-65-220 **Fioralba Cakoni**, **Houssem Haddar** and **Thi-Phong Nguyen*** (tn242@math.rutgers.edu), Department of Mathematics, Rutgers University, 226 Hill Center - Busch Campus, 110 Frelinghuysen Road, Piscataway, NJ 08854-8019. *Imaging of local defects in unknown periodic layers.*

Nondestructive testing of period media is an important problem with grown interest since periodic material are part of many fascinating engineering structures with many technological use such as nanograss. In many situation the periodicity of the healthy periodic material is complicated or difficult to model mathematically, hence computing its Green's function is computationally expensive or even impossible. This work is concerned by the analysis of so-called differential linear sampling method to reconstruct the support of perturbations without using the Green's function of the periodic layer nor reconstruct the periodic background. We use measurements of scattered waves at a fixed frequency. The justification of this method relies on the well-posedeness of a nonstandard interior transmission problem, which until now was an open problem except for the special case when the local perturbation didn't intersect the background inhomogeneities. The analysis of this new interior transmission problem is the main focus of this talk. We then outline the principles and the justification of our inversion method and present some numerical examples that confirm the theoretical behavior of the differential indicator function determining the reconstructable regions in the periodic layer. (Received August 14, 2018)

1143-65-239 **Shanqin Chen*** (chen39@iusb.edu), Department of Mathematical Sciences, 1700 Mishawaka Ave., South Bend, IN 46615. *Fixed-Point Fast Sweeping Weno Methods for Steady State Solution of Scalar Hyperbolic Conservation Laws.*

Fast sweeping methods were developed in the literature to efficiently solve static Hamilton-Jacobi equations. This class of methods utilize the Gauss-Seidel iterations and alternating sweeping strategy to achieve fast convergence rate. They take advantage of the properties of hyperbolic partial differential equations (PDEs) and try to cover a family of characteristics of the corresponding Hamilton-Jacobi equation in a certain direction simultaneously in each sweeping order. The Gauss-Seidel idea and alternating sweeping strategy were adopted to the time-marching type fixed-point iterations to solve the static Hamilton-Jacobi equations, and numerical examples verified at least a 2 times acceleration of convergence even on relatively coarse grids. In this paper, I applied the same approach to solve steady state solution of hyperbolic conservation laws. I used numerical examples to verify that a 2 times acceleration of convergence is achieved. And the computational cost is exactly the same as the time-marching scheme at each iteration. Based on the Gauss-Seidel iterations, I explored the successive overrelaxation (SOR) approach to further improve the performance of our fixed-point sweeping methods. (Received August 15, 2018)

1143-65-244 **M. Aggul**, **J. Connors**, **D. Erkmen** and **A. Labovsky*** (aelabovs@mtu.edu). *A Defect-Deferred Correction Method for Fluid-Fluid Interaction.*

A method is proposed to improve two aspects of numerical simulations for a model of two fluids coupled across a flat interface. This problem is motivated by atmosphere-ocean interaction. A deferred correction approach lifts the numerical order of accuracy formally from first order (very common in applications) to second order, in terms of the time interval of communication between the fluid code components. This is accomplished in a two-step predictor-corrector type method. In the second step, a further defect correction is included as well. The "defect" represents artificial diffusion used in the fluid solvers, which is often included to control numerical noise or to model subscale mixing processes. The addition of the defect correction adds only marginally to the expense, but in exchange may provide a significant reduction of overdiffusive effects.

The method is stable, optimally convergent and also allows for the usage of legacy codes. A computational example using a known (manufactured) solution illustrates the theoretical predictions. We observe a computational benefit in this example even for coarse time steps and over a wide range of artificial viscosity values. (Received August 15, 2018)

1143-65-245 **Nicolae Tarfulea*** (tarfulea@pnw.edu). *Numerical approach for a class of differential equations with constraints.*

Important applications involve constrained hyperbolic systems of differential equations on infinite domains. In general, for the pure Cauchy problem the solution satisfies the constraints for all time whenever the initial data does (e.g., Maxwell's equations and Einstein's field equations in various hyperbolic formulations). Frequently, the numerical solutions to such evolution problems are computed on artificial space cutoffs because of the necessary boundedness of computational domains. Therefore, well-posed boundary conditions are needed at the artificial boundaries. Moreover, these boundary conditions have to be chosen in such a way that the numerical solution of the cutoff system approximates as best as possible the solution of the original problem on infinite domain, and this includes the preservation of constraints. In this talk, we consider well-posed, constraint-preserving boundary conditions for a hyperbolic system with constraints. Then, we construct an equivalent extended system, which

includes the constraints as dynamical variables. Because of the constraints directly entering the evolution, the extended system may present a preferable alternative for numerical approximation. (Received August 15, 2018)

1143-65-256 **Jingwei Hu*** (jingweihu@purdue.edu). *A second-order asymptotic-preserving and positivity-preserving exponential Runge-Kutta method for a class of stiff kinetic equations.*

We introduce a second-order time discretization method for stiff kinetic equations. The method is asymptotic-preserving (AP) - can capture the Euler limit without numerically resolving the small Knudsen number; and positivity-preserving - can preserve the non-negativity of the solution which is a probability density function for arbitrary Knudsen numbers. The method is based on a new formulation of the exponential Runge-Kutta method and can be applied to a large class of stiff kinetic equations including the BGK equation (relaxation type), the Fokker-Planck equation (diffusion type), and even the full Boltzmann equation (nonlinear integral type). Furthermore, we show that when coupled with suitable spatial discretizations the fully discrete scheme satisfies an entropy-decay property. Various numerical results are provided to demonstrate the theoretical properties of the method. This is joint work with R. Shu. (Received August 15, 2018)

1143-65-270 **Cecile Piret** (nldissan@mtu.edu), Michigan Tech 1400 Townsend Drive, Houghton, MI 49931, **Nadun Dissanayake*** (nldissan@mtu.edu), Michigan Tech 1400 Townsend Drive, Houghton, MI 49931, and **John Gierke** (jsgierke@mtu.edu), Michigan Tech 1400 Townsend Drive, Houghton, MI 49931. *The Radial Basis Function Method Applied to Groundwater Flow and Solute Transport Models.* Preliminary report.

This talk will focus on using the Finite Difference-based Radial Basis Functions (RBF-FD) method to solve groundwater flow and contaminant transport equations in a heterogeneous geological environment. With this procedure, we combine RBFs' strengths in representing complex geometries with its ability to accurately discretize differential operators, and attain a new robust modeling approach for stably and accurately computing the solution even in the vicinity of active wells, mathematically represented as singularities. We validate our method and verify its high order of accuracy by solving a well-known benchmark problem. Numerical results for groundwater flow equations in heterogeneous media will be presented and compared to results obtained with the USGS Finite Difference-based software MODFLOW that is customarily used by the geological community. (Received August 16, 2018)

1143-65-295 **Zhanjing Tao*** (taozhanj@msu.edu), **Anqi Chen**, **Mengping Zhang** and **Yingda Cheng**. *Sparse grid central discontinuous Galerkin method for linear hyperbolic systems in high dimensions.*

In this paper, we develop sparse grid central discontinuous Galerkin (CDG) scheme for linear hyperbolic systems with variable coefficients in high dimensions. The scheme combines the CDG framework with the sparse grid approach, with the aim of breaking the curse of dimensionality. A new hierarchical representation of piecewise polynomials on the dual mesh is introduced and analyzed, resulting in a sparse finite element space that can be used for non-periodic problems. Theoretical results, such as L^2 stability and error estimates are obtained for scalar constant coefficient problems. CFL conditions are studied numerically comparing discontinuous Galerkin (DG), CDG, sparse grid DG and sparse grid CDG methods. We show that the proposed sparse grid CDG method allows for the largest time steps among all four methods. Numerical results including scalar linear equations, acoustic and elastic waves are provided. (Received August 17, 2018)

1143-65-299 **Aycil Cesmelioglu*** (cesmelio@oakland.edu) and **Prince Chidyagwai** (pchidyagwai@loyola.edu). *A Monolithic Finite Element Method for a Fluid-Poroelastic Structure Interaction Problem.* Preliminary report.

The interaction of a fluid with a poroelastic material takes place in many multiphysics problems in science and engineering. For example, blood flow is affected by the porous and deformable nature of the arterial wall and simulations may be beneficial for medical research. This interaction is modeled by the coupling of the time-dependent Stokes equations with the fully dynamic Biot equations. In this talk, we present a monolithic scheme based on the finite element method and its analysis under the assumption that the domain is fixed. We first reduce the second order in time problem to a first order problem and derive our monolithic scheme using the backward Euler method to discretize in time and the finite element method to discretize in space. We use inf-sup stable finite elements for the Stokes velocity and pressure pair and for the structure displacement and pore fluid pair. Wellposedness and stability of the scheme will be explored, and error estimates will be provided. A heuristic stabilization technique will also be discussed to take care of the non-physical oscillations that may happen with realistic problem parameters. A few numerical experiments will be presented to corroborate the error analysis. (Received August 17, 2018)

1143-65-313 **Mahboub Baccouch***, 6001 Dodge st., DSC 233, omaha, NE 68182. *Asymptotically exact posteriori error estimates for the local discontinuous Galerkin method for nonlinear third-order Korteweg-de Vries equations in one space dimension.*

In this talk, we present an implicit a posteriori error estimates for the local discontinuous Galerkin (LDG) method for nonlinear third-order KdV equations in one space dimension. Optimal a priori error estimates for the LDG solution and for the two auxiliary variables that approximate the first- and second-order derivatives are derived in the L^2-norm. The order of convergence is proved to be $p+1$, when piecewise polynomials of degree at most p are used. We further show that the LDG solution is superconvergent with order $p+3/2$ toward a special Gauss-Radau projection of the exact solution. We use this superconvergence result to show that the LDG error on each element can be split into two parts. The first part is proportional to the $(p+1)$-degree right Radau polynomial and the second part converges with order $p+3/2$ in the L^2-norm. These results allow us to construct computationally simple a posteriori LDG error estimates.. Furthermore, we prove that these a posteriori error estimates converge to the exact errors in the L^2-norm under mesh refinement with order $p+3/2$. Finally, we prove that the global effectivity index converges to unity at $O(h^{1/2})$ rate. Several numerical experiments are provided to validate the theoretical results. (Received August 17, 2018)

1143-65-331 **Bo Dong*** (bdong@umassd.edu), **Yanlai Chen** and **Jiahua Jiang**. *Optimally convergent HDG method for fifth-order KdV equations.*

We develop and analyze the first hybridizable discontinuous Galerkin (HDG) method for solving fifth-order Korteweg-de Vries (KdV) type equations. We show that the semi-discrete scheme is stable with proper choices of the stabilization functions in the numerical traces. For the linearized fifth-order equations, we prove that the approximations to the exact solution and its four spatial derivatives as well as its time derivative all have optimal convergence rates. The numerical experiments, demonstrating optimal convergence rates for both the linear and nonlinear equations, validate our theoretical findings. (Received August 17, 2018)

1143-65-342 **Hengguang Li***, Department of Mathematics, Wayne State University, Detroit, MI 48202, and **Xun Lu**. *Finite element condition numbers on a class of anisotropic meshes.*

New 3D anisotropic mesh algorithms were proposed for the finite element method to approximate elliptic equations with singularities. These algorithms are simple, intuitive, and impose less geometric constraints on the domain. The resulting mesh is generally anisotropic and the associated numerical approximation has optimal convergence. In this talk, we report new developments in these algorithms both in 2D and 3D, especially sharp estimates on the condition numbers of the finite element stiffness matrices from these meshes. (Received August 18, 2018)

1143-65-345 **Jinchao Xu** and **Yukun Li*** (li.7907@osu.edu), Columbus, OH 43210, and **Shuonan Wu** and **Arthur Bousquet**. *Stability and Accuracy of Numerical Schemes for Phase Field Modeling.*

In this talk, I will talk about the accuracy and stability of partially and fully implicit schemes for phase field modeling. Through theoretical and numerical analysis of Allen-Cahn and Cahn-Hillard models, we investigate the potential problems of using partially implicit schemes, demonstrate the importance of using fully implicit schemes and discuss the limitation of energy stability that are often used to evaluate the quality of a numerical scheme for phase-field modeling. We will discuss some important properties of phase-field models, such as unconditional stability, the discrete maximum principle, adaptivity and fast solvers. (Received August 18, 2018)

1143-65-350 **Anqi Chen*** (chenanq3@msu.edu), **Yong Liu**, **Mengping Zhang** and **Yingda Cheng**. *Superconvergence of ultra-weak discontinuous Galerkin methods for linear Schrödinger equations in one-dimension.*

In this paper, we analyze the superconvergence properties of the ultra-weak discontinuous Galerkin method for one-dimensional linear Schrödinger equations. We prove superconvergence of $(k+2)$-th order of the DG solution towards a special projection designed according to flux parameters. Combine with the recently developed correction functions technique, $(2k)$-th order superconvergence rate for cell averages and numerical flux, as well as $(2k$-1)-th order for numerical flux of derivative, of the DG solution are proved. In addition, at a class of special points, the derivative and function values of the DG solution are proven to be superconvergent with order $k+1$ and $k+2$, respectively. We also apply the post-processing technique to enhance the accuracy of our scheme and prove the superconvegence rate of $(2k)$-th order by negative-norm estimates. (Received August 18, 2018)

1143-65-368 **Mahboub Baccouch*** (mbaccouch@unomaha.edu), 6601 university Dr. N, DSC 233, omaha, NE 68182-0001. *A finite difference method for stochastic second-order boundary-value problems driven by additive white noises.*

In this talk, we develop and analyze a finite difference method for scalar stochastic two-point boundary-value problems (SBVPs) driven by additive white noises. We first introduce an approximate SBVP by replacing the white noise process with its piecewise constant approximation. We prove that the solution of the modified SBVP converges to the solution of the original SBVP. The order of convergence is proved to be two in the mean-square sense. The new approximate SBVP is shown to have better regularity which facilitates the convergence proof for the proposed scheme. We then apply the standard finite difference method for deterministic SBVPs to approximate the solution of the new stochastic SBVP. Convergence analysis is presented for the numerical solution based on the standard finite difference method. In particular, we prove that the numerical solution converges at $\mathcal{O}(h^2)$ in the mean-square sense, when the second-order accurate three-point formulas to approximate the first and second derivatives are used. Finally, we present several numerical examples to validate the obtained analytical results. (Received August 19, 2018)

1143-65-371 **Amanda E Diegel***, Mathematics and Statistics, PO Box MA, Starkville, MS 39759, and **Susanne C Brenner** and **Li-Yeng Sung**. *Robust Solvers for FEMs for the Cahn-Hilliard Equation.*

We develop a robust solver for a first order mixed finite element splitting scheme for the Cahn-Hilliard equation. The key ingredient of the solver is a preconditioned minimal residual algorithm (with a multigrid preconditioner) whose performance is independent of the spacial mesh size and the time step size for a given interfacial width parameter. The dependence on the interfacial width parameter is also mild. We conclude by showing the extension of the solver to a second order finite element method for the Cahn-Hilliard Equation. (Received August 19, 2018)

1143-65-419 **Jerry L Bona**, **Hongqiu Chen**, **Ohannes Karakashian*** (okarakas@utk.edu) and **Michael M Wise**. *Finite Element Methods for A System Of Dispersive Equations.*

The present study is concerned with the numerical approximation of periodic solutions of systems of Korteweg–de Vries type, coupled through their nonlinear terms. We construct, analyze and numerically validate two types of schemes that differ in their treatment of the third derivatives appearing in the system. One approach preserves a certain important invariant of the system, up to round-off error, while the other, somewhat more standard method introduces a measure of dissipation. For both methods, we prove convergence of a semi-discrete approximation and highlight differences in the basic assumptions required for each. Numerical experiments are also conducted with the aim of ascertaining the accuracy of the two schemes when integrations are made over long time intervals. (Received August 20, 2018)

1143-65-424 **Xiaobing H. Feng*** (xfeng@math.utk.edu), Department of Mathematics, The University of Tennessee, Knoxville, TN 37996. *Discontinuous Ritz methods for calculus of variations problems.*

In this talk I shall present a newly developed discontinuous Ritz (DR) framework for a class of calculus of variations problems. The proposed DR framework can be regarded as a counterpart of the discontinuous Galerkin (DG) framework for PDEs. The focuses of the talk will be to discuss main idea for constructing the discrete energy functional, which is based on the discontinuous Galerkin finite element discrete calculus theory, and to establish its Gamma-convergence to the continuous energy functional. Numerical experiment results will also be presented to demonstrate the efficiency of the proposed DR framework. If time permits, numerical techniques for resolving the so-called Lavrentiev phenomenon will also be presented. This is a joint work with Stefan Schnake of University of Oklahoma. (Received August 20, 2018)

1143-65-437 **Slimane Adjerid*** (adjerids@vt.edu), Department of Mathematics, Virginia Tech , 460 McBryde Hall, Blcksburg, VA 24061, and **Tao Lin** and **Kihyo Moon**. *High-order immersed finite element methods for interface problems.*

We discuss immersed finite element methods for solving interface problems modeled by partial differential equations with discontinuous coefficients. We start with a brief historical review of immersed finite element methods and their advantages. We will address issues and challenges of constructing higher-order immersed finite element spaces and weak Galerkin formulations for high accuracy computations. We will present computational results for several applications and conclude with a list of open questions and future research projects. (Received August 20, 2018)

1143-65-527 **Melvin Leok*** (mleok@ucsd.edu), 9500 Gilman Drive, Dept. 0112, La Jolla, 92093-0112. *Variational discretizations of gauge field theories using group-equivariant interpolation spaces.*

Variational integrators are geometric structure-preserving numerical methods that preserve the symplectic structure, satisfy a discrete Noether's theorem, and exhibit exhibit excellent long-time energy stability properties. An exact discrete Lagrangian arises from Jacobi's solution of the Hamilton–Jacobi equation, and it generates the exact flow of a Lagrangian system. By approximating the exact discrete Lagrangian using an interpolation space and quadrature rule, we can systematically construct variational integrators whose convergence rates are related to the best approximation properties of the interpolation space.

Many gauge field theories can be formulated variationally using a multisymplectic formulation, and we characterize the exact generating functionals that generate the multisymplectic relation. By discretizing these using group-equivariant spacetime finite element spaces, we obtain methods that exhibit a discrete multimomentum conservation law. Lorentzian metric-valued group-equivariant interpolation spaces can be constructed using a generalized polar decomposition. The goal is to use this to construct variational discretizations of general relativity, which is a second-order gauge field theory whose configuration manifold is the space of Lorentzian metrics. (Received August 21, 2018)

1143-65-528 **Zhengdao Chen**, **Baranidharan Raman** and **Ari Stern*** (stern@wustl.edu). *Structure-preserving numerical integrators for relaxation oscillators.*

Relaxation oscillators pose a challenge for numerical integration, due to the presence of fast and slow time scales. Conventional exponential integrators (such as exponential Euler) allow for numerical stability at large time steps, but do a poor job at capturing the limit cycles governing oscillatory behavior unless the time step size is taken very small. In practice, this results in numerical solutions with the wrong amplitude and/or frequency of oscillation. We present a new family of methods that can maintain stability and preserve limit cycles for much larger time step sizes, with no increase in computational effort over exponential Euler. This is illustrated for the Van der Pol oscillator, as well as for the Hodgkin–Huxley model of neuronal dynamics (whose oscillations correspond to neuronal spiking). Although these systems are dissipative, Hamiltonian and symplectic structures play an interesting role. (Received August 21, 2018)

1143-65-581 **Gerard Awanou*** (awanou@uic.edu). *Discrete Aleksandrov solutions of the Monge-Ampere equation.*

A discrete analogue of the Dirichlet problem of the Aleksandrov theory of the Monge-Ampere equation is derived in this paper. The discrete solution is not required to be convex, but only discrete convex. We prove that the uniform limit on compact subsets of discrete convex functions which are uniformly bounded and which interpolate the Dirichlet boundary data is a continuous convex function which satisfies the boundary condition strongly. The domain of the solution needs not be uniformly convex. We obtain the first proof of convergence of a wide stencil finite difference scheme to the Aleksandrov solution of the elliptic Monge-Ampere equation when the right hand side is a sum of Dirac masses. The discrete scheme we analyze for the Dirichlet problem, when coupled with a discretization of the second boundary condition, can be used to get a good initial guess for geometric methods solving optimal transport between two measures. (Received August 22, 2018)

68 ► Computer science

1143-68-167 **Peter J Olver*** (olver@umn.edu), School of Mathematics, University of Minnesota, Minneapolis, MN 55455. *Reassembly of broken objects.*

The problem of reassembling broken objects appears in a broad range of applications, including jigsaw puzzle assembly, archaeology (broken pots and statues), surgery (broken bones and reassembly of histological sections), paleontology (broken fossils and egg shells), and anthropology (more broken bones). I will discuss recent progress on such problems, based on advances in the mathematical apparatus of equivalence and symmetry, moving frames, differential and integral invariant signatures, and invariant numerical approximations. (Received August 09, 2018)

1143-68-243 **Giovanni Di Crescenzo** (gdicrescenzo@perspectalabs.com) and **Delaram Kahrobaei** (dkahrobaei@gc.cuny.edu), corona, NY 11368, **Matluba Khodjaeva*** (mkhodjaeva@jjay.cuny.edu), NY 11368, and **Vladimir Shpilrain** (shpil@groups.sci.ccny.cuny.edu). *Efficient and Secure Delegation to a Single Malicious Server: Exponentiation over Non-Abelian Groups.*

Group exponentiation is an important and expensive operation used in many public-key cryptosystems and, more generally, cryptographic protocols. To expand the applicability of these solutions to computationally weaker devices, it has been advocated that this operation is delegated from a computationally weaker client to a computationally stronger server. Solving this problem in the case of a single, possibly malicious, server, has remained open since a formal model was introduced by Hohenberger and Lysyanskaya in 2005. Recently, we proposed practical and secure solutions applicable to a class of cyclic groups. In this talk, we present efficient and secure solutions applicable to a large class of multiplicative groups, possibly beyond groups currently subject to quantum cryptanalysis attacks. (Received August 15, 2018)

1143-68-367 **Kelsey Horan*** (khoran@gradcenter.cuny.edu), **A Gribov**, **J Gryak**, **D Kahrobaei**, **R Soroushmehr**, **V Shpilrain** and **K Najarian**. *Medical Diagnostics Based on Encrypted Medical Data.*

The Health Insurance Portability and Accountability Act places firm constraints on the privacy practices surrounding all medical data. One problem is that a useful patient database is insecure, while a secure patient database is useless. The cryptographic community has recently developed fully homomorphic encryption schemes, which admit secure computation over encrypted data.

Our work provides secure machine learning via FHE. We provide results from two simulations. The specific FHE scheme that is used in the simulations was developed by Kahrobaei and Shpilrain and is based on homomorphisms between rings.

In the first simulation we play the role of a research center that is external to the data owner; we are given an encrypted database and train a function on the encrypted data. The goal is to accurately use the data without decrypting.

In the second simulation we run several statistical tests on real-life databases encrypted by our method. Again, we play the role of a research center with the goal of using encrypted data to compute diagnostic functions.

The implementations illustrate efficient data mining without decryption while maintaining correctness. It is completely feasible to consider this encryption scheme for highly sensitive federally regulated data. (Received August 19, 2018)

1143-68-398 **Anand D. Sarwate*** (anand.sarwate@rutgers.edu), Department of ECE, Rutgers, The State University of New Jersey, 94 Brett Road, Piscataway, NJ 08854. *Learning latent structures under differential privacy.*

Differential privacy is a framework for understanding privacy risks when performing computation on sensitive data. In differential privacy, the goal is to obscure whether any particular individual's data was used in the computation. In differentially private machine learning methods, the goal is to learn or infer some property of the population: in this sense, privacy is compatible with learning since a good learning algorithm should not depend too strongly on individual data points. Many learning methods seek to infer some latent structure in the data. For example, principle components analysis tries to find a low-dimensional subspace such that most of the data lies close to this subspace. In this talk I will describe techniques for learning such structures under differential privacy. (Received August 19, 2018)

1143-68-417 **Zachary Charles*** (zcharles@wisc.edu) and **Dimitris Papailiopoulos** (dimitris@ece.wisc.edu). *Stability and generalization of convergent learning algorithms under the Loajasiewicz inequality.*

In machine learning we often want to bound the generalization error of an algorithm. This is a measure of how well a learning algorithm generalizes to new data. While directly quantifying the generalization error of an algorithm can be difficult, prior work has shown that stable algorithms generalize well. Roughly speaking, a learning algorithm is stable if small changes in the training data do not lead to large changes in the output model. Using stability, we derive generalization bounds for algorithms that depend only on the convergence of the algorithm and the geometry of the empirical risk function. We focus on empirical risk functions satisfying a version of the Lojasiewicz inequality from real algebraic geometry. While this condition has a rich history in optimization, we further show that it has strong implications for stability and generalization in machine learning. Our results match or improve many state-of-the-art generalization bounds and easily extend to different learning

algorithms. Finally, we show that this condition arises naturally in the theory of neural networks. (Received August 20, 2018)

1143-68-418 **Carmen Alcaraz-Garófano** (carmenalcaraz29@gmail.com) and **Enrique Dominguez*** (enriqued@lcc.uma.es), ETSI Informatica - University of Malaga, 29071 Malaga, Spain. *Digital images analysis by deep learning techniques for melanoma diagnosis.*

Skin cancer was the most commonly diagnosed cancer in the US in 2016. Melanoma accounts for only 1% of all skin cancer cases, but the vast majority of skin cancer deaths. This is a type of skin cancer caused by abnormal multiplication of pigment producing cells that give color to the skin: melanocytes. Melanoma is highly curable when detected in its earliest stages, it is more likely than other skin cancer to spread to other parts of the body. Melanoma, in their initial growth phases, and other benign moles are similarities in their characteristic, which makes the diagnosis difficult between what is malignant and what is benign for experienced dermatologists. Convolutional Neural Networks (CNNs) is one of the most popular deep learning techniques for image analysis. Nowadays, with the help of GPU-accelerated computing techniques, CNNs have been successfully applied to object recognition, recommender systems or image classification. In this work, two different deep learning based methods have been implemented on a computer for detection of melanoma lesions, which could assist a dermatologist in early diagnosis of this cancer. (Received August 20, 2018)

70 ► Mechanics of particles and systems

1143-70-71 **Ryan A Denlinger*** (denlinger@math.utexas.edu), Austin, TX 78712. *On the rigorous validity of collisional kinetic equations.*

One well-accepted definition of validity for kinetic equations is that "typical" microscopic N-particle initial conditions, chosen randomly subject to consistency with some prescribed initial distribution, evolve under (fully deterministic!) Newton's laws in agreement with the expected PDE (for some given scaling) when N tends to infinity. In the case of Boltzmann's equation, such a validity result is only known for hard spheres or similarly localized interactions, and only up to the mean free time for a particle of gas. This result goes back to Oscar Lanford in the 1970s for hard spheres, and his student King for short-range potentials. Lanford's proof is fully perturbative and crucially relies on a Dyson series expansion which can only be expected to converge on a short time interval. Moreover, due to the extreme singularity of the dynamics, so far there is no known alternative validity proof starting from the fully deterministic dynamics. We discuss recent results on precise characterizations of the manner in which the information from the initial time is propagated forwards. Finally we conclude with related open problems, including the derivation of Vlasov+Boltzmann type equations (incorporating mean-field and short-range effects). (Received July 28, 2018)

1143-70-223 **Mark Levi*** (levi.psu@gmail.com), Mathematics Department, Penn State University, University Park, PA 16802. *Tire track geometry, Schroedinger's equation, Berry's phase and the Keller-Masolv index.*

I will describe some recent results on the connections between the objects mentioned in the title. (Received August 14, 2018)

1143-70-247 **Manuele Santoprete*** (msantopr@gmail.com), 75 University West, Wilfrid Laurier University, 75 University Avenue West, Waterloo, ON N2L 3C5, Canada. *On the Relationship between Two Notions of Compatibility for Bi-Hamiltonian Systems.*

Bi-Hamiltonian structures are of great importance in the theory of integrable Hamiltonian systems. The notion of compatibility of symplectic structures is a key aspect of bi-Hamiltonian systems. Because of this, a few different notions of compatibility have been introduced. In this talk we will discuss some of these notions and show that, under some additional assumptions, compatibility in the sense of Magri implies a notion of compatibility due to Fassò and Ratiu, that we dub bi-affine compatibility. (Received August 15, 2018)

1143-70-512 **Tanya Schmah*** (tschmah@uottawa.ca) and **Cristina Stoica** (cstoica@wlu.ca). *Controlling rigid body attitude via shape change.* Preliminary report.

Satellite attitude control is typically achieved via reaction wheels (i.e. rotors) or magnets, which leave the moment of inertia fixed. We investigate an alternative control mechanism: sliding point masses, which change the moment of inertia and thus the angular velocity, while angular momentum remains fixed and nonzero. (Received August 21, 2018)

1143-70-569 **Scott David Kelly*** (scott@kellyfish.net). *Dynamics of mechanically coupled nonholonomic systems.*

It was observed by Huygens that pendulum clocks mounted to a common mantel will synchronize as a result of mechanical coupling. This talk will explore the influence of analogous coupling on the dynamics of wheeled vehicles rolling atop a common platform. The Chaplygin sleigh surmounted by an actuated rotor has been shown previously to exhibit interesting properties as a nonlinear control system and as a simplified model for a rotor-driven aquatic vehicle. It will be shown that a passive version of such a device, involving a spring-loaded rotor, can be induced to reorient and follow an active version of the device when the two are coupled through a common support, recalling the entrainment of passive bodies by active bodies that's commonly observed, but attributed to more complicated coupling, in fluids. (Received August 21, 2018)

74 ► Mechanics of deformable solids

1143-74-39 **Silas Alben*** (alben@umich.edu) and **Xiaolin Wang**. *Dynamics and locomotion of flexible foils in a frictional environment.*

Abstract—Flexible foils have long been used as a generic model for the bodies and appendages of organisms (e.g. fish and snakes) in locomotion. To understand the range of possible dynamics including efficient locomotion, we have used analysis and computations together with experiments to study flexible foils in a frictional environment. Resonances can occur at certain flapping frequencies, scaled by elastic parameters. Resonances correspond to peaks in propulsive force, but also input power supplied to the foil, and are often states of low efficiency. Other generic phenomena are the transition from periodic to non-periodic and chaotic dynamics as the heaving amplitude increases or the bending rigidity decreases, and the spontaneous emergence of traveling wave motions. We have determined more generally which planar snake motions are optimal for efficiency. The optimal motions help to explain the widespread observations of traveling wave motions in biological snakes. (Received July 06, 2018)

1143-74-466 **Vakhtang Putkaradze*** (putkarad@ualberta.ca), Department of Mathematics, University of Alberta, Edmonton, T6G2J1, Canada. *Geometric theory of flexible and expandable tubes conveying fluid.*

We present a theory for the three-dimensional evolution of tubes with expandable walls conveying fluid. Our theory can accommodate arbitrary deformations of the tube, arbitrary elasticity of the walls, and both compressible and incompressible flows inside the tube. We also present the theory of propagation of shock waves in such tubes and derive the conservation laws and Rankine-Hugoniot conditions in arbitrary spatial configuration of the tubes, and compute several examples of particular solutions. The theory is derived from a variational treatment of Cosserat rod theory extended to incorporate expandable walls and moving flow inside the tube. Time permitting, we shall also show how the geometric approach to the problem allows writing the Poisson bracket for the system. The results presented here are useful for biological flows and industrial applications involving high speed motion of gas in flexible tubes. (Received August 20, 2018)

76 ► Fluid mechanics

1143-76-25 **Ling Xu*** (lingxu@umich.edu), 530 Church Street, Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, and **Robert Krasny** (krasny@umich.edu). *Effects of the convection and diffusion in the viscous Lamb dipole.*

Self-propelled Lamb dipoles are fundamental units of large-scale vortical flows, for example, the ocean currents. Here we present a numerical study of the viscous Lamb dipole for Reynolds numbers in the range [125, 1000]. The focus is on the effects of convective and diffusion. The influence of these two terms are isolated and discussed by comparing solutions of the Navier-Stokes equation (NSE) with solutions of the diffusion equation (DE). (Received June 20, 2018)

1143-76-33 **Saeed Jafari Kang**, **Esmaeil Dehdashti** and **Hassan Masoud*** (hmasoud@mtu.edu), Michigan Technological University, 1400 Townsend Dr., Houghton, MI 49931. *Marangoni propulsion of spheroidal particles.*

We theoretically study the surfing motion of chemically and thermally active particles located at a flat liquid-gas interface that sits above a liquid layer of finite depth. The particles' activity creates and maintains a surface tension gradient resulting in the auto-surfing. It is intuitively perceived that Marangoni surfers propel towards

the direction with a higher surface tension. Remarkably, we find that the surfers may propel in the lower surface tension direction depending on their geometry and proximity to the bottom of the liquid layer. In particular, our analytical calculations for Stokes flow and diffusion-dominated scalar (i.e. chemical concentration and temperature) fields indicate that spherical particles undergo reverse Marangoni propulsion under confinement whereas disk-shaped surfers always move in the expected direction. We extend our results by proposing an approximate formula for the propulsion speed of oblate spheroidal particles based on the speeds of spheres and disks. Overall, our findings pave the way for designing microsurfers capable of operating in bounded environments. (Received July 03, 2018)

1143-76-37 **Silas Alben*** (alben@umich.edu). *Optimal Convection Cooling Flows in Channels and General 2D Geometries.*

We generalize a recent method for computing optimal 2D convection cooling flows in a horizontal layer to a wide range of geometries, including those relevant for technological applications. We write the problem in a conformal pair of coordinates which are the pure conduction temperature and its harmonic conjugate. We find optimal flows for cooling a cylinder in an annular domain, a hot plate embedded in a cold surface, and a channel with hot interior and cold exterior. With a kinetic energy constraint, the optimal flows consist of vortices ranging in size from the length of the hot surface to a small cutoff length at the interface of the hot and cold surfaces. With a constraint on input power (fixed rate of viscous dissipation), the optimal flows are dominated by large-scale vortices, with the same size as the flow domain. We also adapt the method to the special case of channel cooling by incorporating inflow and outflow boundary conditions. For an energy budget given by Pe squared, the optimal flows give heat transfer that scales as Pe to the power 2/5, larger than that of Poiseuille flow, which scales as Pe to the power 1/3. (Received July 06, 2018)

1143-76-42 **Matt Novack*** (mnovack@math.utexas.edu) and **Alexis Vasseur**. *The Inviscid 3D Quasi-Geostrophic System on Bounded Domains.*

We present a formal derivation of the inviscid 3D quasi-geostrophic system (QG) from primitive equations on a bounded, cylindrical domain. A key point in the derivation is the treatment of the lateral boundary and the resulting boundary conditions it imposes on solutions. To our knowledge, these boundary conditions are new and differentiate our model from closely related models which have been the object of recent study. These boundary conditions are natural for a variational problem in a particular Hilbert space. We construct solutions and prove an elliptic regularity theorem corresponding to the variational problem, allowing us to show the existence of global weak solutions to (QG). (Received July 08, 2018)

1143-76-63 **Robert Krasny*** (krasny@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109, **Peter A. Bosler** (pabosle@sandia.gov), Center for Computing Research, Sandia National Laboratories, Albuquerque, NM 87123, and **Ling Xu** (lingxu@umich.edu), Department of Mathematics, University of Michigan, Ann Arbor, MI 48109. *A New Implementation of the Vortex Method.* Preliminary report.

We discuss a new implementation of the vortex method for the incompressible Euler equations. This work focuses on general smooth vorticity distributions as opposed to vortex sheets. As usual in a vortex method the vorticity is carried by Lagrangian particles and the velocity is recovered by the Biot-Savart integral. The new implementation uses remeshing and adaptive refinement to maintain accuracy and resolve small-scale features in the flow, and a treecode algorithm is used to reduce the CPU time from $O(N^2)$ to $O(N \log N)$, where N is the number of particles representing the flow map. The method is demonstrated for problems involving vortex dynamics on a rotating sphere and in two-dimensional free space including axisymmetrization of an elliptic vortex. (Received July 24, 2018)

1143-76-98 **Alexander P Hoover*** (ahoover1@uakron.edu). *The emergence of neuromechanical resonance in jellyfish locomotion.*

In order for an organism to have an robust mode of locomotion, the underlying neuromuscular organization must be maneuverable in a changing environment. In jellyfish, the activation and release of muscular tension is governed by the interaction of pacemakers with the underlying motor nerve net that communicates with the musculature. This set of equally-spaced pacemakers located at bell rim alter their firing frequency in response to environmental cues, forming a distributed mechanism to control the bell's muscular contraction. When turning, pacemakers induce an asymmetrically timed contraction with the bell musculature. In this work, we explore the control of neuromuscular activation with a model jellyfish bell immersed in a viscous fluid and use numerical simulations to describe the interplay between active muscle contraction, passive body elasticity, and fluid forces. The fully-coupled fluid structure interaction problem is solved using an adaptive and parallelized version of the

immersed boundary method (IBAMR). This model is then used to explore the interplay between the speed of neuromechanical activation, fluid dynamics, and the material properties of the bell. (Received August 02, 2018)

1143-76-107 **Sookkyung Lim*** (sookkyung.lim@uc.edu), 4199 French Hall West, Cincinnati, OH 45221, and **Yongsam Kim** and **Yunyoung Park**. *Single-Flagellated Bacterial Swimming: Run, Reverse, and Flick.*

Single-flagellated bacteria propel themselves by rotating a flagellar motor, translating rotation to the filament through a compliant hook and subsequently driving the rotation of the flagellum. The flagellar motor alternates the direction of rotation between counterclockwise and clockwise, and this leads to the forward and backward directed swimming. Such bacteria can change the course of swimming as the hook experiences its buckling caused by the change of bending rigidity. In this paper, we present a comprehensive model of a monotrichous bacterium as a free swimmer in a viscous fluid. We describe a cell body as a massive rigid body using the penalty method and a flagellum as an elastic rod using Kirchhoff rod theory. The hydrodynamic interaction of the bacterium is described by the regularized Stokes formulation. Our model of a single-flagellated microorganism is able to mimic the swimming pattern that is well matched with the experimental observation. Furthermore, we find the critical thresholds of the rotational frequency of the motor and the bending modulus of the hook for the buckling instability, and investigate the dependence of the buckling angle and the reorientation of the swimming cell after buckling on the physical and geometrical parameters of the model. (Received August 03, 2018)

1143-76-184 **Montassar Aidi Sharif*** (sharifm5@msu.edu), Department of Electrical and Computer Enginee, Michigan State University, East Lansing, MI 48824, **Matthew J. McHenry** (mmchenry@uci.edu), Department of Ecology & Evolutionary Biology, University of California, Irvine, CA 92697, and **Xiaobo Tan** (xbtan@egr.msu.edu), Dept of Electrical & Computer Engineering, Michigan State University, East Lansing, MI 48824. *The role of morphology in sensitivity of artificial lateral lines.*

The lateral line system, consisting of flow-sensing units called neuromasts, enables fishes and amphibians to perceive their hydrodynamic surroundings. Recently the lateral line has inspired much interest in developing its engineering counterpart for underwater robots. Through a combined modeling and experimentation study, we explore how size, shape, and stiffness of a neuromast influence its sensitivity in detecting flow stimuli. In particular, we examine the validity of an analytical sensitivity model for biological superficial neuromasts, as the neuromast scale increases, through comparison with a finite-element model that captures fluid-structure interactions. The finite-element model is further exploited to understand how geometry and stiffness play a role in the behavior of an artificial neuromast, and prototypes of the latter are developed to corroborate the model. (Received August 10, 2018)

1143-76-192 **Longhua Zhao*** (lxz315@case.edu), **Li Zhang** and **Yang Ding**. *Trapping and Manipulation by micro-fluidic tweezers in a highly viscous fluid.*

Nanowire fluidic tweezers have been developed to gently and accurately capture, manipulate, and deliver micro objects. The mechanism behind the capture and release process has not yet been well explained. Utilizing the method of regularized Stokeslet, we study a cylindrical nanowire tumbling and interacting with spherical particles in the Stokes regime. The capture phenomenon observed in experiments is reproduced and illustrated with the trajectories of micro-spheres and fluid tracers. The flow structure and the region of capture are quantitatively examined and compared for different sizes of particles, various tumbling rates, and dimensions of the tweezers. We find that pure kinematic effects can explain the mechanism of capture and transport of particles. We further reveal the relation between the capture region and stagnation points in the displacement field, i.e., the displacement for tracer particles in the moving frame within one rotation of the wire. (Received August 12, 2018)

1143-76-205 **Andrew M Hess*** (hessand6@egr.msu.edu) and **Tong Gao**. *Evolutionary Optimization of Soft Swimming Robots.*

Engineering a soft robotic swimmer presents a unique challenge due to the inherently large numbers of degrees of freedom associated with their design. We present a method of developing optimal designs for soft swimmers powered by artificial muscle. To do so, the U-NSGA-III optimization method is coupled with a FD/DLM FSI method simulating robotic fish actuated by an artificial muscle model. Since U-NSGA-III is a multi-objective method it in effect produces a map of potentially optimal solutions. This information can then be employed in the design of robotic swimmers as well as the research of swimming methods. We successfully evolve multiple, unique swimmers that are biomimetic in nature from an initial set of randomly selected design parameters, in essence reproducing a small piece of natural evolution. (Received August 13, 2018)

1143-76-366 **Charles R. Doering*** (doering@umich.edu) and **Christopher J. Miles**.
Diffusion-limited mixing by incompressible flows.

Incompressible flows can be effective mixers by advecting tracer concentrations to produce small filamentation length scales. In addition, diffusion is generally beneficial to mixing due to its ability to homogenize a passive tracer. However we provide numerical evidence that in cases where advection and diffusion are both actively present, diffusion may actually limit the mixing effectiveness of optimal flows. This appears to be due to the presence of a limiting length scale corresponding to a generalized Batchelor length. This length scale limitation may in turn affect long-term mixing rates. More specifically, we consider local-in-time flow optimization under energy and enstrophy flow constraints with the objective of maximizing the mixing rate. We observe that, for enstrophy-bounded optimal flows, the strength of diffusion may not impact the long-term mixing rate. For energy-constrained optimal flows, however, an increase in the strength of diffusion can decrease the mixing rate. We provide analytical lower bounds on mixing rates and length scales achievable under related constraints, i.e., point-wise bounded speed or rate-of-strain. This work was recently published in *Nonlinearity* **31**, 2346–2359 (2018). (Received August 19, 2018)

1143-76-383 **Tessa Stevens**, **Jodi Turk**, **Longhua Zhao** and **Wei Zhang***, Mechanical Engineering Department, Cleveland State University, Cleveland, OH 44115. *Flying Spiders: Effects of the length of a dragline and the spider mass in ballooning.*

Most spiders use a type of aerial dispersal "ballooning" to move from one location to another. By ballooning, spiders can reach distances as far as 3200 km and heights of up to 5 km. Though a large number of observations of spider ballooning have been reported, it remains a mysterious phenomenon. What dominate the three stages of spider takeoff, flight, and settling? There are many factors to consider, including a spider's mass, morphology, posture, the silken dragline properties, and local meteorological conditions (turbulent level and thermal stability). A thorough understanding of the roles of these critical parameters is not only of ecological significance but also essential for improving advanced technologies for bio-inspired innovations of airborne robotic devices. The preliminary laboratory test is to determine how the silk dragline length and spider mass affect the dynamics of freefall at Reynolds numbers of several thousand, using recordings by a high-speed camera. The vertical velocities of the dragline and the induced flow structures are compared against numerical models of coupled fluid-structure interaction. Such results are expected to shed lights on the intriguing flow physics of spider ballooning and validate new models. (Received August 19, 2018)

1143-76-404 **David Goluskin*** (goluskin@uvic.ca) and **Giovanni Fantuzzi**. *Numerical bounds on average and instantaneous energy in the Kuramoto–Sivashinsky equation.*

This talk is a sequel to that of Fantuzzi. First I will present bounds on time-averaged energy in the Kuramoto–Sivashinsky equation. These bounds are computed by using semidefinite programming to construct auxiliary functionals of higher than quadratic degree – a generalization of the background method. Then I will describe a related framework for using semidefinite programming to compute bounds on instantaneous extrema over global attractors. This too will be illustrated using the Kuramoto–Sivashinsky equation. Results support the conjecture that spatially averaged energy remains bounded as the domain grows. (Received August 20, 2018)

1143-76-405 **Giovanni Fantuzzi*** (giovanni.fantuzzi10@imperial.ac.uk), CAGB210, Imperial College London, London, SW7 2AZ, United Kingdom. *Optimization of background fields using semidefinite programming.*

Quantitative analysis of turbulent flows, in particular of the mean turbulent transport of mass, momentum or heat, is one of the fundamental challenges in fluid mechanics. Given the lack of exact turbulent solutions and the complexity of fully resolved numerical simulations, a common approach is to derive rigorous bounds on the turbulent transport directly from the equations of motion. This talk will review a recent approach for bounding time-averaged scalar quantities, which is based on so-called *auxiliary functionals* of the flow variables. It will be demonstrated that constructing quadratic auxiliary functionals of the "energy plus linear terms" form amounts to looking for a background field in the traditional "background method" by Doering & Constantin [Phys. Rev. E **53**, 5957 (1996)]. It will also be shown that background fields can be optimized numerically using efficient algorithms for semidefinite programming, thereby enabling one to compute the best possible bounds on offer. Optimized bounds on the mean vertical heat flux for various convective flows will be presented to illustrate the potential of the proposed methods, as well as the remaining challenges for bounding mean turbulent transport in fluid flows. (Received August 20, 2018)

1143-76-461 **Yuanyuan Feng** and **Gautam Iyer***, Dept. of Math. Sci, WEH #6113, Carnegie Mellon University, Pittsburgh, PA 15206. *Dissipation Enhancement by Mixing.*

We quantitatively study the interaction between diffusion and mixing in both the continuous, and discrete time setting. In discrete time, we consider a mixing dynamical system interposed with diffusion. In continuous time, we consider the advection diffusion equation where the flow of the advecting vector field is assumed to be sufficiently mixing. Our main focus is to explicitly estimate the dissipation time based on the mixing rate. Moreover, in the discrete time setting, we show that the L^2 energy decays double exponentially in time, and this double exponential rate is achieved for by a large class of toral automorphisms. (Received August 20, 2018)

1143-76-494 **Federico Fuentes*** (federico.fuentes@cornell.edu), 582 Malott Hall, Cornell University, Ithaca, NY 14853, and **David Goluskin** (goluskin@uvic.ca). *Global stability of 2D plane Couette flow beyond the energy stability limit.*

A fundamental question in fluid stability is whether a laminar flow is nonlinearly stable to all perturbations. The typical way to verify this type of stability, called the energy method, is to show that the energy of a perturbation must decay monotonically under a certain Reynolds number called the energy stability limit. The energy method is known to be overly conservative in many systems, such as in plane Couette flow. Here, we present a methodology to computationally construct Lyapunov functions more general than the energy, which is a quadratic function of the magnitude of the perturbation velocity. These new Lyapunov functions are not restricted to being quadratic, but are instead high-order polynomials that depend explicitly on the spectrum of the velocity field in the eigenbasis of the energy stability operator. The methodology involves numerically solving a convex optimization problem through semidefinite programming (SDP) constrained by sums-of-squares polynomial ansatzes. We then apply this methodology to 2D plane Couette flow and under certain conditions we find a global stability limit higher than the energy stability limit. For this specific flow, this is the first improvement in over 110 years. (Received August 20, 2018)

1143-76-516 **Jared P Whitehead*** (whitehead@mathematics.byu.edu), 275 TMCB, Brigham Young University, Provo, UT 84602-0002. *Heat transport in rapidly rotating convection.*

Rigid body rotation has a direct influence on the transport of heat in Rayleigh-Bénard convection, particularly when the rotation rate and the heating rate both lie in intermediate ranges. Unfortunately, traditionally derived asymptotic bounds on the heat transport for the full 3D model do not capture these effects as rigid body rotation does is ignored in the energy balance. Making use of some simplified models of rapidly rotating convection, we derive both numerical and rigorous upper bounds on the heat transport that incorporate the influence of rotation. The impact of these bounds on the physical setting, and comparison with recent numerical and experimental data is carried out as well. (Received August 21, 2018)

78 ► Optics, electromagnetic theory

1143-78-439 **Howard Levinson*** (levh@umich.edu). *Imaging from the Inside Out – Inverse Scattering in Fluorescence Microscopy.*

We propose a novel method to reconstruct the optical properties of a scattering medium with subwavelength resolution. The method is based on the solution to the inverse scattering problem with photoactivated internal sources. Numerical simulations of three-dimensional structures demonstrate that a resolution of approximately $\lambda/25$ is achievable. An iterative algorithm that solves both the source localization and the inverse scattering problem will be discussed along with numerical results. (Received August 20, 2018)

81 ► Quantum theory

1143-81-52 **Anna Vershynina*** (anna@math.uh.edu), Department of Mathematics, University of Houston, Houston, TX 77006. *How fast can entanglement be generated in quantum systems?*

We investigate the maximal rate at which entanglement can be generated in bipartite quantum systems. The goal is to upper bound this rate. All previous results in closed systems considered entanglement entropy as a measure of entanglement. I will present recent results, where entanglement measure can be chosen from a large class of measures. The result is derived from a general bound on the trace-norm of a commutator, and can, for example, be applied to bound the entanglement rate for Renyi and Tsallis entanglement entropies. At the end I will quickly review the generalization of the problem to open systems. (Received July 20, 2018)

1143-81-53 **Shannon L Starr*** (slstarr@uab.edu), Mathematics Dept, 1300 University Blvd, Birmingham, AL 352941170. *Interplay of classical probability and quantum spin systems.* Preliminary report.

It is well known that many for many examples a quantum spin system may be mapped onto a classical spin system in 1 dimension higher. We will firstly discuss how this picture helps to rigorously explain a phenomenon known as Emptiness Formation Probability in quantum spin systems. Then we will ask the reverse question, can spectral methods from quantum spin chains be useful for answering probabilistic questions for classical models? The answer is yes, for example, for proving concentration of measure bounds for the length of the longest increasing sub-sequence of a random permutation (using a result of B Nachtergaele). (Received July 21, 2018)

1143-81-133 **Martin Fraas*** (fraas@vt.edu), 460 McBryde Hall, Virginia Tech 225 Stanger Street, Blacksburg, VA 24061. *Perturbation Theory for Quantum Trajectories.*

Quantum trajectories are certain Markov processes on a complex projective space. They describe evolution of a quantum system subject to a repeated indirect measurement. For a given set of matrices $\mathcal{A}$ and a unit vector x, a probability of a sequence of matrices $V_1, V_2, \dots, V_n$, $V_j \in \mathcal{A}$ is proportional to $\|V_n \cdots V_1 x\|^2$. The Markov process is given by $x_n \sim V_n \cdots V_1 x$. In this talk I will first review basic properties of this process and then discuss how the measure and the process change if the underlaying set of matrices $\mathcal{A}$ changes. (Received August 06, 2018)

1143-81-222 **Chris Marx*** (cmarx@oberlin.edu), Oberlin College, Department of Mathematics, 10 N Professor Street, Oberlin, OH 44074, and **Peter Hislop**. *Dependence of the density of states on the probability distribution for discrete random Schrödinger operators.*

We prove that the the density of states measure (DOSm) for discrete random Schrödinger operators on $\mathbb{Z}^d$ is weak-star Hölder-continuous in the probability measure. One immediate application provides quantitive continuity estimates for the disorder dependence of the DOSm and the integrated density of states (IDS) in the weak disorder regime. These results hold for a general compactly supported single-site probability measure, without any further assumptions. The few previously available results for the disorder dependence of the IDS in the weak disorder regime valid for dimensions $d \geq 2$ had to assume absolute continuity of the single-site measure and thus excluded the Bernoulli-Anderson model. As a further application, we obtain quantitative continuity of the Lyapunov exponent in the probability measure and weak-star topology for discrete random Schrödinger operators. (Received August 14, 2018)

1143-81-280 **Alvin S Moon***, 1 Shields Ave, Dept. of Mathematics, Davis, CA 95616, and **Bruno Nachtergaele**. *Ground state spectral gaps of quantum spin chains with Local Topological Quantum Order.*

We investigate the question of ground state phase stability in a quantum spin system by discussing sufficient conditions for the persistence of a uniform spectral gap. Stability of the ground state spectral gap has been rigorously studied for the class of interactions with finite-volume Hamiltonians which are frustration free, finite range, uniformly bounded and gapped, and have ground state spectral projectors that satisfy Local Topological Quantum Order (LTQO). We present a continuation of this body of work for 1D integer lattice quantum spin models, i.e. quantum spin chains, with interactions defined with respect to open boundary conditions.The main result of this talk shows the Hamiltonians of such an interaction have stable ground state spectral gaps, uniform in the system size, by proving a lower bound on the gap size as a function of the LTQO, the strength of weak but spatially extensive perturbations of the interaction, and the presence of edge perturbations. Lastly, we also discuss applications to fermion models on the 1D integer lattice. (Received August 16, 2018)

1143-81-284 **Bruno Nachtergaele**, **Robert Sims** and **Amanda Young*** (amyoung@math.arizona.edu). *Spectral gap stability for frustration-free quantum spin systems with discrete symmetry breaking.* Preliminary report.

In recent years, several results have appeared proving spectral gap stability for frustration-free quantum spin systems with topologically ordered ground states. The key property for these proofs is that the ground states of the models are indistinguishable by local operators. In this talk, we will discuss how to modify the topological order condition so that the stability results extend to models with discrete symmetry breaking, for which the ground states can be distinguished by local operators. (Received August 16, 2018)

1143-81-301 **Ralph M Kaufmann**, **Sergei Khlebnikov** and **Birgit Kaufmann*** (ebkaufma@math.purdue.edu), 150 N. University Street, West Lafayette, IN 47907. *New results for the topology of the gryroid wire network.*

The gyroid wire network is a highly interesting triply periodic structure that can be synthesized in the lab on the nanoscale. We analyze the bandstructure of the Harper Hamiltonian on this gyroid wire network. It exhibits several level crossings. The topology at these level crossings is very intriguing and can be characterized by Chern numbers calculated on 2-d slices in the Brillouin zone. The symmetry of the underlying structure leads to strong constraints for these topological invariants. We report on the newest results about local and global models for the topology at the level crossings points. This is joint work with R. Kaufmann and S. Khlebnikov. (Received August 17, 2018)

1143-81-348 **Jacob Shapiro*** (jshapiro@itp.phys.ethz.ch), Wolfgang-Pauli-Str. 27, 8093 Zurich, Switzerland, and **Clement Tauber**. *Strongly Disordered Floquet Topological Systems.*

We study the strong disorder regime of Floquet topological systems in dimension two, that describe independent electrons on a lattice subject to a periodic driving. In the spectrum of the Floquet propagator we assume the existence of an interval in which all states are localized–a mobility gap. First we generalize the relative construction from spectral to mobility gap, define a bulk index for an infinite sample and an edge index for the half-infinite one and prove the bulk-edge correspondence. Second, we consider completely localized systems where the mobility gap is the whole circle, and define alternative bulk and edge indices that circumvent the relative construction and match with quantized magnetization and pumping observables from the physics literature. Finally, we show that any system with a mobility gap can be reduced to a completely localized one. All the indices defined throughout are equal. (Received August 18, 2018)

1143-81-374 **Ramis Movassagh*** (ramis@us.ibm.com), IBM Research, 75 Binney Street, Cambridge, MA 02142, and **Oles Shtanko**, 02139. *Applications of Free Probability Theory to Floquet Topological Phase transitions.*

Suppose the eigenvalue distributions of two matrices M1 and M2 are known. What is the eigenvalue distribution of the sum M1 + M2? This problem has a rich pure and applied math history. Free probability theory (FPT) answers this question under certain conditions. We will describe FPT and show how it successfully quantifies the stability of periodically driven topological phases. Using FPT we analytically calculate the gap, critical exponents, and phase transition point to the ergodic phase. These physical quantities are important for the understanding of quantum matter, yet are hard to compute exactly. Nevertheless, using FPT and other ideas from random matrix theory excellent approximations can be found in a wide variety of problems. (Join work with Oles Shtanko) (Received August 19, 2018)

82 ► Statistical mechanics, structure of matter

1143-82-230 **Houssam Abdul-Rahman***, 617 N. Santa Rita Ave., Tucson, AZ 85721, and **Robert Sims** and **Günter Stolz**. *Low Energy Localization Properties of Disordered Harmonic Oscillators.* Preliminary report.

We consider a class of disordered harmonic oscillator systems associated with an effective one particle Hamiltonian that is localized (only) at the bottom of its spectrum. We establish energy-restricted versions of Lieb-Robinson bounds, quasi-locality properties of the time evolution of local observables, and of dynamic correlations bound at general eigenstates. We will show how this is done through the introduction of projections onto the suitable invariant subspaces for the Hamiltonian. (Received August 14, 2018)

1143-82-385 **Rajinder S Mavi*** (mavir@ripon.edu), Todd Wehr Hall, 300 W. Seward St., Ripon, WI 54971, and **Rodrigo Matos** and **Jeffrey Schenker**. *Dynamical and spectral properties of random Schrodinger operators with strongly correlated potentials.* Preliminary report.

We consider a random Schrodinger operator with strongly correlated potentials at arbitrarily large distances. We will study the dynamical and spectral properties of the Hamiltonian. The introduction of such models are motivated by the study of a localized polaron, which we will comment on. (Received August 19, 2018)

1143-82-518 **Hossam Abdul-Rahman**, **Christoph Fischbacher*** (cfischb@uab.edu) and **Gunter Stolz**. *Recent Progress on the Quantum XXZ Spin Model on General Graphs.*

We report on recent progress on the XXZ quantum spin model defined on general graphs. After reviewing its general definition, we discuss Combes-Thomas bounds from which we derive estimates on the structure of

eigenfunctions and on spectral projections. We use this to show bounds on entanglement entropy in various situations. (Received August 21, 2018)

90 ► Operations research, mathematical programming

1143-90-86 **Radu V. Balan*** (rvbalan@math.umd.edu), Department of Mathematics, University of Maryland, College Park, MD 20742, and **Naveed Haghani**. *Optimizations using Deep Learning.* Preliminary report.

This talk will present a deep network architecture to solve a binary assignment problem. The classical solution using transport theory turns the problem into a convex optimization problem, specifically a linear program. A deep network is designed and trained to solve the similar problem. Various strategies will be analyzed, and numerical performance will be presented. (Received July 31, 2018)

1143-90-359 **Nandini Rakala*** (nrakala2015@my.fit.edu), Dept. of Mathematical Sciences, Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901, **Munevver Mine Subasi** (msubasi@fit.edu), Dept. of Mathematical Sciences, Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901, and **Ersoy Subasi** (esubasi@fit.edu), Dept. of Engineering Systems, Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901. *Multi-Objective Extension to Logical Analysis of Data and its Applications in Medicine.*

We extend a machine learning based method known as Logical Analysis of Data (LAD) to handle discrete multi-objective optimization datasets. LAD is a classification method based on combinatorics, optimization, and theory of Boolean functions. LAD provides excellent solutions to medical problems using clinical, genomic, and proteomics datasets. The key ingredient of LAD is the identification of patterns, distinguishing between disjoint subgroups of observations. We propose an algorithmic approach to generate Pareto optimal LAD patterns. Given a binary data $\Omega = \Omega^+ \cup \Omega^-$, where $\Omega^+ \cap \Omega^- = \emptyset$, a pattern P is a sub-cube of $\{0,1\}^n$, where n is the number of features in the dataset: $P = \bigwedge_{j \in N_P} x_j$, where $N_P \subseteq \{1, \ldots, n\}$ and $x_j \in \{0,1\}$. We define a pattern P^* to be strong (strict) Pareto optimum for the multi-objective problem iff there is no other pattern P such that $Cov(P) \subset Cov(P^*)$, where $Cov(P) = \{x \in \Omega : P(x) = 1\}$. P^* is weak (non-strict) Pareto optimum iff $Cov(P) \subseteq Cov(P^*)$ for some pattern P. The proposed approach identifies set of strong/weak Pareto optimal patterns to predict slow and rapid progressions of Chronic Kidney Disease patients in the AASK Dataset. (Received August 19, 2018)

91 ► Game theory, economics, social and behavioral sciences

1143-91-124 **V. Bilò**, **I. Caragiannis**, **M. Flammini**, **A. Igarashi**, **G. Monaco**, **D. Peters**, **C. Vinci** and **W. S. Zwicker*** (zwickerw@union.edu). *Fair division of a graph: envy-freeness up to one good, or two.*

In the classical fair-division framework, agents have private measures over a continuous cake (such as the [0,1] interval) and seek to divide it in a fair way. An allocation wherein each agent measures her own piece as largest (or tied) is "envy free" (a popular fairness criterion). One might also demand that each agent get a contiguous piece (an interval, if the cake is [0,1]).

If we replace our cake with a finite set of indivisible objects then envy-free allocations may no longer exist, but one can always find an "EF1" division – in which any envy agent A may feel for B's share can be cancelled by pretending B no longer holds the single item (from her share) that A values most. What is the analogue, in this setting, of "contiguous piece?" We argue that it is "connected subgraph" by providing differing results for 2 agents, for 3, for 4, and for 5 or more, decreasingly constructive. Each builds on a classical technique from the continuous setting – cut-and-choose (from the Old Testament), moving knives (à la Stromquist), and Sperner's Lemma (as applied by Su) – though interesting complications abound. In each case the paramount question becomes "Which graphs always admit connected EF1 allocations?" (Received August 05, 2018)

1143-91-147 **Jonathan K Hodge*** (hodgejo@gvsu.edu). *Graph theoretic models of interdependence in referendum elections.*

In referendum elections, voters are often required to cast simultaneous votes on multiple questions or proposals. The separability problem occurs when voter preferences on one or more proposals depend on the predicted outcomes of other proposals—or, in other words, when voter preferences on the various proposals are *interdependent*. In this talk, we will explore how graphs can be used both to generate diverse voter preferences and to represent the interdependence relationships among the proposals in a referendum election. We will also consider applications to election simulation and sequencing. Much of this work was developed collaboratively with students as part of the Grand Valley State University Summer Mathematics REU. (Received August 07, 2018)

1143-91-194 **David McCune*** (mccuned@william.jewell.edu), **Michael Jones** and **Jennifer Wilson**. *An iterative procedure for apportionment and its use in the Georgia Republican Primary.*

Apportionment methods are well-studied in the contexts of apportioning House seats to states proportional to state population or apportioning House seats to political parties proportional to vote totals. They are not well-studied in the context of apportioning delegates to candidates in presidential primaries. In the Republican Presidential Primaries, most state Republican parties are allowed to create their own apportionment method for allocating delegates to candidates. This freedom has allowed many states to create apportionment methods that do not appear in the classical apportionment literature. In this talk we discuss the delegate apportionment method created and used by the Georgia Republican Party. We compare Georgia's method with Hamilton's method (the most common method for apportioning delegates), we give formulas for the thresholds of inclusion and exclusion, and we discuss the apportionment paradoxes suffered by the method. (Received August 12, 2018)

1143-91-234 **Diana S Cheng*** (dcheng@towson.edu), 8000 York Road, Towson, MD 21286, and **Peter Coughlin** (coughlin@econ.umd.edu), University of Maryland College Park, Department of Economics, College Park, MD 20742. *An analysis of hypothetical figure skating team events using equations from power indices.*

At the 2014 Winter Olympic Games, a new figure skating competition called the 'team event' was contested. The introduction of the new event raises questions of what countries might have earned medals if this team event had been contested in the past. In this presentation, we develop a method for determining the results of a hypothetically conducted team event, and apply the method to a hypothetical competition in 2010 using results from individual events at the Winter Olympic Games. We also show how relative contributions of skaters to their teams could be measured using equations from the Banzhaf and Shapley-Shubik power indices. These methods could be useful for fans and for electors who vote on candidates for figure skating halls of fame. (Received August 15, 2018)

1143-91-294 **Karen Saxe*** (kxs@ams.org), 1527 18th St NW, American Mathematical Society, Washington, DC 20036. *Partisan gerrymandering and redistricting outlook for 2020.*

Challenges of partisan gerrymandering have been gaining traction in our courts, including in the Supreme Court. This talk will give a quick background on how redistricting is done by the states, then offer an update on how mathematics and statistics have been called on by the courts in their deliberations. We'll conclude with an overview of proposed changes for the 2020 redistricting cycle. (Received August 17, 2018)

1143-91-310 **Steven J. Brams**, **Mehmet S. Ismail** and **D. Marc Kilgour*** (mkilgour@wlu.ca), Department of Mathematics, Waterloo, ON N2L3C5, Canada, and **Walter Stromquist**. *Catch-Up: A Rule That Makes Service Sports More Competitive.*

Service sports include two-player contests such as volleyball, badminton, and squash. We analyze four rules, including the Standard Rule (*SR*), in which a player continues to serve until he or she loses. The Catch-Up Rule (*CR*) gives the serve to the player who has lost the previous point—as opposed to the player who won the previous point, as under *SR*. We also consider two Trailing Rules that make the server the player who trails in total score. Surprisingly, compared with *SR*, only *CR* gives the players the same probability of winning a game while increasing its expected length, thereby making it more competitive and exciting to watch. Unlike one of the Trailing Rules, *CR* is strategy-proof. By contrast, the rules of tennis fix who serves and when; its tiebreaker, however, keeps play competitive by being fair—not favoring either the player who serves first or who serves second. (Received August 17, 2018)

1143-91-526 **Steven J. Brams*** (steven.brams@nyu.edu), Dept. of Politics, New York University, 19 West 4th St., 2nd Floor, New York, NY 10012. *Stabilizing Cooperative Outcomes in Games: Theory and Cases.* Preliminary report.

We analyze the 78 2 x 2 distinct strict ordinal games, 57 of which are conflict games that contain no mutually best outcome. In 19 of the 57 games (33%), including Prisoners' Dilemma and Chicken, a cooperative outcome–one that is at least next-best for each player–is not a Nash equilibrium (NE). But this outcome is a nonmyopic equilibrium (NME) in 16 of the 19 games (84%) when the players start at this outcome and make farsighted calculations, based on backward induction; in the other three games, credible threats can induce cooperation. In two of the latter games, the NMEs are "boomerang NMEs," whereby players have an incentive to move back and forth between two diagonally opposite NMEs, one of which is cooperative. In Prisoners' Dilemma, the NE and one NME are not Pareto-optimal, but we prove that in all normal-form two-person and n-person games with strict preferences, there is at least one Pareto-optimal NME. As examples of NMEs that are not NEs, we analyze two games that plausibly model the choices of players in international relations: (i) no first use of nuclear weapons; and (ii) the 2015 nuclear agreement between Iran and the United States. (Received August 21, 2018)

1143-91-546 **Karl-Dieter Crisman*** (karl.crisman@gordon.edu), **Jian Cui** and **Min-Sun Kim**. *Broad Support in Two-Person Elections.* Preliminary report.

Suppose that an award is to be given to one of two candidates by a group of voters from several different departments of an organization. The usual majoritarian model is too simplistic even for this election, because there are recognized subgroups of the electorate whose (joint) opinions may also be deemed relevant. For instance, the majority-losing candidate may receive more votes from all but one department, which votes unanimously for the other candidate. The relevance of this hypothetical situation to the Brexit decision or the US Electoral College should be clear, and is often mentioned in the literature, where it is sometimes known as the 'referendum paradox'.

In this talk, we investigate the tradeoffs between the different winners (using concepts such as majority deficit) in the *simplest* cases possible, such as with two candidates or three subgroups. On the one hand, we extend previously known results for quasi-polynomials representing the number of paradoxical outcomes for various impartiality cultures. On the other hand, we also examine a quota-type system which (intentionally) allows numerous ties and give some preliminary results regarding the types and numbers of violations which may occur there. (Received August 21, 2018)

1143-91-561 **Tao Zhang*** (tz636@nyu.edu), 10.081B, 10th Floor, 2 Metrotech, Brooklyn, NY 11201, and **Quanyan Zhu**. *Mechanism Design of Differential Privacy of Machine Learning Algorithms over Networks.*

Differential privacy offers a strong guaranteed bound on the privacy leakage that a data owner (DO) may incur in machine learning processes. Improving the differential privacy of learning algorithms is often at odds with the performance of machine learning. DOs usually have natural privacy concerns while the machine learner (MLR) prefers guaranteed learning performances. Optimally addressing the tradeoff between privacy and performance is pivotal to establish a sustainable collaboration between DOs and MLR. To this end, we consider a problem of centralized machine learning algorithm using data collaboratively gathered from a group of DOs and propose a mechanism design approach to construct a framework of differentially private machine learning when the incentives of DOs and MLRs, respectively, to preserve privacy and improve performance are misaligned. First, each DO has a private valuation of the mechanism and reports her privacy budget to the MLR. After receiving all the reports, the MLR allocates a privacy budget to each DO. The MLR is the mechanism designer, who aims to maximize the utility of the learning outputs while providing acceptable privacy level for the DOs based on their valuation by choosing an optimal privacy budget allocation rule and an optimal pricing rule. (Received August 21, 2018)

1143-91-567 **Michael A. Jones*** (maj@ams.org), Mathematical Reviews, 416 Fourth Street, Ann Arbor, MI 48104, and **David McCune** and **Jennifer Wilson**. *The Elimination Paradox.*

To award delegates in their presidential primary, the U.S. Democratic Party uses Hamilton's method of apportionment after eliminating any candidates that receive less than 15 percent of the vote. We refer to the 15 percent as a cutoff. Although states are not required to use the same method in the Republican presidential primary, many of the methods, such as the methods used by Georgia and Kansas, have similar cutoffs. For Hamilton's method with the cutoff and the methods used in Georgia and Kansas, we illustrate how a remaining candidate may have his or her delegate total decrease as a result of other candidates being eliminated; this leads to a new Elimination Paradox. We relate this paradox to the New States, No Show, and Population Paradoxes and show that divisor methods are not susceptible to the Elimination Paradox. We conclude with instances in which

the Elimination Paradox may occur in other contexts, including parliamentary systems. (Received August 21, 2018)

1143-91-576 **Duane Cooper*** (dcooper@morehouse.edu), Department of Mathematics, Morehouse College, 830 Westview Dr. SW, Atlanta, GA 30314. *Addressing Fairness of Representation in Single- and Multimember Districts.* Preliminary report.

The mathematical community has been extensively engaged of late in questions of best ways to conduct redistricting of legislatures and other representative bodies, especially in response to gerrymandering and other partisan practices. In this presentation, we examine questions of fair representation in districting practices and the potential of multimember districts in addressing these same issues. (Received August 22, 2018)

92 ► Biology and other natural sciences

1143-92-10 **Shawn D Ryan*** (s.d.ryan@csuohio.edu), 2121 Euclid Ave., RT 1538, Cleveland, OH 44115. *Onset of Collective Dynamics in Active Biosystems.*

A novel modeling and computational approach is used to investigate the origin of self-organization in bacterial suspensions. The key feature of this approach is the incorporation of interbacterial interactions motivated by experimental observations while allowing for efficient computation for a large number of particles. The first part of the talk investigates the emergence of striking effective properties of a bacteria suspension in the collective state. The mathematical analysis leads to explicit formulas for the effective viscosity as well as the effective normal stress differences describing the complete rheological behavior of an active suspension in terms of known physical parameters. Next, numerical analysis of a corresponding thin film PDE model confirms the experimental observation that particle size and shape rather than the concentration of bacteria governs the size and duration of the collective state in bacterial suspensions. The results of the analysis exemplify the delicate balance between hydrodynamic interactions and collisions governing mesoscopic collective motion in bacterial suspensions. (Received May 14, 2018)

1143-92-12 **Henry C. Astley*** (hastley@uakron.edu), 235 Carroll St., Biomimicry Research and Innovation Center, Dept. of Biology, Akron, OH 44325, and **Kelimar Diaz**, **Joseph R Mendelson III** and **Daniel I Goldman**. *Sidewinding, Slithering, Sand, and Snakes; How complex substrates and surprising failures can lead to innovative locomotor solutions.*

Sand is an extremely challenging substrate for locomotion. Depending upon how it is loaded, sand may jam and solidify, providing firm footing, or yield and flow, potentially leading to slipping. Furthermore, these different outcomes can result from small and subtle changes in loading regime; incline further exacerbates these difficulties. Yet in spite of this, sandy deserts are teeming with animals moving across this challenging substrate with a variety of locomotor modes, with sidewinding being one of the most remarkable. This talk will review the mechanics of moving on sand and the remarkable effectiveness with which the sidewinder rattlesnake (*Crotalus cerastes*) navigates this challenging terrain, including ascending steep dunes, rapidly turning without slipping, and negotiating obstacles. We will present new data on the locomotion of a diverse range of snakes on sand and the challenges of undulating bodies on the sand surface. Finally, we will show how the failures vipers on sand using other locomotor modes may have allowed them to evolve sidewinding, thereby achieving remarkable locomotor performance on one of the most challenging natural substrates. (Received May 19, 2018)

1143-92-135 **Chuan Xue*** (xue.41@osu.edu), Columbus, OH 43210. *The Role of Intracellular Signaling in the Stripe Formation in Engineered E. Coli Populations.*

Recent experiments showed that engineered Escherichia coli colonies grow and self-organize into periodic stripes with high and low cell densities in semi-solid agar. The stripes establish sequentially behind a radially propagating colony front, similar to the formation of many other periodic patterns in nature. These bacteria were created by genetically coupling the intracellular chemotaxis pathway of wild-type cells with a quorum sensing module. I will present multiscale models to investigate how the intracellular pathway affects the stripe formation. I will first discuss a detailed hybrid model that treats each cell as an individual particle and incorporates intracellular signaling via an internal ODE system. Then I will discuss a mean-field PDE model derived from the hybrid model which significantly reduces computational cost. The analysis is justified by the tight agreement between the PDE model and the hybrid model in 1D simulations. Numerical simulations of the PDE model in 2D with radial symmetry agree with experimental data semi-quantitatively. (Joint work with Min Tang and Xiaoru Xue) (Received August 06, 2018)

1143-92-178 **Danielle Holz*** (dah414@lehigh.edu), **Gillian L. Ryan**, **Aaron Hall** and **Dimitrios Vavylonis**. *Lamellipodia Protrusion driven by Actin Polymerization: Excitable Dynamics and Dendritic Network Structure.*

Crawling cells exhibit cycles of protrusion and retraction of actin-rich lamellipodia when adhered to a 2D surface. These periodic fluctuations in the leading edge position indicate excitable actin dynamics. We developed a model in 2D with a self-recruiting activator of actin polymerization and delayed inhibition while also considering movement of the membrane which responds to changes in the number of free barbed ends of filaments. Cycles of protrusion and retraction can be reproduced if the polymerization rate at the barbed ends depends on the local concentration at the leading edge and the opposing force from the membrane. The mechanism behind the dendritic actin network structure in lamellipodia (through Arp2/3 complex side branching) and remodeling by severing and depolymerization is also important for a better understanding of cell motility. We constructed a 3D stochastic filament-level model to understand how the actin network structure changes from a short dense brushwork near the leading edge to a structure with longer, more linear filaments further away. Implementing polymerization, depolymerization, branching, capping, severing and debranching in the model produces a network near the leading edge that is in good agreement with recent electron microscopy experiments. (Received August 10, 2018)

1143-92-188 **Zengding Bai** (baiz@iu.edu), 402 N Blackfort Street, LD 270, Math Dept, Indianapolis, IN 46202, and **Luoding Zhu*** (luozhu@iupui.edu), 402 N Blackfort Street, LD270, Math Dept, Indianapolis, 46202. *Modeling and simulation of blood flow past the distal anastomosis of arteriovenous graft.*

Arteriovenous grafting (AVG) is a common device applied in hemodialysis for kidney failure patients. It is often failed because of the intimal hyperplasia formed around the AVG anastomosis. In order to help understand the mechanism of the formation of intimal hyperplasia, we investigate the flow patterns and force distributions near the distal anastomosis by modeling and simulation. The anastomosis structure (graft and vein) is modeled by elastic fibers. The surrounding tissue is modeled by elastic springs in viscous fluid. The blood is modeled by viscous incompressible fluid and the flow is numerically simulated by the lattice-Boltzmann method. The fluid-structure-interaction is treated by the immersed boundary method. We perform series of simulations using different Reynolds numbers and AVG configurations including attached angles and vein-graft diameter ratio. Both rigid and deformable cases are considered. Flow fields are visualized and compared. Wall shear stress, wall shear stress gradient, wall normal stress gradient, etc. on the vein/AVG walls are computed and analyzed. Significant differences between the rigid and the deformable cases are found. (Received August 11, 2018)

1143-92-202 **Sarah Dianne Olson*** (sdolson@wpi.edu). *A tail of two sperm.*

Microorganisms such as sperm often swim in close proximity. In this talk, we highlight results showing how swimming speeds and efficiency vary between a single swimmer and two or more swimmers in different fluid environments. Each swimmer is modeled via a centerline representation where forces are solved for using elastic rod theory. The swimming speeds and surrounding fluid velocity is solved for using regularized fundamental solutions. We highlight how swimming speeds vary when comparing to asymptotic analysis as well as how our understanding of motility in groups changes based on whether we are modeling two or three dimensional movement. (Received August 13, 2018)

1143-92-274 **Magdalena Stolarska*** (mastolarska@stthomas.edu), 2115 Summit Ave., Mail # OSS 201, Saint Paul, MN 55105. *Modeling the role of cell-substrate interaction in cell spreading.*

The material properties of the extracellular matrix or a two-dimensional substrate with which a cell interacts affect the biochemical processes occurring within the cell. For instance, cell spread areas and focal adhesion (FA) areas are known to increase with substrate stiffness. To better understand the mechanisms of cell spreading and FA evolution, I will present a 2D model and finite element simulations of a spreading cell interacting with a deformable substrate through FA complexes. FA complexes are modeled by collections of linear springs that depend on local concentrations of a ligand-activated bound integrin and can form and break dynamically in a stress and strain dependent manner. The cell is treated as a hypoelastic material that undergoes active deformations that represent cell spreading. Using this model, it can be shown that the increased spread areas occur from mechanochemical interactions and coupling between cell spreading and FA evolution, and is not dependent on the balance of mechanical forces alone. (Received August 16, 2018)

1143-92-277 **Carson Chow*** (carsonc@mail.nih.gov), NIDDK/NIH/LBM, BLdg 12A Rm 4007, Bethesda, MD 20892. *The dynamics of gene transcription.*

Gene transcription is the biological process in which DNA is transcribed to RNA and is central to cellular and organismal biology. A great wealth of knowledge about how it works has been uncovered over the past half century yet much is still not fully understood. Here, I will review some recent theoretical and experimental advances that have allowed us to peer more closely into the detailed molecular mechanisms underlying this marvelously complex process. In particular, I will focus on steroid-regulated gene transcription, which is of great importance for development, growth, homeostasis, and diseases. I will show how a theoretical framework where group theory makes a surprising appearance can reconcile seemingly disparate observations from precise quantitative measurements in multi-cellular experiments and dynamical behavior observed in single-cell and single-molecule imaging experiments. (Received August 16, 2018)

1143-92-288 **Lingxing Yao*** (lyao@uakron.edu), OH , and **Yoichiro Mori**. *A mathematical model and simulations of cell migration.* Preliminary report.

Differences in solute concentration across a semipermeable membrane of cells generates transmembrane osmotic water flow. The interaction of such flows with membrane and flow mechanics is an important area in many biological applications. Another driving force people observe in cell migration is the polymerization/depolymerization cycle of actin network inside the cell. In this presentation, we will discuss a mathematical model that allows us studying the interplay between diffusive, osmotic and mechanical effects from all factors, and its numerical simulations. In the model, an osmotically active solute obeys an advection-diffusion equation in a region demarcated by a deformable membrane. The interfacial membrane allows transmembrane water flow which is determined by osmotic and mechanical pressure differences across the membrane. Actin network is constantly in polymerization cycle and interact with the elastic membrane. The numerical method is based on an immersed boundary method for fluid-structure interaction and a Cartesian grid embedded boundary method for the solute and actin network. We demonstrate our numerical algorithm with the test case of an osmotic engine, a recently proposed mechanism for cell propulsion (Received August 16, 2018)

1143-92-290 **Jeremy P D'Silva*** (jpdsilva@umich.edu), 5166 SPH-II, 1415 Washington Heights, Ann Arbor, MI 48105, and **Marisa C Eisenberg** (marisae@umich.edu), 5166 SPH-II, 1415 Washington Heights, Ann Arbor, MI 48105. *Modelling perineural invasion: understanding the active role of nerves in the nerve-tumor interaction.*

Perineural invasion (PNI) is the phenotype in which tumor cells surround and enter nerves. PNI is associated with recurrence and metastasis of head and neck cancer (HNC). Recent studies have demonstrated a mechanism by which HNC can induce neurite outgrowth towards itself: when stimulated by the neuropeptide galanin (Gal), the tumor secretes Gal, which leads to neurite outgrowth towards the tumor. In order to gain an understanding of the distances, spatial arrangements, and temporal sequences of these events, we must understand the parameters that control them. We developed a hybrid model for PNI: we model Gal diffusion with a PDE and neurite outgrowth with an agent-based model (ABM). The ABM incorporates several biological features of neurite outgrowth; the model captures qualitative features of PNI. We performed a sensitivity analysis to demonstrate that uncertainty in biological parameter values can have a significant impact on the mechanistic model outputs. Our sensitivity analyses identify biologically relevant parameters that need additional experimental study: our results indicate that further biological research is needed to refine our understanding of the spatiotemporal dynamics of PNI. (Received August 16, 2018)

1143-92-440 **Wanda Strychalski*** (wis6@case.edu), Department of Mathematics, Applied Mathematics, and Statistics, 10900 Euclide Ave, Cleveland, OH 44106. *3D Computational Modeling of Bleb Initiation Dynamics.*

Blebbing occurs in cells under high cortical tension when the membrane locally detaches from the actin cortex, resulting in pressure-driven flow of the cytosol and membrane expansion. Some cells use blebs as leading edge protrusions during migration, particularly in 3D environments. Blebs can be initiated through either a localized loss of membrane-cortex adhesion or ablation of the cortex in a region. A 3D dynamic computational model of the cell is presented that includes mechanics of and the interactions among the cytoplasm, the actin cortex, and the cell membrane. The model is used to quantify bleb expansion dynamics and shapes that result from simulations using different initiation mechanisms. Results from model simulations with a viscous fluid cytoplasm model show much smaller and broader blebs when they are initiated via cortical ablation than when they are initiated by removing membrane-cortex adhesion. Results from experiments have suggested that cytoplasmic elasticity is important for limiting bleb size. Simulation results using the poroelastic model of the cytoplasm provide

qualitatively similar bleb morphology regardless of the initiation mechanism. The scaling of bleb expansion time as a function of poroelastic parameters in the 3D model is also quantified. (Received August 20, 2018)

1143-92-444 **Matt Akamatsu**, **Ritvik Vasan**, **Julian Hassinger** and **Padmini Rangamani*** (prangamani@ucsd.edu), 9500 Gilman Dr, La Jolla, CA 92093-0411. *Modeling local cell movements for trafficking.*

Endocytosis is a complex cellular process in which cells take up molecules from their external environment. This is a complex process that involves morphological and topological changes to the cellular membrane and is governed by actin remodeling and membrane mechanics. Recently, our lab has been focused on developing multiscale mechanics models for capturing the key features of endocytosis including the role of membrane tension, actin remodeling, and the coupling between the two. We will discuss the role of multiscale modeling in deciphering the contributions of membrane mechanics and cytoskeletal mechanics. (Received August 20, 2018)

1143-92-485 **Caitlin Hult*** (cshult@umich.edu), **David Adalsteinsson**, **Paula A. Vasquez**, **Josh Lawrimore**, **Kerry Bloom**, **Yunyan He**, **Benjamin Walker**, **Dane Taylor** and **M. Gregory Forest**. *Dynamic chromosomal crosslinks influence nucleolus spatiotemporal dynamics in the yeast genome: Modeling approaches and visualization techniques.*

The genome in living yeast cells is a highly dynamic system where entropic interactions and nuclear confinement drive the formation of domains of high chromosomal interaction, known as topologically associating domains. We investigate the dynamic organization of all 16 chromosomes in living yeast cells during interphase, using coarse-grained, entropic polymer chain models. We are interested in determining the mechanisms, such as packaging molecules that create loops within chromatin fibers, that govern inter- and intra-chromatin fluctuations and the mechanisms that induce global features of the entire genome as well as more localized features of the nucleolus. We present novel modeling and visualization techniques for nucleolus dynamics, and show that enrichment of dynamic chromosomal crosslinks drives phase separation of the nucleolus. Through the use of network analyses, we aim to further our understanding of and ability to detect dynamic gene-community structure. (Received August 20, 2018)

1143-92-488 **Clark Bowman**, **Karen Larson**, **Alexander Roitershtein**, **Derek Stein** and **Anastasios Matzavinos*** (matzavinos@brown.edu), Division of Applied Mathematics, 182 George Street, Providence, RI 02912. *Bayesian uncertainty quantification for particle-based simulation of lipid bilayer membranes.*

A number of problems of interest in applied mathematics and biology involve the quantification of uncertainty in computational and real-world models. A recent approach to Bayesian uncertainty quantification using transitional Markov chain Monte Carlo (TMCMC) is extremely parallelizable and has opened the door to a variety of applications which were previously too computationally intensive to be practical. In this talk, we first explore the machinery required to understand and implement Bayesian uncertainty quantification using TMCMC. We then describe dissipative particle dynamics, a computational particle simulation method which is suitable for modeling biological structures on the sub-cellular level, and develop an example simulation of a lipid membrane in fluid. Finally, we apply the algorithm to a basic model of uncertainty in our lipid simulation, effectively recovering a target set of parameters (along with distributions corresponding to the uncertainty) and demonstrating the practicality of Bayesian uncertainty quantification for complex particle simulations. (Received August 20, 2018)

1143-92-522 **Moxun Tang*** (tang@math.msu.edu), Department of Mathematics, Michigan State University, East Lansing, MI 48824. *Modelling Wolbachia-driven mosquito-borne disease control by differential equations.*

Abstract: Mosquito-borne diseases, such as dengue and Zika, are threatening over half of the world's population. Due to the lack of effective vaccines and drugs, current control programs have attempted to suppress mosquito populations by insecticide spraying. Massive applications of insecticides have greatly suppressed mosquito densities and limited disease transmission in some areas, but also caused serious environmental problems and insecticide resistances. In this talk, I will describe a new control method based on the intracellular bacterium *Wolbachia* that induces cytoplasmic incompatibility in mosquitoes. It causes early embryo death from the crossing of *Wolbachia*-infected males and uninfected wild females, but has no apparent impact on the viability of the progeny of infected females. In Guangzhou, China, the *Wolbachia* driven incompatible insect technique has been combined with the sterile insect technique in the development of a biologically safe method to control *Aedes*

albopictus population since 2015. I will introduce our recent modeling approaches based on differential equations, some containing time delays, reaction-diffusion terms, or stochastic switching on environmental conditions. (Received August 21, 2018)

1143-92-534 **Christina L Hamlet*** (ch051@bucknell.edu), **Eric D Tytell**, **Lisa Fauci** and **Kathleen Hoffman**. *Computational Multiscale Modeling of the Effects of Mechanosensory Feedback in Lamprey Swimming.*

The lamprey is a model organism for locomotion and neurophysiology research. A central pattern generator (CPG) produces rhythmic signals which drive the animal's basic swimming mode. Edge cells located along the spinal cord provide feedback to the organism based on the bending of the body. In previous work, we constructed a multiscale integrative model of a flexible swimmer driven by a prescribed CPG, calcium dynamics, muscle mechanics, body dynamics and fluid-structure interactions. An updated CPG is modeled as two chains of coupled oscillators which are capable of receiving information from the bending dynamics of the body. The functional form of such sensory feedback from edge cells in the lamprey is not known. Using experimental information from natural organisms, we propose functional forms and examine their effects on swimming stability and energetics in the computational model. (Received August 21, 2018)

1143-92-552 **Calina A Copos***, copos@cims.nyu.edu, and **Robert D Guy**, guy@math.ucdavis.edu. *A model of the cell cytoplasm rheology in confined environments.*

Microfluidic devices have found numerous applications in biology and medicine because of their ability to efficiently control and replicate microenvironments. Cell migration through microfluidic channels has gained interest as an experimental method for one-dimensional, directed migration and has been applied to study red blood cell flow, differentiation of cancer cells, and the role of interstitial flow in tumor cell migration. In such confined microenvironments, the rheology of the cytoplasm becomes an important factor in determining the escape time across the channel. With this goal in mind, we consider a poroelastic immersed boundary method in which a fluid permeates a porous, elastic structure of negligible volume fraction, and extend this method to include stress relaxation of a moving, deforming material. Finally, we use this modeling framework to study the passage of a cell through a microfluidic channel. In this confined experimental setup, we demonstrate that the rheology of the cell cytoplasm is important for capturing the transit time through a narrow channel in the presence of a pressure drop in the extracellular fluid. (Received August 21, 2018)

1143-92-574 **Caitlin Hult*** (cshult@umich.edu), **Joshua T. Mattila**, **Simeone Marino**, **Jennifer J. Linderman** and **Denise E. Kirschner**. *The role of neutrophils in M. tuberculosis infection.* Preliminary report.

Gaining a better understanding of the immune response to infection with the bacteria *Mycobacterium tuberculosis (Mtb)* is crucial to help combat the increased prevalence of multi-drug resistant strains, the current complexity and length of treatment, and the inherent difficulties of experimental work. Computational modeling of the complex immune response which results in the formation of lung granulomas can enable analysis of what is currently a relatively black box for scientists, particularly with regard to the role of neutrophils. Due to the duration and dynamic nature of this response, coupled with the involvement of immune processes that occur over tissue, cellular, and molecular scales, we take a multi-scale and mechanistic computational modeling approach. We build an agent-based model at the cellular scale which reads out at a tissue scale that incorporates mathematical elements including diffusion and recruitment and use a middle out approach to make this model multi-scale by adding molecular scale dynamics. Through the incorporation of a neutrophil cell type into this hybrid agent-based computational model, *GranSim*, we investigate the spatiotemporal dynamic formation of lung granulomas in response to *Mtb* infection. (Received August 21, 2018)

93 ► Systems theory; control

1143-93-237 **Shuai Wang**, 110 Cummington Mall, Boston University, Boston, MA , and **John Baillieul*** (johnb@bu.edu), 110 Cummington Mall, Boston, MA 02215. *Orthogonality, Duality, and Variational Principles in Mixed Source Electrical Networks.*

Problems in classical mechanics are frequently solved by means of the principle of least action. Classical circuit theory, on the other hand, is based on Kirchhoff's laws, Ohm's law, and the principle of superposition. These laws can be conveniently formulated as a system of linear equations that determine the currents and voltages throughout the circuit. When the circuit topology is changed by adding or removing a branch, there is a general redistribution of the current flowing throughout the whole circuit. The change of the flow increases with

the extent of the redistribution, and the redistribution then ceases when a new equilibrium is attained. The equilibrium is considered stable since the circuit always returns to it after small disturbances. In this talk, we examine whether the stability of the equilibrium can be found as a set of electrical values where the I^2R losses across a circuit are minimized subject to the circuit laws mentioned above. We shall propose a principle of least power loss as a theoretical basis for understanding classical electrical networks that are driven by a mixture of current and voltage sources. (Received August 15, 2018)

94 ► Information and communication, circuits

1143-94-249 **Dima Grigoriev** and **Vladimir Shpilrain*** (shpil@groups.sci.ccny.cuny.edu).

Tropical cryptography. Preliminary report.

In our earlier work, we employed *tropical algebras* as platforms for several cryptographic schemes by mimicking some well-known "classical" schemes in the "tropical" setting. What it means is that we replaced the usual operations of addition and multiplication by the operations $\min(x, y)$ and $x + y$, respectively. An obvious advantage of using tropical algebras as platforms is unparalleled efficiency because in tropical schemes, one does not have to perform any multiplications of numbers since tropical multiplication is the usual addition. In the present work, we use extensions of tropical matrix algebras by homomorphisms as platforms. We call these extensions *semidirect products* since they are similar to a well-known operation (with the same name) in (semi)group theory. (Received August 15, 2018)

00 ► General

1144-00-53 **John Kornak*** (john.kornak@ucsf.edu), San Francisco, CA 94502, and **Karl Young**. *A new approach to Bayesian image analysis.*

Bayesian image analysis can improve image quality, by balancing a priori expectations of image characteristics, with a model for the noise process via Bayes Theorem. We will give a reformulation of the conventional Bayesian image analysis paradigm in Fourier space, i.e. the prior and likelihood are given in terms of spatial frequency signals. By specifying the Bayesian model in Fourier space, spatially correlated priors, that are relatively difficult to model and compute in conventional image space, can be efficiently modeled as a set of independent processes across Fourier space; the priors in Fourier space are modeled as independent, but tied together by defining a "parameter function" over Fourier space for the values of the pdf parameters. The originally inter-correlated and high-dimensional problem in image space is thereby broken down into a series of (trivially parallelizable) independent one-dimensional problems. We will describe the Bayesian image analysis in Fourier space (BIFS) modeling approach, illustrate its' computational efficiency and speed, and demonstrate useful properties of isotropy and resolution invariance to model specification. Finally, we will showcase a Python package that is under development to make the approach widely accessible. (Received August 04, 2018)

1144-00-201 **Cheng Cheng*** (cheng87@math.duke.edu) and **Qiyu Sun** (qiyu.sun@ucf.edu). *Stable phaseless sampling and reconstruction of real-valued signals with finite rate of innovations.*

In this talk, we consider the stable reconstruction of real-valued signals with finite rate of innovations (FRI), up to a sign, from their magnitude measurements on the whole domain or their phaseless samples on a discrete subset. FRI signals appear in many engineering applications such as magnetic resonance spectrum, ultra wide-band communication and electrocardiogram. For an FRI signal, we introduce an undirected graph to describe its topological structure. We establish the equivalence between the graph connectivity and phase retrievability of FRI signals, and we apply the graph connected component decomposition to find all FRI signals that have the same magnitude measurements as the original FRI signal has. We also propose a stable algorithm with linear complexity to reconstruct FRI signals from their phaseless samples on the above phaseless sampling set. (Received August 24, 2018)

1144-00-220 **Yue Zhao*** (etuzhao@ucdavis.edu), One Shields Ave, Davis, CA 95616. *A combinatorial description of some representations of degenerate double affine Hecke algebras of type BC_n.*

Let $N = p + q$. Consider the pair (G, K), where $G = GL_N$ and $K = GL_p \times GL_q$. Let $O(G/K)$ be the algebra of regular functions on G/K. This is also a module for $D(G/K)$ which is the algebra of differential operators. Etingof, Freund and Ma defined a Schur Weyl like functor $F_{n,p}$ that sends each $D(G/K)$-module M to a representation $F_{n,p}(M)$ of the degenerate double affine Hecke algebra of type BC_n. In this talk, we will describe the representation $F_{n,p}(O(G/K))$. There are quantum versions of the above: $\mathcal{D}_q(G/K)$, $\mathcal{O}_q(G/K)$ and $\mathcal{F}_n(\mathcal{O}_q(G/K))$. Our ultimate goal is to give a similar description of the representation $\mathcal{F}_n(\mathcal{O}_q(G/K))$. (Received August 27, 2018)

1144-00-255 **M. Helena Noronha*** (helena.noronha@csun.edu), Department of Mathematics- CSUN, Northridge, CA 91330-8313. *How we get students PUMPed into PhDs.*

Underrepresented minority (URM) and first-generation college math majors, as well as those with financial constraints abound in several parts of the country and in particular in Southern California. Some of these students are unaware of the many opportunities available to them, that a PhD degree can boost their careers or, even worse, lack confidence that they can succeed in graduate school. In this talk I will describe how my collaborators and I have been mentoring these math majors at some campuses of the California State University system. Our work is changing the culture of our departments, that is, students are inspired, build self-confidence, and raise their aspirations. We work in the project named PUMP: Preparing Undergraduates through Mentoring towards PhDs. I will also talk about lessons that we have learned, challenges to be faced, and describe how we are extending this work to local Community Colleges. (Received August 27, 2018)

1144-00-282 **Emille Davie Lawrence*** (edlawrence@usfca.edu). *Partisan Gerrymandering and the Efficiency Gap.* Preliminary report.

The United States Census Bureau will conduct its next census in the year 2020. But why is this decennial count so important? Aside from allocating funds for municipalities to receive certain social services, the census is used for the apportionment of Representatives in the House. Recent cases of partisan gerrymandering (redrawing district lines for ulterior political motives) have made it all the way to the Supreme Court and the efficiency gap formula, a formula which quantifies the amount of "wasted votes" by a party, played a pivotal in these cases. We will discuss the efficiency gap formula as it was originally defined by E. McGhee, as well as some competing new alternatives. (Received August 27, 2018)

1144-00-339 **Stephanie J. Somersille***, ssomersille@gmail.com. *Mathematics and Gerrymandering.*

We will briefly discuss the history of redistricting in the United States and then the current status. We will touch on some court cases happening both locally and around the country. We'll talk about various mathematical techniques that are being brought to bear on the issue including attempts to quantify "gerrymandered", to find "fair" maps and to explore the space of all maps. We will discuss the importance and benefits of the collaboration between mathematicians, computer scientists, lawyers, politicians, political and social scientists and others on these issues. (Received August 28, 2018)

03 ► Mathematical logic and foundations

1144-03-138 **Aristotelis Panagiotopoulos*** (panagio@caltech.edu), Department of Mathematics, Caltech, 1200 E. California Blvd, MC 253-37, Pasadena, CA 91125, and **Martino Lupini**. *Unitary equivalence is hard.*

Using a technique developed by Hjorth, Kechris and Sofronidis proved that the problem of classifying all unitary operators $\mathcal{U}(\mathcal{H})$ of an infinite dimensional Hilbert space up to unitary equivalence $\simeq_U$ is strictly more difficult than classifying graph structures with domain $\mathbb{N}$ up to isomorphism.

We introduce a dynamical obstruction for classifying an orbit equivalence relation by one that is induced by a CLI group; recall that a CLI group is a topological group which admits a complete left invariant metric (solvable groups are CLI). We deduce that $\simeq_U$ is not classifiable by CLI group actions. (Received August 21, 2018)

05 ► Combinatorics

1144-05-77 **Rosa C Orellana*** (rosa.c.orellana@dartmouth.edu), Dartmouth College, Mathematics Department, 6188 Kemeny Hall, Hanover, NH 03755, and **Mike Zabrocki**, York University, 4700 Keele St., Toronto, ON M5B1B4, Canada. *The Howe duality for the symmetric group.*

Classical Howe dualities provide a representation theoretical framework for classical invariant theory. It is known that $GL_n(\mathbb{C})$ is Howe dual to $GL_k(\mathbb{C})$ when both act on the polynomial ring in the variables $x_{i,j}$ where $1 \leq i \leq n$ and $1 \leq j \leq k$. In this talk, I will introduce the *multiset partition algebra*, MP_k as the Howe dual to the symmetric group S_n.

This is joint work with Mike Zabrocki (Received August 10, 2018)

1144-05-109 **Cosmin Pohoata*** (apohoata@caltech.edu), 120 West Wilson Ave, Apt 1448, Glendale, CA 911203. *Some new thoughts on an old problem of Erdos and Newman.* Preliminary report.

Suppose $A \subset B + B = \{b + b', b, b' \in B\}$ for finite sets of reals A, B. Trivially, $|B| \geq |A|^{1/2}$. Improving on this bound for sets A with some additional structure is in general a hard problem. The first available result in this spirit is a classical theorem due to Erdős and Newman, who prove that when A is the set of the first m perfect squares and B is a set of integers, we have that $|B| \geq m^{2/3-\epsilon}$ for any $\epsilon > 0$. For sets A with small product set AA, Shkredov and Zhelezov managed to prove that a condition of the form $|AA| \ll |A|^{1+\epsilon}$ for some $\epsilon > 0$ implies $|B| \geq |A|^{1/2+1/442-\epsilon'}$ even if A and B are sets of real numbers (which are not necessarily integers). Here, $AA = \{aa', a, a' \in A\}$. In this talk, we will discuss an improvement of this result in the case when A and B are a set of integers, and furthermore, answering a question of Shkredov and Zhelezov, show that if $|AA| \ll |A|^{1+\epsilon}$ and $A \subset B + B$, then $|B + B| \gg |A|^{10/9-\epsilon''}$ for every $\epsilon'' > 0$. If time permits, some two dimensional variants of this result will be considered. (Received August 22, 2018)

1144-05-127 **Ellen Veomett*** (erv2@stmarys-ca.edu), **Marion Campisi**, **Tommy Ratliff** and **Andrea Padilla**. *Declination as a Metric to Detect Partisan Gerrymandering.*

Partisan gerrymandering is generally (and vaguely) understood to be the drawing of district lines in a way that unfairly benefits a particular political party. Gerrymandering has recently become a hot topic in many communities, including the mathematical community. One of the efforts that mathematicians have been involved with is the creation and analysis of metrics intended to detect the presence of partisan gerrymandering.

In this talk, we will analyze one particular such metric: the declination. This metric was introduced by mathematician Greg Warrington in January 2018, and relies on our intuition of what the results of "packing and cracking" (the tools used to gerrymander) tend to "look like." We prove which pairs of vote share V and seat share S can be achieved in an election with declination 0 (indicating no gerrymandering), and how voter turnout affects what pairs (V, S) are possible. We also discuss implications of our analysis. (Received August 21, 2018)

1144-05-181 **David Jordan** and **Monica Vazirani***, One Shields Ave, Davis, CA 95616. *An elliptic Schur-Weyl construction of the rectangular representation of the DAHA.*

Building on the work of Calaque-Enriquez-Etingof, Lyubashenko-Majid, and Arakawa-Suzuki, Jordan constructed a functor from quantum D-modules on general linear groups to representations of the double affine Hecke algebra (DAHA) in type A. When we input quantum functions on GL(N) the output is $L(k^N)$, the irreducible DAHA representation indexed by an $N \times k$ rectangle. For the specified parameters $L(k^N)$ is Y-semisimple, i.e. one can diagonalize the Dunkl operators. We give an explicit combinatorial description of this module via its Y-weight basis. This is joint work with David Jordan. (Received August 24, 2018)

1144-05-197 **Joshua P. Swanson*** (jswanson@ucsd.edu), **Sara C. Billey** and **Matjaž Konvalinka**. *Tableaux posets and the fake degrees of coinvariant algebras.*

The theory surrounding the coinvariant algebra R of a complex reflection group G exemplifies the beautiful interplay between representation theory, tableaux combinatorics, and symmetric function theory. Here R is a graded G-module. Lusztig's so-called "fake degrees" are polynomials encoding the graded irreducible decomposition of these G-modules and have been studied extensively. Our main result is an essentially complete classification for which irreducibles appear in which degrees of arbitrary complex reflection groups, or equivalently which fake degree coefficients are non-zero. The most involved step of our argument is the type A case where we introduce a new partial order on the standard Young tableaux of a given partition shape which is ranked by the major index statistic up to a shift. The poset is constructed from explicit combinatorial manipulations on tableaux. Building on work of Specht, Shephard–Todd, Stembridge, and others, we are able to amplify the classification to the full infinite family $G(m, d, n)$. (Received August 24, 2018)

1144-05-213 **Sarah Mason*** (masonsk@wfu.edu), 127 Manchester Hall, Winston Salem, NC 27109, and **Cristina Ballantine**, **Zajj Daugherty**, **Angela Hicks** and **Elizabeth Niese**. *Quasisymmetric power sums and plethysm.*

We discuss two quasisymmetric analogues of the power sum basis for symmetric functions. We describe their multiplication, expansion into Gessel's fundamental quasisymmetric functions, and several other useful properties. We also connect this basis to a notion of plethysm on quasisymmetric functions. (Received August 25, 2018)

1144-05-250 **Karen Gunderson*** (karen.gunderson@umanitoba.ca), 186 Dysart Road, Winnipeg, MB R0A 0T0, Canada. *Random geometric graphs in normed spaces.*

Often, random geometric graphs are generated by placing points randomly in a metric space and then joining points within a fixed distance. Recently, Bonato and Janssen introduced another model in which the vertices are a fixed countable dense set in a normed space and pairs at distance at most 1 are joined by an edge with a given probability, independently of all others. While the properties of the resulting graph may depend heavily on the geometry of the underlying space and on the choice of the set of vertices, it was shown that in some cases, the graphs generated in this way will almost surely be isomorphic to each other. In these cases, the set of vertices is said to be *Rado*. I shall discuss some new results on Rado sets in arbitrary finite-dimensional normed spaces. This is based on joint work with Balister, Bollobás, Leader, and Walters. (Received August 27, 2018)

1144-05-310 **Radmila Sazdanovic*** (rsazdanovic@math.ncsu.edu), Department of Mathematics, NC State, SAS Hall PO Box 8205, Raleigh, NC 27695, and **Martha Yip**. *A categorification of the chromatic symmetric function.*

The Stanley chromatic symmetric polynomial X_G of a graph G is a symmetric function generalization of the chromatic polynomial, and has interesting combinatorial properties. We apply the techniques of Khovanov

homology to construct a homology of bigraded S_n-modules, whose bigraded Frobenius series reduces to the chromatic symmetric polynomial at $q = t = 1$. We also obtain analogues of several familiar properties of the chromatic symmetric polynomial in terms of homology, including the decomposition formula for X_G discovered recently by Orellana and Scott, and Guay-Paquet. (Received August 28, 2018)

1144-05-340 **Carolina Medina Graciano*** (cmedina@ifisica.uaslp.mx) and **Gelasio Salazar**. *On the number of unknot diagrams.*

Let D be a knot diagram, and let $\{D\}$ denote the set of diagrams that can be obtained from D by crossing exchanges. If D has n crossings, then $\{D\}$ has 2^n elements. It is well known that at least one of these 2^n diagrams is a diagram of the unknot, from which it follows that every diagram has finite unknotting number. It is easy to see that this argument can be used to show that actually $\{D\}$ has more than one unknot diagram, but it cannot yield more than $4n$ unknot diagrams. We improve this linear bound to a superpolynomial bound, by showing that at least $2^{\sqrt[3]{n}}$ of the diagrams in $\{D\}$ are diagrams of the unknot. We also show that either all the diagrams in $\{D\}$ are diagrams of the unknot, or there is a diagram in $\{D\}$ that is a diagram of the trefoil knot. (Received August 28, 2018)

11 ► Number theory

1144-11-189 **Catalina Camacho-Navarro*** (camacho@math.colostate.edu), **Wanlin Li** (wanlin@math.wisc.edu), **Jackson S Morrow** (jmorro2@emory.edu), **Jack Petok** (petok@rice.edu) and **David Zureick-Brown** (dzb@mathcs.emory.edu). *Modular Curves of low composite level and genus zero subgroups.* Preliminary report.

Let E be an elliptic curve defined over $\mathbb{Q}$ without complex multiplication. For every positive integer N, the Galois group $\mathrm{Gal}(\overline{\mathbb{Q}}/\mathbb{Q})$ induces an action on the N-torsion points of E and so there is a representation $\rho_{E,n}\colon \mathrm{Gal}(\overline{\mathbb{Q}}/\mathbb{Q}) \to \mathrm{GL}_2(\mathbb{Z}/n\mathbb{Z})$. In recent years, Zureick–Brown, Rouse, Sutherland and Zywina have made significant progress towards classifying the subgroups of $\mathrm{GL}_2(\hat{\mathbb{Z}})$ which contain subgroups that are conjugate to images of Galois for some elliptic curve. Based of work by Sutherland–Zywina, Morrow began the study of the composite-(m_1, m_2) image of Galois in the case where m_1 is a power of 2 and m_2 is a prime ≤ 13. We continue the study of composite-(m_1, m_2) image of Galois, using Galois representations and modular curves. For each subgroup of $G \subset \mathrm{GL}_2(\mathbb{Z}/m_1m_2\mathbb{Z})$ where the modular curve has low genus, we construct a hyperelliptic model and use different methods, along with the software Magma to find almost all rational points. Finally we determine which ones correspond to sporadic points. (Received August 24, 2018)

1144-11-246 **Kenny Smith*** (kdsmith106@mail.fresnostate.edu). *An Approximation of the Prime Counting Function with an Error Term.* Preliminary report.

Using known results of the Riemann Zeta function, $\zeta(s)$, we approximate the prime counting function with a remainder term. The proof is dependent on showing $\zeta(s)$ has no zero in the region of the complex plane where the real part of s is greater than or equal to $1 - c/\log t$ for a positive constant c. (Received August 27, 2018)

12 ► Field theory and polynomials

1144-12-350 **Aaron Melman*** (amelman@scu.edu). *Generalizations of the Eneström-Kakeya theorem.*

The Eneström-Kakeya theorem is an elegant theorem that establishes upper (and lower) bounds on the moduli of zeros of polynomials with positive coefficients. We show how it can be generalized and improved in a unifying way by relying on just two tools: appropriate polynomial multipliers and the generalization of an observation by Cauchy. In this way, we derive zero inclusion regions composed of one, two, three, or more smaller disks, rather than just the one disk obtained by the Eneström-Kakeya theorem. (Received August 29, 2018)

13 ► Commutative rings and algebras

1144-13-70 **Toshinori Kobayashi** (m16021z@math.nagoya-u.ac.jp), Furocho, Chikusaku, Nagoya, Aichi 464-8602, Japan, and **Ryo Takahashi*** (takahashi@math.nagoya-u.ac.jp), Furocho, Chikusaku, Nagoya, Aichi 464-8602, Japan. *Ulrich modules over Cohen-Macaulay local rings with minimal multiplicity.*

Let R be a Cohen-Macaulay local ring, and assume that R has minimal multiplicity. In this talk, we explore generation of Ulrich R-modules, and clarify when the Ulrich R-modules are precisely the syzygies of maximal Cohen-Macaulay R-modules. We also investigate the structure of Ulrich R-modules as an exact category. (Received August 09, 2018)

1144-13-103 **Ya. S. Krylyuk*** (krylioukiaroslav@fhda.edu), De Anza College, 21250 Stevens Creek Blvd, Cupertino, CA 95014. *The Poisson Conjecture and its connection to the classical invariant theory.* Preliminary report.

In the talk will be discussed the reformulation of the Poisson Conjecture on the polynomial symplectomorphisms bounded by the given degree and the connection of the algebra of the defining equations of such set to the classical invariant theory. A special attention will be paid to the case of polynomial symplectomorphisms in two variables. (Received August 15, 2018)

1144-13-148 **Srikanth B Iyengar*** (iyengar@math.utah.edu), Department of Mathematics, University of Utah, 155 South 1400 East, Room 233, Salt Lake City, UT 84112-0090. *Finite free complexes over polynomial rings.*

This talk will be about various results (some of recent vintage) and conjectures concerning finite free complexes over polynomial rings. Many of these concern numerical invariants associated with such a complex; notably, the length of the complex, and the ranks of the free modules that appear in it. This thread of research can be traced back to Hilbert's Syzygy Theorem (1890) that states that each finitely generated module over a polynomial ring over a field has a finite free resolution. The modern developments in this subject started with the work of Auslander, Buchsbaum, and Serre in the 1950s, and have since then been a centerpiece in commutative algebra. Another impetus for the subject has come from results and conjectures of Adem, Browder, Carlsson, Halperin, and Swan, among others, on obstructions to groups acting freely on spaces. (Received August 22, 2018)

1144-13-184 **Josh H Pollitz*** (jpollitz@huskers.unl.edu), 904 S S 17TH St, APT C2, Lincoln, NE 68508. *The derived category of a locally complete intersection ring.*

Let R be a commutative noetherian ring. It is well known that R is regular if and only if every complex with finitely generated homology is a perfect complex. The goal of this talk is to explain how one can characterize whether R is locally a complete intersection in terms of how each complex with finitely generated homology relates to the perfect complexes. Namely, R is locally a complete intersection if and only if each nontrivial complex with finitely generated homology can build a nontrivial perfect complex in the derived category using finitely many cones and retracts. In this talk, we will introduce a theory of support varieties and discuss how they can be applied to yield this characterization of locally complete intersections. (Received August 24, 2018)

1144-13-209 **Mark E Walker*** (mark.walker@unl.edu), 203 Avery Hall, University of Nebraska, Lincoln, NE 68588. *Total Betti numbers.*

I will describe some positive results concerning lower bounds on the total Betti numbers of chain complexes and topological spaces that satisfy certain conditions. These results complement the topic of Srikanth Iyengar's invited address at this same meeting, which concerns couter-examples to some related conjectures. Finally, I will speculate about the relationship between these results. (Received August 25, 2018)

1144-13-218 **Hailong Dao***, Department of Mathematics, 405 Snow Hall, 1460 Jayhawk Blvd, Lawrence, KS 66049. *Cohen-Macaulay representation theory modulo numerical equivalence.*

Let R be a commutative Noetherian ring. Cohen-Macaulay representation theory seeks to understand the category of Cohen-Macaulay modules over R. One complicating issue is that this category is quite big. In fact, even the Grothendieck group is typically infinitely generated. In this talk, I will discuss numerical equivalence in this group, motivated by intersection theory. The Grothendieck group of Cohen-Macaulay modules modulo numerical equivalence is finitely generated under mild assumptions, and there is growing evidence that it still contains all the "interesting" objects. Some of this work are joint with K. Kurano and I. Shipman. (Received August 25, 2018)

1144-13-223 **Luchezar L. Avramov***, Deapartment of Mathematics, Universty of Nebraska-Lincoln, Lincoln, NE 68588, and **Nicholas Packauskas** and **Mark E. Walker**. *Quasi-polynomial growth of Betti numbers over local rings.* Preliminary report.

Let $R = Q/I$, where Q is a regular local ring and I is generated by a regular sequence of c elements in the square or the maximal ideal. It is known that for each finitely generated R-module M there are integer-valued polynomials p_+^M and p_-^M with $\deg(p_-^M) < \deg(p_+^M) < c$, such that for $i \gg 0$ the Betti numbers of M are given by $\beta_{2i}^R(M) = p_+^M(2i)$ and $\beta_{2i+1}^R(M) = p_-^M(2i+1)$. It will be shown that the degree of $p_+^M - p_-^M$ is less than $c - q - 1$, where q is the height of the ideal of the associated graded ring of Q generated by the quadratic initial forms of the elements of I. (Received August 26, 2018)

1144-13-227 **Mel Hochster**, **Graham Leuschke*** (gjleusch@syr.edu) and **Rebecca R.G.**. *Splitting properties of big Cohen-Macaulay modules.* Preliminary report.

We examine the splitting behavior of big Cohen-Macaulay modules over Cohen-Macaulay local rings of finite Cohen-Macaulay type. (Received August 26, 2018)

1144-13-248 **Lars Winther Christensen**, **Sergio Estrada** and **Peder Thompson*** (peder.thompson@ntnu.no). *Stable category of Gorenstein flat modules.* Preliminary report.

We define a category of Gorenstein modules associated to a given cotorsion pair, and show it naturally induces a corresponding stable category, recovering the usual stable categories of Gorenstein projective and Gorenstein injective modules. This also gives a suitable stable category of Gorenstein flat modules, which we show is equivalent to the pure derived category of F-totally acyclic complexes of flat modules studied by Murfet and Salarian. This equivalence, which is described explicitly and holds for any coherent ring, extends work of Estrada and Gillespie. Our approach has the advantage that it avoids the use of projectives, so it can be generalized to non-affine noetherian semi-separated schemes, a direction we are also pursuing. The equivalence is given along the same lines as the classical equivalence, due to Buchweitz, between the stable category of maximal Cohen-Macaulay modules and the singularity category of a Gorenstein ring. (Received August 27, 2018)

1144-13-254 **Claudia Miller*** (clamille@syr.edu), **Hamidreza Rahmati** and **Rebecca R.G.**. *Free resolutions of Artinian compressed algebras with application to Frobenius powers of an ideal.*

We construct free resolutions of generic (more precisely, compressed) Artinian graded algebra quotients of polynomial rings and give a method to reduce them to a minimal resolutions. Our result generalizes results of El Khoury and Kustin for Gorenstein algebras of even socle degree with a very different proof. This yields results on the form of the resolution and the degrees of the forms in the matrices of the differentials, but not precise Betti numbers.

If time permits, we discuss an application to the conjectured curious behavior of the Betti numbers of the Frobenius powers of the maximal ideal in hypersurfaces $R = k[x, y, z]/(f)$, where k is an infinite field of positive characteristic. We show that if f is chosen generically, then high enough Frobenius powers of the maximal ideal have identical graded Betti numbers up to explicit shifts. (Received August 27, 2018)

1144-13-301 **Lars Winther Christensen*** (lars.w.christensen@ttu.edu), **Oana Veliche** and **Jerzy Weyman**. *Liaison and the classification of local rings of low codepth.* Preliminary report.

A remarkable classification of local rings of low codepth was initiated 30 years ago by Weyman and by Avramov, Kustin, and Miller. It reigned in—in terms of numerical parameters—the possible multiplicative structures on the Koszul algebra of a local ring of codepth at most 3. Guided by experiments and relying heavily on the theory of liaison, or linkage, we are now able to explain the detailed structure of this classification. (Received August 28, 2018)

14 ► Algebraic geometry

1144-14-21 **Pablo Solis*** (sopablo@stanford.edu). *Monads on $\mathbb{P}^1 \times \mathbb{P}^1$ and Natural Cohomology.* Preliminary report.

A vector bundle has natural cohomology when its cohomology is concentrated in a single degree for every twist. On projective space vector bundles with natural cohomology appear as the extremal rays in polyhedral cone of cohomology tables; this is the geometric analogue of Boij-Soderberg theory. Eisenbud and Schreyer considered the analogous theory in the bi-graded setting of $\mathbb{P}^1 \times \mathbb{P}^1$ where they conjectured that vector bundles with natural cohomology should exist with prescribed cohomology. In this talk I'll sketch a proof of this conjecture. (Received August 27, 2018)

1144-14-57 **Christopher Eur*** (chrisweur@gmail.com). *Divisors on matroids and their volumes.*
The classical volume polynomial in algebraic geometry measures the degrees of ample (and nef) divisors on a smooth projective variety. We introduce an analogous volume polynomial for matroids, and give a complete combinatorial formula. For a realizable matroid, we thus obtain an explicit formula for the classical volume polynomial of the associated wonderful compactification. We then introduce a new invariant called the volume of a matroid as a particular specialization of its volume polynomial, and discuss its algebro-geometric and combinatorial properties in connection to graded linear series on blow-ups of projective spaces. (Received August 05, 2018)

1144-14-58 **Cris Negron*** (negronc@mit.edu), Massachusetts Institute of Technology, Department of Mathematics, Cambridge, MA 02139. *Hochschild cohomology rings of a global quotient orbifolds.* Preliminary report.
I will discuss recent work with Pieter Belmans, Pavel Etingof, and Travis Schedler, in which we investigate Hochschild cohomology rings of global quotient orbifolds. Equivalently, we study the Hochschild cohomology ring of the category of G-equivariant sheaves on a smooth quasi-projective scheme X, with G is a finite group. We obtain a general structure theorem for the (associated graded) Hochschild cohomology ring of such an object, and observe a surprising obstruction to the extension of Kontsevich's formality result to smooth DM stacks. (Received August 06, 2018)

1144-14-104 **Mengyuan Zhang*** (myzhang@berkeley.edu), 1061 Evans Hall, University of California Berkeley, Berkeley, CA 94720. *General projections of curves on smooth surfaces into* $\mathbb{P}^3$*.* Preliminary report.
We study the liaison theory on singular hypersurfaces X in $\mathbb{P}^3$ arising as general projections of smooth surfaces S. We show that 1) a smooth divisor class is unique in its elementary biliaison equivalence on X; 2) if a curve C on X is directly linked to a curve D that is an isomorphic projection from a curve on S, then the Hilbert function of C is computable via cohomologies of various line bundles on S; 3) taking S to be rational scrolls, a smooth curve C on X admits a direct linkage to a curve D that is an isomorphic projection. In particular, we compute the Hilbert function of C. We also examine the families of these projection curves, computing their dimensions as well as the dimensions of the tangent spaces at the corresponding points of the Hilbert scheme. (Received August 15, 2018)

1144-14-158 **Rongxiao Mi*** (rongxiao@umich.edu), 5828 East Hall, 530 Church Street, Ann Arbor, MI 48109. *Type II Extremal Transitions in Gromov-Witten theory.*
There has been a long-standing interest in understanding the change of Gromov-Witten invariants under extremal transitions. In this talk, I will describe a framework that relates two quantum D-modules under extremal transition. Several examples of Type II extremal transitions will be given and explained. (Received August 22, 2018)

1144-14-193 **Ben Wormleighton*** (b.wormleighton@berkeley.edu), 4415 Webster Street, Oakland, CA 94609. *Hilbert series of orbifold del Pezzo surfaces.* Preliminary report.
There are two classes of cyclic quotient singularities that are of especial interest in mirror symmetry for Fano varieties: T-singularities and residual singularities, characterised by being smoothable and rigid respectively. I will describe some insight their geometry offers into the structure of Hilbert series of orbifold del Pezzo surfaces, and how this provides nonexistence results for when a power series is not the Hilbert series of such a variety. In the toric case this also has applications to lattice point counting, which I will outline. (Received August 24, 2018)

1144-14-233 **Katrina Honigs*** (honigs@math.utah.edu). *Q-rational points and derived equivalence.*
The derived category of coherent sheaves on a smooth, projective variety connects to many different areas of study in algebraic geometry. There are many open questions about which properties of a variety are detected by this invariant. This talk will focus on the question of whether the property of having a k-rational point is shared by any two smooth, projective k-varieties with equivalent derived categories, and in particular will feature new examples of derived equivalent Q-varieties where one has a Q-point and the other does not. (Received August 26, 2018)

1144-14-236 **Borys Kadets*** (bkadets@mit.edu). *Sectional monodromy groups of projective curves.*
Fix a degree d projective curve $X \subset \mathbb{P}^r$ over a field K. The talk is concerned with the Galois group G_X of the field extension defined by the intersection of X with the hyperplane $x_0 + t_1x_1 + ... + t_rx_r = 0$ over $K(t_1, ..., t_r)$. It is well-known that G_X is related to the Hilbert polynomial of X. For example, when K has characteristic

zero $G_X = S_d$; this is the reason for the characteristic zero assumption in Harris' extension of Castelnuovo's inequality. We study the group G_X for the fields of positive characteristic. When $r \geq 3$ we can list all nonstrange nondegenerate projective curves with $A_d \not\subset G_X$. All of them turn out to be smooth and rational. (Received August 26, 2018)

1144-14-237 **Dmitrii Kubrak*** (dmkubrak@gmail.com). *$\mathbb{G}_m$-weights of differential 1-forms on conical resolutions of singularities.*

A conical resolution $\pi : X \to Y$ is a resolution of singularities endowed with a $\mathbb{G}_m$-action that contracts Y to a single point. Given a conical resolution $\pi : X \to Y$ over a field K one can ask what are the $\mathbb{G}_m$-weights of the vector space $H^0(X, \Omega^1_X)$ of differential 1-forms on X. In a joint work with R.Travkin arXiv:1611.08340 we prove that under some mild conditions on π all weights are nonnegative and all $\mathbb{G}_m$-invariant forms are closed. Moreover, there are no nonzero $\mathbb{G}_m$-invariant forms if K is of char 0, but there can exist some if K is of char p. In a current work in progress with A.Prikhodko we apply new results by Bhatt, Morrow and Scholze to show that if π is a reduction mod p there is a bound from below on the dimension of the space of $\mathbb{G}_m$-invariant 1-forms in terms of the 1-st etale $\mathbb{F}_p$-cohomology of the rigid generic fiber of the quotient stack $[X/\mathbb{G}_m]$ which we also expect to be isomorphic to the singular $\mathbb{F}_p$-cohomology of the topological space $X(\mathbb{C})$. (Received August 26, 2018)

1144-14-256 **Yongbin Ruan** (ruan@umich.edu), 3064 East Hall, 530 Church Street, Ann Arbor, MI 48109-1043, and **Ming Zhang*** (zhangmsq@umich.edu), 5080 East Hall, 530 Church Street, Ann Arbor, MI 48109-1043. *Verlinde algebra and quantum K-theory with level structure.* Preliminary report.

In this talk, I will first introduce the level structure in quantum K-theory. When the target is the Grassmannian, I will explain the wall-crossing approach to obtain the relation between quantum K-invariants with level structure and GL Verlinde numbers.

Based on a joint work with Yongbin Ruan. (Received August 27, 2018)

1144-14-265 **Bronson Lim*** (bronson@math.utah.edu), 733 Windsor Street East, Salt Lake City, UT 84102. *Motivic Semiorthogonal Decompositions for Abelian Varieties.* Preliminary report.

Let G be a finite group acting effectively on a smooth quasi-projective variety X. Additive invariants of the G-equivariant derived category of X are known to decompose into additive invariants of certain varieties related to X and the G-action. Polishchuk and Van den Bergh have conjectured that such a decomposition should arise from a semiorthogonal decomposition of derived categories. We prove that these conjectured semiorthogonal decompositions exists when X is an Abelian variety in arbitrary dimension. (Received August 27, 2018)

1144-14-277 **David Stapleton***, 9500 Gilman Dr., La Jolla, CA 92093. *The degree of irrationality of hypersurfaces in Fano varieties.*

The degree of irrationality of an algebraic variety is the minimal degree of a dominant rational map to projective space of the same dimension. This generalizes the notion of gonality of a curve. While of a classical flavor, this birational invariant has not received much attention in higher dimensions until the recent collective works of Bastianelli, Cortini, De Poi, Ein, Lazarsfeld, Pirola, and Ullery. In this talk we will show how to compute the degree of irrationality of hypersurfaces in various Fano varieties: projective spaces, Grassmannians, quadrics, cubic threefolds, cubic fourfolds, and (2,2)-complete intersection threefolds. We will highlight the connection between the degree of irrationality and existence of low degree curves which sweep out the Fano variety. This is joint work with Brooke Ullery. (Received August 27, 2018)

1144-14-289 **Kristin E DeVleming*** (kdev@uw.edu). *Moduli of surfaces in $\mathbb{P}^3$.*

We will discuss a compactification of the moduli space of degree $d \geq 5$ surfaces in $\mathbb{P}^3$, i.e. a parameter space whose points correspond to such surfaces and their degenerations. Using the KSBA framework and the minimal model program, we consider these surfaces as divisors D in $\mathbb{P}^3$ and study the moduli space of pairs $(\mathbb{P}^3, D)$. These tools allow us to explicitly understand the singular pairs arising as degenerations of $(\mathbb{P}^3, D)$ and give a modular description of the compactification. (Received August 27, 2018)

1144-14-296 **Sarah Frei*** (sfrei@uoregon.edu). *Galois representations of moduli spaces of sheaves.*

We will study moduli spaces of stable sheaves on K3 surfaces defined over an arbitrary field. While these varieties have been studied extensively over the complex numbers, they have only recently been studied more thoroughly over other fields and were used by Charles to prove the Tate conjecture for K3 surfaces over finite fields. In this talk, we will discuss the cohomology groups of the moduli spaces as Galois representations. Our main result is that for any two K3 surfaces, a Galois equivariant isomorphism between their etale cohomology groups implies

an isomorphism as Galois representations between the cohomology groups of moduli spaces of stable sheaves on each of equal dimension. In particular, when the K3 surfaces are defined over a finite field, this implies that the moduli spaces have the same zeta functions. (Received August 27, 2018)

1144-14-305 **Georg Oberdieck** (georgo@math.uni-bonn.de) and **Dulip Piyaratne*** (piyaratne@math.arizona.edu), Department of Mathematics, University of Arizona, 617 N. Santa Rita Avenue, Tucson, AZ 85721, and **Yukinobu Toda** (yukinobu.toda@ipmu.jp). *Donaldson–Thomas invariants and Bridgeland stability conditions on abelian threefolds.*

In this talk we will discuss about the reduced Donaldson–Thomas theory of abelian threefolds using Bridgeland stability conditions. In particular, we will show the invariance of the reduced Donaldson–Thomas invariants under all derived autoequivalences, up to explicitly given wall-crossing terms. This is a joint work with Georg Oberdieck and Yukinobu Toda. (Received August 28, 2018)

1144-14-320 **Leo Herr*** (leo.herr@colorado.edu). *Log gromov-witten invariants and their product formulas.*

We will discuss the product formula in logarithmic Gromov-Witten Theory. The version Y. P. Lee and F. Qu previously obtained for projective log smooth schemes has a restriction – one of the factors must have trivial log structure. We emphasize an alternative approach to the one in their paper, and suggest how this approach might remove the restriction. (Received August 28, 2018)

1144-14-325 **Caitlin King Stanton*** (stanton1@stanford.edu). *Complete Quadrics.* Preliminary report.

It is well-known that there are 3264 conics tangent 5 general smooth quadrics in $\mathbb{P}^2$. This result can be proved by taking a suitable space that parametrizes conics in $\mathbb{P}^2$ and computing T^5, where T is the divisor corresponding to the condition of being tangent to a general conic. To answer similar questions about higher dimensional quadrics, we would like to use the space of complete n-quadrics. In this talk we will discuss this space, including how we can use torus-fixed points to find generators for the Chow group. (Received August 28, 2018)

1144-14-327 **Bourdon Abbey**, **Ejder Ozlem*** (ejder@math.colostate.edu), **Yuan Liu**, **Frances Odumodu** and **Bianca Viray**. *Points of unusually low degree on modular curves.*

Motivated by the classification problem of torsion subgroups of elliptic curves over a number field of fixed degree, we study the points on modular curve $X_1(n)$ of unusually low degree. Such points correspond to elliptic curves with unusually small mod n Galois representations. In this talk we discuss these so called sporadic points on $X_1(n)$ and explain these connections. (Received August 28, 2018)

1144-14-331 **Adrian I. Zahariuc*** (azahariuc@math.ucdavis.edu). *Severi-type problems.*

Severi varieties are (roughly speaking) parameter spaces for curves of fixed homology class and geometric genus on projective surfaces. By a celebrated theorem of Harris from the mid 80s, Severi varieties of the projective plane are irreducible. By extension, a "Severi-type problem" is the question of whether the Severi varieties of a certain projective surface are irreducible, or, if they aren't, of identifying the irreducible components. Known cases include Hirzebruch surfaces $\mathbb{F}_n$ (Tyomkin '07) and rational curves on del Pezzo surfaces (Testa '10). However, even among surfaces whose Severi varieties are reasonably easily seen to have the expected dimension, the vast majority of cases are currently wide open. In this talk, I will try to give a very quick overview of the (few) existing methods to approach Severi-type problems, their virtues, limitations, and relation to other questions concerning curves on surfaces. (Received August 28, 2018)

1144-14-354 **Jonathan Mboyo Esole** and **Monica Jinwoo Kang*** (jkang@fas.harvard.edu), 17 Oxford St., Physics Dept. Harvard University, Cambridge, MA 02138. *Characteristic numbers of crepant resolutions of Weierstrass models.*

We compute characteristic numbers of crepant resolutions of Weierstrass models corresponding to elliptically fibered fourfolds Y dual in F-theory to a gauge theory with gauge group G. In contrast to the case of fivefolds, Chern and Pontryagin numbers of fourfolds are invariant under crepant birational maps. It follows that Chern and Pontryagin numbers are independent on a choice of a crepant resolution. We present the results for the Euler characteristic, the holomorphic genera, the Todd-genus, the L-genus, the $\hat{A}$-genus, and the curvature invariant X_8 that appears in M-theory. We also show that certain characteristic classes are independent on the choice of the Kodaria fiber characterizing the group G. That is the case of $\int_Y c_1^2 c_2$, the arithmetic genus, and the $\hat{A}$-genus. Thus, it is enough to know $\int_Y c_2^2$ and the Euler characteristic $\chi(Y)$ to determine all the Chern numbers of an elliptically fibered fourfold. We consider the cases of $G = \mathrm{SU}(n)$ for $(n = 2, 3, 4, 5, 6, 7)$, $\mathrm{USp}(4)$, $\mathrm{Spin}(7)$, $\mathrm{Spin}(8)$, $\mathrm{Spin}(10)$, G_2, F_4, E_6, E_7, or E_8. (Received August 29, 2018)

15 ► Linear and multilinear algebra; matrix theory

1144-15-27 **Mao-Ting Chien*** (mtchien@scu.edu.tw), Department of Mathematics, Soochow University, Taipei, Taiwan. *Hyperbolic ternary forms of unitary bordering matrices.*

Let A be an $n \times n$ matrix, the determinantal ternary form of A is defined by $F_A(t,x,y) = \det(t\,I_n + x\,\Re(A) + y\,\Im(A))$. A ternary form $F(t,x,y)$ is hyperbolic with respect to $(1,0,0)$ if the univariate polynomial $F(t,x,y)$ has only real roots for any non-zero real numbers x and y, and $F(1,0,0) = 1$. Clearly, $F_A(t,x,y)$ is hyperbolic. Conversely, for any hyperbolic ternary form $F(t,x,y)$ of degree n, the Helton-Vinnikov theorem asserts that there exists an $n \times n$ symmetric matrix S such that $F(t,x,y) = F_S(t,x,y)$. Assume A is an $n \times n$ unitary bordering matrix. We prove that A is unitarily similar to a symmetric matrix. We also investigate the unitary similarity between the matrix A and the Helton-Vinnikov symmetric matrix S which admits the determinantal representation of the ternary form $F_A(t,x,y)$ satisfying $F_A(t,x,y) = F_S(t,x,y)$. (Received July 12, 2018)

1144-15-211 **Rongrong Wang***, 428 S. Shaw Lane, East Lansing, MI 48823, and **Iwen Mark**, **Rayan Saab** and **Wei-husan Yu**. *Sigma Delta quantization on wide-band signals.* Preliminary report.

Abstract: Sigma Delta quantization has been known to work efficiently on low-frequency signals or on Gaussian samples of sparse signals, in the sense that the rate-distortion decreases quickly as the number of samples increases. Extending this result to the more practical spectrally sparse or wavelet domain sparse signals faces two issues. 1. the high-frequency components in the measurements cannot be well preserved by Sigma Delta quantization. 2. very little is known about the singular-vectors of the high order finite difference matrices which play a crucial role in the Sigma Delta analysis. In this talk, we will address these problems and subsequently prove the reconstruction guarantee under partial Fourier measurements and Haar basis. (This is joint work with Mark Iwen, Rayan Saab, and Wei-husan Yu). (Received August 25, 2018)

1144-15-257 **Keaton Hamm*** (hamm@math.arizona.edu). *CUR Decompositions and Applications.*

This talk will present some viewpoints of a matrix decomposition (or approximation) method called CUR. We will discuss how the exact decomposition version gives a solution to the subspace clustering problem in the ideal case, and mention extensions when the data contains noise. Particularly, we present an algorithm for subspace clustering of noisy data, and demonstrate its performance on the Hopkins155 motion segmentation dataset. Related to this, we will discuss a matrix perturbation analysis for CUR approximations of an observed matrix which is a small perturbation of a low rank matrix. (Received August 27, 2018)

16 ► Associative rings and algebras

1144-16-8 **Ahmed Sebbar*** (sebbar@chapman.edu), 363 N. Center Street, Orange, CA 92866, **Daniele Struppa** (struppa@chapman.edu), One University Drive, Orange, CA 92866, **Mihaela Vajiac** (mbvajiac@chapman.edu), One University Drive, Orange, CA 92866, and **Adrian Vajiac** (avajiac@chapman.edu), One University Drive, Orange, CA 92866. *Bicomplex algebra and the fields* $\mathbb{Q}(i), \mathbb{Q}(i,\sqrt{2})$.

We give the right meaning of the result that the zeta function of the bicomplex algebra is the square of the Dedekind zeta function of $\mathbb{Q}(i)$. This allows us to connect bicomplex algebra to the spectral theory of the three dimensional hyperbolic space and to the quadratic extension $\mathbb{Q}(i,\sqrt{2})$ of $\mathbb{Q}(i)$. (Received May 09, 2018)

1144-16-17 **Cris Negron**, **Yury Volkov** and **Sarah Witherspoon*** (sjw@math.tamu.edu). *Derivatives, derivations, and Hochschild Cohomology.*

Differentiation of functions on the real line obeys the Leibniz rule. More generally, linear operators on rings that obey this rule are called derivations. Generalizing yet further from linear to multilinear operators naturally leads to the subject of Hochschild cohomology, a source of important algebraic invariants for rings. It arises in many settings, for example, in algebraic deformation theory, in representation theory, and in noncommutative geometry. In this talk, we will give a brief introduction to Hochschild cohomology and some of its applications, and we will survey some recent work on its structure as a graded Lie algebra. (Received June 24, 2018)

1144-16-30 **Jieru Zhu***, jieru.zhu-1@ou.edu. *Two boundary centralizer algebras for* $\mathfrak{q}(n)$.

The Sergeev duality states that the action of the Type Q Lie superalgebra $\mathfrak{q}(n)$ and the Sergeev algebra fully centralize each other on the tensor space. Hill-Kujawa-Sussan (2011) generalized this work to the one boundary setting. We further study the two boundary generalization and define the degenerate two boundary affine Hecke-Clifford algebra $\mathcal{B}_d$ using generators and relations. It admits a $\mathfrak{q}(n)$-linear action on $M \otimes N \otimes V^{\otimes d}$ for the natural

representation V and arbitrary $\mathfrak{q}(n)$-modules M and N. When M and N are polynomial modules parametrized by a staircase and a single row partition, respectively, the action of $\mathcal{B}_d$ factors through a quotient algebra $\mathcal{H}_d$. Using combinatorial tools such as the Bratteli diagram and shifted Young tableaux, we construct simple modules for $\mathcal{H}_d$. These modules occur as irreducible $\mathcal{H}_d$-summands of $M \otimes N \otimes V^{\otimes d}$. (Received July 16, 2018)

1144-16-31 **Joshua Sussan***, CUNY Medgar Evers, Department of Mathematics, 1650 Bedford Ave., Brooklyn, NY 11225. *p-DG structures in higher representation theory.*

The study of p-DG algebras arises naturally when trying to categorify quantum groups at prime roots of unity. We will review this framework and construct some categorical representations for the case of sl(2). (Received July 18, 2018)

1144-16-43 **Nicolas Andruskiewitsch***, Medina Allende s/n, Ciudad Universitaria, 5016 Cordoba, Argentina, and **Ivan Angiono** and **Istvan Heckenberger**. *On Nichols algebras of finite GK-dimension.*

The problem of the classification of pointed Hopf algebras with finite GK-dimension leads naturally to the analogous problem of classification of Nichols algebras of finite GK-dimension over abelian groups. In the paper [1] we formulated a Conjecture on Nichols algebras of diagonal type with finite GK-dimension. Then we considered a class of braided vector spaces called blocks and classified those whose Nichols algebras have finite GK-dimension. Our main result is the classification of those braided vector spaces that are direct sums of blocks and points with finite GK-dimension, assuming the Conjecture.

Joint work with Iván Angiono (Universidad Nacional de Córdoba) and István Heckenberger (Universität Marburg).

[1] On finite GK-dimensional Nichols algebras over abelian groups. Abstract and file, arXiv:1606.02521. Mem. Amer. Math. Soc., to appear. (Received July 30, 2018)

1144-16-50 **Nicolas Andruskiewitsch** and **Ivan Angiono***, Medina Allende s/n, Ciudad Universitaria, 5000 Cordoba, Cordoba, Argentina, and **Istvan Heckenberger**. *On Nichols algebras of finite GK-dimension, part II.*

The problem of the classification of pointed Hopf algebras with finite GK-dimension leads naturally to the analogous problem of classification of Nichols algebras of finite GK-dimension over abelian groups. In [1] we classify braided vector spaces that are direct sums of blocks and points with finite GK-dimensional Nichols algebras, assuming a conjecture on braided vector spaces of diagonal type. This leads to new examples of Nichols algebras of finite GK dimension and, under bosonization, to new Hopf algebras of the same kind.

In this talk we will present these examples of Hopf algebras, with special focus on those which are domains. We will also describe liftings associated to the blocks whose Nichols algebras have finite GK dimension, namely Jordan and super Jordan braidings [2].

Joint work with Nicolás Andruskiewitsch (Universidad Nacional de Córdoba) and István Heckenberger (Universität Marburg).

[1] On finite GK-dimensional Nichols algebras over abelian groups. Mem. Amer. Math. Soc., to appear. [2] Liftings of Jordan and super Jordan planes. Proc. Edinb. Math. Soc., II. Ser., to appear. (Received August 02, 2018)

1144-16-52 **Elizabeth Wicks*** (lizwicks@uw.edu). *Frobenius-Perron Theory of Modified ADE Bound Quiver Algebras.* Preliminary report.

The Frobenius-Perron dimension for an abelian category was recently introduced. We apply this theory to the category of representations of the finite-dimensional radical square zero algebras associated to certain modified ADE graphs. In particular, we take an ADE quiver with arrows in a certain orientation and an arbitrary number of loops at each vertex. We show that the Frobenius-Perron dimension of this category is equal to the maximum number of loops at a vertex. Along the way, we introduce a result which can be applied in general to calculate the Frobenius-Perron dimension of a radical square zero bound quiver algebra. We use this result to introduce a family of abelian categories which produce arbitrarily large irrational Frobenius-Perron dimensions. (Received August 03, 2018)

1144-16-59 **Jason P Bell*** (jpbell@uwaterloo.ca) and **Dragos Ghioca**. *Periodic subvarieties and primitive ideals.*

Let G be a semiabelian variety defined over a field of characteristic 0, endowed with an endomorphism Φ. We prove there is no proper subvariety $Y \subset G$ which intersects the orbit of each periodic point of G under the action of Φ. As an application, we are able to give a topological characterization of the annihilator ideals of irreducible

representations in certain skew polynomial algebras. This is joint work with Dragos Ghioca (Received August 06, 2018)

1144-16-64 **Birge Huisgen-Zimmermann***, Department of Mathematics, University of California, Santa Barbara, CA 93106. *Iterated tilting of truncated path algebras.* Preliminary report.

We start by addressing the key position held by truncated path algebras within the class of arbitrary basic finite dimensional algebras. We then describe the homological assets of truncated path algebras, the main focus being the theory of iterated strong tilting (in the sense of Auslander and Reiten) admitted by these algebras. (This is joint work with M. Saorín.) (Received August 07, 2018)

1144-16-65 **K. R. Goodearl***, Department of Mathematics, University of California, Santa Barbara, CA 93106. *Integral Forms for Quantum Cluster Algebras.* Preliminary report.

An integral form for a quantum cluster algebra A over a field K is a subring of A which is a quantum cluster algebra over a "small" subring D of K. In the preferred case, D is generated as a ring by one or more non-roots of unity and their inverses. We will discuss some known existence results for such integral forms, and follow with some instances in which D requires inverses for elements other than non-roots of unity. This is joint work with Milen Yakimov. (Received August 07, 2018)

1144-16-111 **Chelsea Walton*** (notlaw@illinois.edu), Urbana, IL 61801. *On the quadratic dual of the Fomin-Kirillov algebras.*

I will discuss joint work with James Zhang on the ring-theoretic and homological properties of the quadratic dual (or Koszul dual) $\mathcal{E}_n^!$ of the Fomin-Kirillov algebras $\mathcal{E}_n$; the preprint is available at https://arxiv.org/abs/1806.09263.

Although the title, coauthors, and subject of this talk are subject to change. (Received August 16, 2018)

1144-16-123 **Bach Nguyen**, **Kurt Trey Trampel*** (ktramp2@lsu.edu) and **Milen Yakimov**. *Quantum Cluster Algebras and Discriminants.*

A general construction is built for quantum cluster algebras at roots of unity. For such an algebra, we construct a canonical central subalgebra that is isomorphic to the classic cluster algebra with the same exchange matrix. In special cases, this recovers the central subalgebras of quantum groups at roots of unity used by De Concini-Kac-Procesi. We take first steps to study the representation theory of these quantum cluster algebras. In particular, we prove a general theorem on the form of the discriminants of these algebras. Applicable examples are quantum Schubert cells and quantum double Bruhat cells. (Received August 20, 2018)

1144-16-170 **Manuel L. Reyes***, Bowdoin College, Department of Mathematics, 8600 College Station, Brunswick, ME 04011, and **Daniel Rogalski**. *Twisted Calabi-Yau algebras of dimension $d \leq 3$.*

The class of twisted Calabi-Yau algebras forms a common generalization of both Calabi-Yau algebras and Artin-Schelter (AS) regular algebras. After reviewing the basic definitions of these algebras, I will discuss the equivalence between the twisted Calabi-Yau property and a certain generalized AS regularity property. I will then discuss several results on the structure of twisted Calabi-Yau algebras of dimension $d \leq 3$, with particular attention to those algebras that are homomorphic images of path algebras of quivers. (Received August 23, 2018)

1144-16-178 **José Oswaldo Lezama Serrano*** (jolezamas@unal.edu.co), Universidad Nacional de Colombia, Bogotá, D.C. , Colombia, and **Jaime Andrés Gómez Ortíz**. *Yoneda algebra and Koszulity of finitely semi-graded algebras.*

In this talk, we introduce the class of semi-graded algebras and discuss the computation of its Yoneda algebra and Poincaré series. The Koszulity behavior of these algebras is also analyzed by the computation of the associated lattice. Finitely semi-graded algebras include properly the class of finitely graded algebras generated in degree one as well as many important examples of skew PBW extensions. (Received August 23, 2018)

1144-16-208 **Mee Seong Im*** (meeseongim@gmail.com), United States Military Academy, Department of Mathematical Sciences, Thayer Hall #252, Official Business, West Point, NY 10996. *Representations of degenerate affine Brauer superalgebras.* Preliminary report.

Periplectic Lie superalgebras $\mathfrak{p}(n)$ form the first family of so-called "strange" Lie superalgebras in the classification of reductive Lie superalgebras. In the process to construct higher Schur-Weyl duality for $\mathfrak{p}(n)$, non-semisimple algebras known as degenerate affine Brauer superalgebras (with defining parameter 0) were constructed in order to be used as a tool in understanding the representation theory of $\mathfrak{p}(n)$. I will describe an explicit collection of representations of degenerate affine Brauer superalgebras, which is our work-in-progress. This is joint with Zajj Daugherty, Iva Halacheva, and Emily Norton. (Received August 27, 2018)

1144-16-222 **Van Cat Nguyen** (nguyen@hood.edu), Dpartment of Mathematics, Hood College, Frederick, MD 21701, **Xingting Wang*** (wangxingting84@gmail.com), Department of Mathematics, 204 Academic Support Building B, Washington, DC 20059, and **Sarah Witherspoon** (sjw@math.tamu.edu), Department of Mathematics, College Station, TX 77843. *Finite generation of cohomology rings of some pointed Hopf algebras in positive characteristic.*

It is a long standing conjecture that the cohomology ring of a finite-dimensional Hopf algebra is always finitely generated. So far affirmative answers for noncommutative and noncocommutative Hopf algebras are given in a case by case basis. In this talk, over a base field of characteristic $p > 2$, we prove the cohomology rings of the bosonization of the rank 2 Nichols algebra of Jordan type over a cyclic group of order p and their liftings in $p = 3$ are finitely generated. We will apply the twisted tensor product and Anick resolutions to achieve that goal. (Received August 26, 2018)

1144-16-229 **Ellen E. Kirkman*** (kirkman@wfu.edu), Box 7388 Wake Forest University, Department of Mathematics and Statistics, Winston-Salem, NC 27109, and **Andrew Conner**, **W. Frank Moore** and **Chelsea Walton**. *Noncommutative Knörrer's periodicity and noncommutative Kleinian singularities.*

Let A be a left noetherian Artin-Schelter regular algebra, f a normal and regular element of A of positive degree, and take $B = A/(f)$. Using "twisted matrix factorizations", introduced by the first three authors with Cassidy, we prove a version of Knörrer's Periodicity Theorem in this context. We show there exists a bijection between the set of isomorphism classes of indecomposable non-free maximal Cohen-Macaulay B-modules and those over (a noncommutative analog of) its second double branched cover $(B^{\#})^{\#}$. We apply these results to the noncommutative Kleinian singularities studied by the first and fourth authors with Chan and Zhang. (Received August 26, 2018)

1144-16-235 **Jonathan Brundan*** (brundan@uoregon.edu). *Unfurling the Heisenberg category.* Preliminary report.

There has been interest recently in various monoidal categories such as the Kac-Moody 2-categories of Khovanov, Lauda and Rouquier, and the Heisenberg categories of Khovanov, Licata, Savage and Mackaay. These categories are defined initially by generators and relations, but to work with them one also needs to know bases for their morphism spaces. I will explain Ben Webster's approach to proving such basis theorems. My focus will be on the simplest example of Heisenberg category, but the method is quite general. (Received August 26, 2018)

1144-16-271 **Jerry Lodder*** (jlodder@nmsu.edu), Mathematical Sciences, Dept. 3MB, Box 30001, New Mexico State University, Las Cruces, NM 88003. *An E_∞-subalgebra of Hochschild Cochains.*

We study a naturally occurring E_∞-subalgebra of the full E_2-Hochschild cochain complex arising from coherent cochains. For group rings and certain category algebras, these cochains detect $H^*(B\mathcal{C})$, the simplicial cohomology of the classifying space of the underlying group or category, $\mathcal{C}$. In this setting the simplicial cup product of cochains on $B\mathcal{C}$ agrees with the Gerstenhaber product and Steenrod's cup-one product of cochains agrees with the pre-Lie product. We extend the idea of coherent cochains to algebras more general than category algebras and dub the resulting cochains autopoietic. These cochains facilitate the calculation of the Hochschild cohomology of certain category algebras. Also, autopoietic deformations can be defined, and with $\mathbf{Z}/2$-coefficients, their obstructions can be expressed in terms of actual Steenrod squares. Elementary Adem relations show that the obstructions vanish in certain cases. (Received August 27, 2018)

1144-16-281 **S. Fryer*** (fryer@ucsb.edu), **T. Kanstrup**, **E. Kirkman**, **A. Shepler** and **S. Witherspoon**. *Color Lie rings and PBW deformations of skew group algebras.*

We examine color Lie rings arising from finite groups of diagonal matrices acting linearly on finite dimensional vector spaces, and show that (under certain conditions) their enveloping algebras are quantum Drinfeld orbifold algebras, i.e. PBW deformations of certain skew group algebras. Conversely, every quantum Drinfeld orbifold algebra of a particular type arising from the action of an abelian group can be realized as the universal enveloping algebra of a color Lie ring. Special cases of these results yield more familiar objects: for example, a Lie superalgebra is simply a color Lie ring with only two colors and base ring $\mathbb{K}$. This approach builds on previous work by Levandovskyy-Shepler and Shepler-Witherspoon, which use Hochschild cohomology to study PBW deformations of skew group algebras. (Received August 27, 2018)

1144-16-328 **Johan Steen*** (jsteen1@ucsc.edu). *The Gerstenhaber bracket via the homotopy category.* Preliminary report.

It is well known that the Hochschild cohomology ring of an associative algebra is both graded commutative and admits a Lie bracket. Both operations were first given by formulas on the level of cochains, but nowadays the cup product is often more elegantly defined as splicing of exact sequences or as compositions in the graded endomorphism ring of the algebra in the derived (or homotopy) category of the associated enveloping algebra.

In joint work with Reiner Hermann, we consider the latter perspective, and describe the Gerstenhaber bracket in terms of the non-symmetric tensor triangulated structure that this category possesses. I will describe this construction, and also discuss Schwede's loop construction and Buchweitz' fundamental groups of morphisms, as our work relies heavily on theirs. (Received August 28, 2018)

17 ► Nonassociative rings and algebras

1144-17-121 **Michael Reeks*** (mreeks@uottawa.ca) and **Christopher Leonard**. *Traces of tensor product categories.*

The trace is a decategorification functor which can often reveal additional structure not visible in the Grothendieck group. For instance, the categories of modules over the cyclotomic KLR algebra associated to a Lie algebra $\mathfrak{g}$ of type ADE have Grothendieck groups isomorphic to highest weight integrable representations of the quantum group $U_q(\mathfrak{g})$, while their traces are isomorphic to Weyl modules over the current algebra of $\mathfrak{g}$. Webster introduced a generalization of cyclotomic KLR algebras called tensor product algebras. Modules over the these algebras categorify tensor products of highest weight integrable modules of $U_q(\mathfrak{g})$. In this talk, we investigate the trace of Webster's tensor product categorification, and show that it is isomorphic to a tensor product of Weyl modules. (Received August 20, 2018)

1144-17-191 **Peter Tingley***, 1032 W. Sheridan Rd., Chicago, IL 60660. *Quiver varieties and root multiplicities for symmetric Kac-Moody algebras.*

We present combinatorial upper bounds on dimensions of certain imaginary root spaces for symmetric Kac-Moody algebras. These come from the realization of the infinity crystal using quiver varieties. We formulate the framework quite generally, but only work out specifics for one special case. We conjecture that our bound is quite tight, and give both computational evidence and heuristic justification for this conjecture. (Received August 24, 2018)

1144-17-242 **Crystal Hoyt**, **Ivan Penkov** and **Vera Serganova***, Department of Mathematics, UC Berkeley, Berkeley, CA 94720. *$sl(\infty)$-modules arising from categorical action on the category $\mathcal{O}$ for general linear superalgebra.*

We introduce new categories of $sl(\infty)$-modules which depend on the choice of a certain reductive subalgebra $k \subset sl(\infty)$. The simple objects of these categories are tensor modules which were previously studied, however, the choice of k provides flexibility for indecomposable objects. If we choose k to have two infinite-dimensional diagonal blocks, then a certain injective object $K(m|n)$ realizes a categorical $sl(\infty)$-action on the category $\mathcal{O}_{m|n}$ of the Lie superalgebra $gl(m|n)$. We conjecture that the socle filtration of $K(m|n)$ coincides with "degree of atypicality filtration" on the category $\mathcal{O}_{m|n}$ and give some evidence that this conjecture holds. (Received August 27, 2018)

18 ► Category theory; homological algebra

1144-18-14 **Zhaoting Wei*** (zwei3@kent.edu). *Base changes of categorical resolutions of singularities.*

Categorical resolution of a singular variety X, introduced by Kuznetsov and Lunts, is a pair of adjoint functors between the derived category of quasi-coherent sheaves $D(X)$ and a smooth triangulated category T, which satisfies certain conditions. In this talk we will discuss base changes of categorical resolutions. Our approach is to reduce the two triangulated categories in the categorical resolution to derived categories of dg-modules over dg-algebras. Then we could change the bases for dg-algebras. As an application we study exceptional collections of categorical resolutions of singular curves over non-algebraically closed fields. This talk is based on the work arXiv:1701.05687. If time permits, we will talk about the attempts to do base change through dg-enhancement and internal homs between dg-categories. The latter approach is more intrinsic but still has some gaps to be filled. (Received June 08, 2018)

1144-18-28 **Jon Belcher***, 4650 WHITE ROCK CIR APT 6, Boulder, CO 80301. *Bridge Cohomology.* The connection between Hochschild and cyclic cohomologies with generalized De Rham homology and index theories for arbitrary algebras has long been established by the work of Connes, Karoubi, Loday, Feigin, Tsygan, et al. Here we generalize these cohomology theories even further, essentially creating a theory that establishes a step-wise bridge between the two. This theory can then be used to establish similar geometric results for manifolds with boundaries, and may have applications in exterior differential systems, as well as extend to higher K-theories. (Received July 13, 2018)

1144-18-55 **Paul Balmer***, balmer@math.ucla.edu. *The nine real Artin-Tate motives at the prime two.* Preliminary report.

In this joint work with Martin Gallauer (UCLA/Oxford), we investigate the me spectrum of the tensor-triangulated category of Artin-Tate motives over the real numbers, with integral coefficients. This relies on very interesting earlier work of Gallauer in the case of Tate motives over algebraically closed fields. For the reals, the subtlety is concentrated at the prime 2, where the spectrum appears to have 5 points and 9 Thomason subsets, which we shall make explicit in the talk. (Received August 05, 2018)

1144-18-75 **Alistair Savage*** (alistair.savage@uottawa.ca), Department of Mathematics & Statistics, University of Ottawa, Ottawa, ON K1N 6N5, Canada. *Quantum Heisenberg categorification.*

The Heisenberg algebra plays a vital role in many areas of mathematics and physics. We will describe a family of quantum Heisenberg categories, depending on a choice of central charge, that categorify this algebra. When the central charge is nonzero, these categories act on modules for cyclotomic quotients of the affine Hecke algebra. In central charge zero, we obtain an affinization of the HOMFLY-PT skein category, which acts on modules for $U_q(\mathfrak{gl}_n)$. We will also discuss how the categories can be generalized by adding a Frobenius superalgebra into the construction. This is joint work with Jon Brundan. (Received August 10, 2018)

1144-18-154 **Joanna Meinel** and **Van C. Nguyen***, Department of Mathematics, Hood College, Frederick, MD 21701, and **Bregje Pauwels**, **Maria Julia Redondo** and **Andrea Solotar**. *Gerstenhaber structure on the Hochschild cohomology of a class of special biserial algebras.*

Gerstenhaber bracket gives a graded Lie algebra structure on the Hochschild cohomology and plays a role in the deformation theory of algebras. In this talk, we describe the Gerstenhaber structure on the Hochschild cohomology of a class of self-injective special biserial algebras. Each of these algebras is presented as a quotient of the path algebra of a certain quiver, modulo some relations. In degree one, we show that the cohomology is isomorphic, as a Lie algebra, to a direct sum of copies of a subquotient of the Virasoro algebra. Furthermore, we describe the cohomology in degree n as a module over this Lie algebra by providing its decomposition as a direct sum of indecomposable modules. (Received August 22, 2018)

1144-18-161 **Nicolle Gonzalez*** (nesandov@usc.edu). *Categorical Bernstein Operators.*

Bernstein operators are certain infinite series of products of symmetric functions introduced by Bernstein and shown by Zelevinsky to create and annihilate Schur functions. When viewed in the context of vertex operators, the Bernstein operators are at the core of the celebrated Boson-Fermion correspondence, a relationship that relates the actions of the Heisenberg and Clifford algebras on Fock space.

In this talk we will discuss a categorification of these operators in the diagrammatic language of Khovanov's Heisenberg category and describe how these functors satisfy categorical analogues of the properties mentioned above. (Received August 23, 2018)

1144-18-167 **Liang Ze Wong*** (wonglz@uw.edu). *Cohen-Montgomery Duality and the Grothendieck Correspondence.* Preliminary report.

Cohen-Montgomery duality gives a correspondence between group-graded algebras and algebras with a group action. It has since been generalized from k-algebras to k-linear categories, with gradings or actions by a groupoid. The Grothendieck correspondence is a very similar duality between fibrations and functors, and this too has been generalized to the k-linear setting. I will introduce these two dualities, and show that the latter may be considered a generalization of Cohen-Montgomery duality to situations where we only have a grading or action by a category instead of a groupoid. (Received August 23, 2018)

1144-18-228 **Beren Sanders*** (beren@ucsc.edu). *The spectrum of the category of derived Mackey functors.*

I will discuss a project (joint with Irakli Patchkoria and Christian Wimmer) on computing the spectrum of the derived category of G-Mackey functors (in the sense of Kaledin) for G a finite group. This category can be regarded as a linearization of the G-equivariant stable homotopy category and our computation can be best appreciated in comparison with our earlier work (joint with Paul Balmer) on computing the spectrum of the G-equivariant stable homotopy category. Ultimately, our goal is to explain (within the confines of a 20-minute talk) how the spectrum of our linearized equivariant category lies between the spectrum of the equivariant stable homotopy category and the spectrum of the Burnside ring, being a refinement of the latter and a chromatic truncation of the former. (Received August 26, 2018)

1144-18-239 **Benjamin Briggs*** (briggs@math.utah.edu). *Stable invariance of the p-power structure on Hochschild cohomology.*

This is joint work with Lleonard Rubio y Degrassi.

Understanding the relationship between two group algebras which happen to be connected by a stable equivalence of Morita type is an important problem. The positive part of the Hochschild cohomology $HH^*(kG/k)$ is an invariant under these stable equivalences, via the transfer maps of Linckelmann. How much of the rich structure on Hochschild cohomology is also invariant? It's known that when the transfer maps aren't isomorphisms they can fail to respect the Lie algebra structure. Nonetheless we show that the full restricted Lie algebra structure on $HH^{>0}(kG/k)$ is invariant under stable equivalences of Morita type ("restricted" means with its p-power structure). For free we also get invariance of another Dyer-Lashof-Cohen operation on Hochschild cohomology (which doesn't seem to have been used by modular representation theorists).

We do this by stabilising some methods used originally by Keller. The proof applies equally well to certain singular equivalences between Gorenstein algebras. (Received August 26, 2018)

19 ► K-theory

1144-19-80 **Joseph Gubeladze*** (soso@sfsu.edu), Department of Mathematics, San Francisco State University, San Francisco, CA 94132. *Unimodular rows over monoid rings.*

For a commutative Noetherian ring R of dimension d and a submonoid M of an abelian group G, the elementary action on unimodular n-rows over the monoid ring $R[M]$ is transitive for $n \geq \max(d+2, 3)$. The starting point is the case of polynomial rings, i.e., when M is a free commutative monoid, considered by A. Suslin in the 1970s. This result has applications in the study of splitting and cancellation properties of projectie modules and higher K-stabilizations over $R[M]$. (Received August 11, 2018)

20 ► Group theory and generalizations

1144-20-18 **Christopher M. Drupieski***, c.drupieski@depaul.edu, and **Jonathan R. Kujawa**. *Support schemes for infinitesimal unipotent supergroups.* Preliminary report.

Let k be a field of characteristic $p \geq 3$, and let G be an infinitesimal unipotent k-supergroup scheme. In this talk I will report on work with Jonathan Kujawa, in which we investigate the cohomological spectrum $|G|$ of G, as well as the cohomological support schemes $|G|_M \subset |G|$ associated to each finite-dimensional rational G-supermodule M. Generalizing the classical results of Suslin, Friedlander, and Bendel, we show that there is a homeomorphism between $|G|$ and the scheme $V_r(G)$ of Hopf superalgebra homomorphisms $\nu : P_r \to kG$, where P_r is a naturally arising Hopf superalgebra, and this homeomorphism restricts to a homeomorphism between $|G|_M$ and a naturally defined Zariski closed conical subscheme $V_r(G)_M \subset V_r(G)$. To make these identifications, we rely in an essential way on a nilpotence detection theorem for arbitrary finite unipotent supergroup schemes by Benson, Iyengar, Krause, and Pevtsova. (Received June 25, 2018)

1144-20-46 **Richard M. Green*** (rmg@euclid.colorado.edu), Department of Mathematics, University of Colorado Boulder, Campus Box 395, Boulder, CO 80309-0395, and **Tianyuan Xu** (tx7@queensu.ca), Department of Mathematics and Statistics, Queen's University, Kingston, Ontario K7L 3N6, Canada. *Coxeter groups with finitely many elements of* **a***-value 2.*

The partition of a Coxeter group W into left, right, and two-sided Kazhdan–Lusztig cells is closely related to topics in combinatorics, representation theory, and algebraic geometry. Lusztig's **a**-function, which is a function

from W to the nonnegative integers, takes constant values on each Kazhdan–Lusztig cell. For $w \in W$, we have $\mathbf{a}(w) = 0$ if and only if w is the identity, and we have $\mathbf{a}(w) = 1$ if and only if w is a nonidentity element that is "rigid", meaning that it has a unique reduced expression. It is not difficult to classify the irreducible Coxeter groups having finitely many rigid elements. This talk will discuss the solution of the analogous problem for elements of **a**-value 2. (Received August 01, 2018)

1144-20-71 **David J Benson**, , United Kingdom, and **Jon F Carlson*** (jfc@math.uga.edu), Department of Mathematics, University of Georgia, Athens, GA 30602. *Virtual projectivity and the stable module category.*

We consider maps that induce the zero map in high degrees of cohomology. The analogous idea for objects is virtual relative projectivity, high degree cohomology of one object factoring through a tensor product with another. These notions have some interesting connections with generation of the stable category for the modular group algebra of a finite group as well as for any supergroup scheme. (Received August 09, 2018)

1144-20-116 **Sami H. Assaf*** (shassaf@usc.edu) and **David E. Speyer**. *Specht modules decompose as alternating sums of restrictions of Schur modules.*

Schur modules give the irreducible polynomial representations of the general linear group GL_t. Since the symmetric group $\mathfrak{S}_t$ is a subgroup of GL_t, we may restrict Schur modules to $\mathfrak{S}_t$ and decompose the result into Specht modules, the irreducible representations of $\mathfrak{S}_t$. In this talk, I present joint work with David Speyer in which we show that when we invert the above expansion in the representation ring for $\mathfrak{S}_t$ for t large, the coefficients that appear are alternatingly positive by degree. In particular, this allows us to define a new basis of symmetric functions whose structure constants are stable Kronecker coefficients and which expand alternatingly into Schur functions. (Received August 19, 2018)

1144-20-120 **Eric M Friedlander*** (ericmf@usc.edu). *Cohomology of Unipoent Group schemes.*

We shall discuss efforts to compute the cohomology $H^*(U, k)$ of unipotent group schemes over a field k of positive characteristic. The case of Frobenius kernels $U = (U_3)_{(r)}$ of the Heisenberg group U_3 serves as a guide. (Received August 19, 2018)

1144-20-128 **James C Cameron*** (jcameron@math.ucla.edu), UCLA Math Department, Box 951555, Los Angeles, Los Angeles, CA 90095-1555. *Stratification for cochain algebras on Borel constructions of G-spaces.* Preliminary report.

I will show that for a compact Lie group G and a compact G-CW complex X the derived category of cochains on the Borel construction of X is stratified by the equivariant cohomology ring. When X is a point this generalizes the previously known result of stratification for the derived category of cochains on BG. I will also demonstrate how by choosing X appropriately the stable module category of G can be studied via a category with more structure. (Received August 21, 2018)

1144-20-157 **Daniele Rosso*** (drosso@iu.edu) and **Alistair Savage**. *Affine Frobenius Hecke Algebras.*

We study the structure and representation theory of affine Frobenius Hecke algebras and their cyclotomic quotients. These algebras are quantum deformations of the affine wreath product algebras studied by the second author and appear naturally in the context of Heisenberg categorification. Special cases include affine Hecke algebras and Yokonuma-Hecke algebras. (Received August 22, 2018)

1144-20-226 **N. Bhaskhar*** (nbhaskh@g.ucla.edu), **A. Merkurjev** and **V. Chernousov**. *The norm principle for type D_n groups over complete discretely valued fields.*

Norm principles examine the behaviour of the images of group morphisms (from a linear algebraic group to a commutative one) over field extensions, with respect to the norm map. These have been previously studied by Merkurjev-Gille in conjunction with the rationality of the algebraic group in question. However a result of Merkurjev and Barquero shows that norm principle holds in general for all reductive groups of classical type without D_n components. In this talk, we investigate the D_n case over an arbitrary complete discretely valued field K with residue field k (of characteristic not 2).

We show that if the norm principle holds for such groups (arising from quadratic forms) over all finite extensions of the residue field k, then it holds for such groups defined over K. This yields new examples of fields over which the norm principle holds for the groups under consideration. As a further application, we also relate the possible failure of the norm principle to the non-triviality of certain Tate-Shafarevich sets. (Received August 26, 2018)

1144-20-243 **Caroline Gruson** and **Vera Serganova*** (serganov@math.berkeley.edu), UC Berkeley, Department of Mathematics, Berkeley, CA 94720. *Geometric approach to the fermionic Fock space, via flag varieties and representations of algebraic (super)groups.*

We use parabolic induction and restriction functors for the family of algebraic supergroups to categorify the representation of Clifford algebra in the Fock space. (Received August 27, 2018)

1144-20-321 **Robert Boltje*** (boltje@ucsc.edu) and **Burkhard Külshammer**. *Refinements of Alperin's weight conjecture and Wedderburn components over* $\mathbf{Q}_p$.

Alperin's block-wise weight conjecture in the Knörr-Robinson formulation states that the number of irreducible characters in a nontrivial p-block of a finite group G can be expressed as an alternating sum of the numbers of irreducible characters in corresponding blocks of stabilizers of chains of non-trivial p-subgroups of G. We explain how this is equivalent to the contractibility of a yet to be constructed natural chain complex associated to the block. Further, in joint work with Burkhard Külshammer, we give new refinements of the conjecture in terms of p-types of Wedderburn components of blocks over $\mathbf{Q}_p$. (Received August 28, 2018)

26 ► Real functions

1144-26-200 **Fred Halpern*** (fredhalp@gmail.com), 10845 N. Central Expwy #1141, Dallas, TX 75231. *From Discrete to Analytic Inequality.*

Mathematical folklore suggests that many discrete inequalities have analytic analogs. We formalize this intuition with a methodology that systematically provides discrete inequalities with valid analytic analogs.

A key insight is we must start with a very general inequality valid for all n and all collections of n-sequences whose (surprisingly) manipulation of sequence terms are homogeneous. The generality yields inequalities that are manipulated to provide a uniform system of inequalities between Riemann sums.

We state a general master theorem. The Holder (Cauchy–Schwarz) and Minkowski inequalities are easy corollaries. It also yields an Analytic analogue to the Arithmetic-Geometric Mean inequality (interesting special cases provided).

The collections of n-sequences can be restricted by conditions on the sequences (positive, monotone, convex) if the corresponding condition on functions yield Riemann sums whose terms satisfy the conditions. Jensen's and Chebyshev's sum inequalities are corollaries. .

The method also yields double integral inequalities corresponding to double sums of doubly indexed sequences inequalities (e.g., Minkowski's double sum inequality) and convolution inequalities (e.g., Young's inequality). (Received August 24, 2018)

28 ► Measure and integration

1144-28-34 **Andrew Vince*** (avince@ufl.edu), Department of Mathematics, University of Florida, Gainesville, FL 32611. *When does an Iterated Function System have an Attractor?*

We address the question in the title for an affine, Mobius, and projective iterated function system (IFS). In particular, the role of contractivity of the functions in the IFS is clarified. (Received July 20, 2018)

1144-28-37 **Vyron S Vellis*** (vyron.vellis@uconn.edu), Department of Mathematics, University of Connecticut, 341 Mansfield Road U1009, Storrs, CT 06269. *Fractional rectifiability.*

Given a bounded set $E \subset \mathbb{R}^n$, when is it possible to construct a nice map (Holder, Lipschitz) from the unit interval into $\mathbb{R}^n$ so that E is contained in its image? In this talk we discuss an extension of Peter Jones' traveling salesman construction, which provides a sufficient condition for E to be contained in a $(1/s)$-Hölder curve, $s \geq 1$. The original result, corresponding to the case $s = 1$, identified subsets of rectifiable curves. When $s > 1$, $(1/s)$-Hölder curves are more exotic objects than rectifiable curves that include fractal curves and space-filling curves as basic examples. This talk is based on a joint work with Matthew Badger and a joint work with Matthew Badger and Lisa Naples. (Received July 23, 2018)

1144-28-124 **Michel L. Lapidus*** (lapidus@math.ucr.edu), Department of Mathematics, Surge Bdg., 900 University Ave., Riverside, CA 92521-0135. *An Overview of Fractal Complex Dimensions.*

We will present an overview of the theory of fractal complex dimensions developed by the author and his collaborators, with emphasis on the higher-dimensional case of bounded subsets of Euclidean space. The latter higher-dimensional theory is developed in a recent book by the author, G. Radunovic and D. Zubrinic (Springer,

2017), entitled "Fractal Drums and Fractal Zeta Functions: Higher-Dimensional Theory of Complex Dimensions". (Received August 20, 2018)

1144-28-139 **Steven M Senger*** (stevensenger@missouristate.edu) and **Eyvindur Ari Palsson**. *Falconer type point configuration problems.*

The classical Falconer distance problem asks for the minimum Hausdorff dimension, s, such that any subset $E \subset \mathbb{R}^d$ of Hausdorff dimension greater than s will have a distance set (the set of distances determined by pairs of points in E) of positive Lebesgue measure. We consider variants of this problem involving more points. (Received August 21, 2018)

1144-28-140 **Xianghong Chen*** (xchen@georgiasouthern.edu), Department of Mathematical Sciences, Georgia Southern University, Statesboro, GA 30460, and **Tian-You Hu** (hut@uwgb.edu), Department of Mathematics, University of Wisconsin-Green Bay, Green Bay, WI 54311. *Asymptotics of signed Bernoulli convolutions scaled by multinacci numbers.*

For $\beta > 1$, we consider the signed Bernoulli convolution

$$\nu_\beta^{(n)} := *_{j=1}^{n} \left(\frac{1}{2}\delta_{\beta^{-j}} - \frac{1}{2}\delta_{-\beta^{-j}} \right), \ n \geq 1,$$

which can be regarded as a variant of the classical Bernoulli convolution with signed charges. The general asymptotic behavior of $\nu_\beta^{(n)}$ is still quite mysterious. However, in the case when β satisfies

$$\beta^m = \beta^{m-1} + \cdots + \beta + 1$$

for some integer $m \geq 2$, the exact asymptotic of the total variation $\|\nu_\beta^{(n)}\|$ can be obtained. We will discuss related questions and draw some connections to multiplicative chaos. (Received August 21, 2018)

1144-28-275 **Sze-Man Ngai*** (smngai@georgiasouthern.edu), Department of Mathematical Sciences, Georgia Southern University, Statesboro, GA 30460. *Spectral dimension of Laplacians defined by self-similar measures with overlaps and application to heat kernel estimates.*

We report some results on the spectral dimension of fractal Laplacians defined by one-dimensional self-similar measures with overlaps. As an application, we show that spectral dimension plays an important role in obtaining heat kernel estimates for the associated Laplacians. Some of this work is joint with Qingsong Gu, Jiaxin Hu, Wei Tang and Yuanyuan Xie. (Received August 27, 2018)

1144-28-324 **Krystal Taylor***, 231 W. 18th Ave., MW 622. Columbu, Columbus, OH 43210. *Determining Structure in Lipschitz Images of Fractal Sets and an Application to Pinned Distance Sets.*

Fractals are sets with intricate structure at infinitely many scales. One robust way to deal with such arbitrary objects is to decompose them into more usable components. Two powerful methods of decompositions include the Fourier transform and projection theorems.

In this talk, we use these tools to establish relationships between the dimension (Hausdorff or Fourier dimension) of a pair of thin sets and the interior, dimension, and measure of the images of the pair under families of Lipschitz maps. For instance, in a joint work with K. Hambrook, we consider lower bounds on the dimension of the product set XY, where X is a set of scalars and Y is a subset of Euclidean space. In a joint work with K. Simon, we determine the measure of $X + S^1$ when X is a set of Hausdorff dimension 1, as well as the interior of $X + S^1$ when X is a suitable Cartesian product of Cantor sets. We then use these result to study distance sets, and we give the first known result in the literature on the interior of pinned distance sets. (Received August 28, 2018)

30 ► Functions of a complex variable

1144-30-7 **Ahmed Sebbar*** (sebbar@chapman.edu), 363 N. Center Street, Orange, CA 92866. *On a function similar to the polylogarithm function.*

The polylogarithm function defined by $Li_s(z) = \sum \frac{z^n}{n^s}$ has so many beautiful and well known properties. In particular it has the following expansion (Wirtinger)

$$Li_s(z) = \Gamma(1-s)\left(\log\frac{1}{z}\right)^{s-1} + \sum_{r=0}^{\infty} \zeta(s-r)\frac{(\log z)^r}{r!}$$

where ζ is the Riemann zeta function. We give a similar identity for the new series

$$\mathcal{M}i_s(z) = \sum_{n=1}^{\infty} \frac{\mu(n)}{n^s} z^n$$

$$\mathcal{M}i_s(z) = \sum_{n=1}^{\infty} \frac{\mu(n)}{n^s} z^n$$

where μ is the Möbius function. Some other related results will also be given. (Received May 09, 2018)

1144-30-42 **Irina Peterburgsky*** (irdotcom@hotmail.com), 1496 Beacon Street, Brookline, MA 02446. *Generalization of classical extremal problems for Hardy classes to the case of functions with higher dimensional domain.*

We study extremal problems for Hardy classes of analytic functions on polydisc taking on values in Banach spase. These problems could be viewed as far reaching generalization of classical extremal problems for Hardy classes of scalar-valued analytic functions on the unit disk of a complex plain. Existence, uniqueness, and form of extremal functions have been found in the present paper. (Received July 30, 2018)

1144-30-92 **Tamás Forgács*** (tforgacs@csufresno.edu) and **Khang Tran**. *An inequality for cyclotomic exponential polynomials.* Preliminary report.

In this talk we consider cyclotomic polynomials $p(x) = \sum_{k=0}^{n-1} \omega_k^\ell e^{x\omega_k}$, where $\omega_k = e^{(2k-1)\pi i/n}$ is an n-th root of -1. In particular, we show that for any $\ell \in \mathbb{N}$ and $x \geq 0$ such that $\omega_1^\ell e^{x\omega_1} = \omega_0^\ell e^{x\omega_0} \in \mathbb{R}$, the inequality

$$\left| \sum_{k=0}^{1} \omega_k^\ell e^{x\omega_k} \right| > \left| \sum_{k=2}^{n-1} \omega_k^\ell e^{x\omega_k} \right|$$

holds. Whence the sign of $p(x)$ is determined by the first (two) summand(s). We will discuss the implications of this inequality to the zero distribution of polynomials generated by a function of the form $\frac{1}{P(t)+zt^rQ(t)}$, where P and Q are hyperbolic polynomials with some mild restrictions on their relative root location. (Received August 13, 2018)

1144-30-105 **Matvei Libine*** (mlibine@indiana.edu). *Algebra of Quaternionic Functions.*

I plan to talk about a new algebra structure on quaternionic functions that commutes with the conformal group action.

This is a joint work with Igor Frenkel from Yale University. (Received August 15, 2018)

1144-30-115 **Xiangdong Xie*** (xiex@bgsu.edu), **Bruce Kleiner** and **Stefan Muller**. *Rigidity of quasiconformal maps of non-rigid Carnot groups.*

It is well-known that Euclidean and Heisenberg groups admit rich classes of quasiconformal maps. We show that any global quasiconformal maps of any other non-rigid Carnot groups are necessarily bilipschitz. In particular, any global quasiconformal map of a complex Heisenberg group is holomorphic or anti-holomorphic, and any global quasiconformal map of $H \times H$ (H is a Heisenberg group) is a product map. This is joint work with Bruce Kleiner and Stefan Muller. (Received August 18, 2018)

1144-30-143 **Richard Adams*** (integragsr2001@mail.fresnostate.edu). *Zero Distribution of Hyperbolic Polynomials with Four-Term Recurrence.*

For any real numbers a, b, c, we form the sequence of polynomials $\{P_n(z)\}_{n=0}^{\infty}$ satisfying the four-term recurrence

$$P_n(z) = -azP_{n-1}(z) - bP_{n-2}(z) - czP_{n-3}(z), \ n \in \mathbb{N},$$

with the initial conditions $P_0(z) = 1$ and $P_{-n}(z) = 0$. We find necessary and sufficient conditions on a, b, c under which the zeros of $P_n(z)$ are real for all n, and provide an explicit real interval on which $\bigcup_{n=0}^{\infty} \mathcal{Z}(P_n)$ is dense, where $\mathcal{Z}(P_n)$ is the set of zeros of $P_n(z)$. (Received August 22, 2018)

1144-30-159 **Zair Ibragimov*** (zibragimov@fullerton.edu), 800 N State College Blvd, Fullerton, CA 92831. *Averaging one-point hyperbolic-type metrics.*

It is known that the $\tilde{j}$-metric, the half-Apollonian metric, and the scale-invariant Cassinian metric are not Gromov hyperbolic. These metrics are defined as a supremum of *one-point* metrics (i.e., metrics constructed using one boundary point) and the supremum is taken over all boundary points. The aim of this paper is to show that taking the average instead of the supremum yields a metric that is Gromov hyperbolic. Moreover, we show that the Gromov hyperbolicity constant of the resulting metric does not depend on the number of boundary points used in taking the average. We also provide an example to show that the average of Gromov hyperbolic metrics is not, in general, Gromov hyperbolic. This is a joint work with Asuman Aksoy and Wesley Whiting. (Received August 22, 2018)

1144-30-199 **John Ryan*** (jryan@uark.edu), Department of Mathematics, University of Arkansas, Fayetteville, AR 72701, **Wanqing Cheng** (jryan@uark.edu), Department of Mathematics, University of Arkansas, Fayetteville, AR 72701, and **Uwe Kaehler** (jryan@uark.edu), Universidade de Aveiro. *On the Pi operator on spheres and real projective space.*

We shall set up a Pi operator or Ahlfors Beurling transform on the n-sphere and real projective spaces. This is joint work with Wanqing Cheng (Arkansas) and Uwe Kaehler (Aveiro, Portugal). (Received August 24, 2018)

1144-30-261 **Miguel A Jimenez Bravo*** (mjim92@csu.fullerton.edu), 800 North State College Blvd., Fullerton, CA 92831. *One-parametric family of distance-ratio metrics.* Preliminary report.

We studied one-parametric family of distance-ratio metrics $\tilde{j}_{c,a}$ on general metric space settings. We show that $\tilde{j}_{c,a}$ is δ-hyperbolic with $\delta = \log(2c+1)$. We also show that any two members of the family are geometrically equivalent to each other. (Received August 27, 2018)

1144-30-263 **Chulhee Y Lee*** (chulheeyohan@csu.fullerton.edu), 800 N. State College Blvd., Fullerton, CA 92831. *One-parametric family of scale-invariant Cassinian metrics.* Preliminary report.

We studied one-parametric family of scale-invariant Cassinian metrics $\tilde{\tau}_{c,a}$ on general metric space settings. We show that $\tilde{\tau}_{c,a}$ is δ-hyperbolic with $\delta = \log(2c+1)$. We also show that any two members of the family are geometrically equivalent to each other. We also show that scale-invariant Cassinian metrics are geometrically equivalent to distance-ratio metrics. (Received August 27, 2018)

1144-30-294 **Kourosh Tavakoli*** (ktavakoli@okcu.edu). *Two Conformal-Like Metrics.*

In this talk we study two conformal-like metrics for some regions in the plane. We investigate how these two metrics are related to each other. (Received August 27, 2018)

32 ► Several complex variables and analytic spaces

1144-32-39 **Alí Guzmán Adán***, Clifford Research Group, Department of, Mathematical Analysis, Ghent University, Krijgslaan 281, 9000 Ghent, Belgium, and **Frank Sommen**. *Integration in superspace via distributions and some applications.*

In this talk, we approach integration over general domains and surfaces in superspace by means of distribution theory. This definition is inspired by Hörmander's formula, which is a simple layer integral that provides a distributional approach to classical real integration. We will define domains and surfaces in superspace in a purely analytical way by means of smooth even phase functions g. This allows to consider the Heaviside and Dirac distributions on such domains and surfaces respectively by means of their compositions with g expanded in a formal Taylor series. These compositions can be seen then as formal characteristic functions leading to simple definitions for the domain and surface integrals. This approach turns out to be well-defined and has some interesting applications. In particular, we will briefly show how to compute volumes and surface areas of some super-geometric bodies, i.e. a super-paraboloid and a super-hyperboloid. Moreover, some extensions of the Cauchy-Pompeiu formula for monogenic superfunctions and of the Bochner-Martinelli formula for holomorphic superfunctions will be presented. (Received July 25, 2018)

1144-32-81 **Alain Yger*** (yger@math.u-bordeaux.fr), Institut de Mathématiques, 351 Cours de la Libération, 33405 Talence, France. *Multivariate residue calculus with an eye towards non-commutative algebra.* Preliminary report.

Multivariate residue calculus has been developed within the last thirty years as a powerful tool towards division or interpolation questions in commutative algebra as well as complex geometry. In this talk, I will focus on the intimate relation between the concept of multivariate residue and that of trace in operator theory. I will also present how some aspects of such theory could be transposed towards a non-commutative setting, as for example Principal Value distributions and related residue currents through ad hoc d-bar operators, Cauchy-Weil formulas and Bergman-Weil expansions, integration currents over zero sets and Lelong equations, ... I will show how the (commutative, but with zero divisors) bi-complex setting as well as the (non-commutative) quaternionic setting provide frames for such potential applications. (Received August 12, 2018)

1144-32-315 **Mihaela B Vajiac***, Keck 365, Chapman University, One University Drive, Orange, CA 92866, and **Irene M Sabadini** (irene.sabadini@polimi.it) and **Adrian I Vajiac** (avajiac@chapman.edu). *Inequalities in Bicomplex Analysis and Geometry.*

We consider the well known Bernstein and Erdős-Lax inequalities in the case of bicomplex polynomials. We shall prove that the validity of these inequalities depends on the norm in use and we consider the cases of the Euclidean, Lie, Dual Lie and hyperbolic-valued norms and moduli. In the case of these two norms we also show the validity of the Maximum Modulus Principle for bicomplex holomorphic functions and consequences for the geometry of these spaces. (Received August 28, 2018)

1144-32-318 **Adrian I Vajiac*** (avajiac@chapman.edu), One Universty Drive, Orange, CA 92866. *Hypercomplex Analysis: general theory and applications.*

In this talk I will present an overview of the general theory of hypercomplex algebra and analysis, with an emphasis on the study of the associated differential operators, notions and results of holomorphy in this context. Hypercomplex numbers over the field $\mathbb{Q}$ have been studied by E. Artin et al. in the context of analytic number theory, and recently (over $\mathbb{R}$) by physicists such as Catoni et al. in the study of Minkowski space–time geometry and physics. The main purpose of this present work is to bring a unified view of the general theory of hypercomplex analysis, studying both the common features and the differences among several cases of e.g. complex, hyperbolic, multicomplex, ternary, quaternionic, and more general Clifford algebras. For example, we make use of results of abstract algebraic results to properly define notions of conjugations, leading to the study of $\bar{\partial}$–operators and differing notions of holomorphy. This is a part of an extensive collaborative work with D. Alpay, A. Sebbar, D.C. Struppa and M.B. Vajiac. (Received August 28, 2018)

34 ► Ordinary differential equations

1144-34-153 **Lale Asik*** (lale.asik@ttu.edu), Department of Mathematics and Statistics, Texas Tech University, Broadway and Boston, Lubbock, TX 79409-1042, and **Jackson Kulik** (jackson.kulik@ttu.edu), **K.R. Long** (krlong014@gmail.com) and **Angela Peace** (a.peace@ttu.edu). *Dynamics of a Stoichiometric Producer-Grazer System with Seasonal Effects on Light Level.*

Many population systems are subject to seasonally varying environments. As a result, many species exhibit seasonal changes in their life-history parameters. It is quite natural to try to understand how seasonal forcing affects population dynamics subject to stoichiometric constraints, such as nutrient/light availability and food quality. Here, we use a variation of a stoichiometric Lotka-Volterra type model, known as the LKE model, as a case study, focusing on seasonal variation in the producer's light-dependent carrying capacity. Positivity and boundedness of model solutions are studied, as well as numerical explorations and bifurcations analyses. In the absence of seasonal effects, the LKE model suggests that the dynamics are either stable equilibrium or limit cycles. However, through bifurcation analysis we observe that seasonal forcing can lead to complicated population dynamics, including periodic and quasi-periodic solutions.
(Received August 22, 2018)

1144-34-264 **Marisabel R Rodriguez** (yun.kang@asu.edu), **Robert E Page** and **Yun Kang*** (yun.kang@asu.edu), Mesa, AZ 85212. *Effects of Vitellogenin in Age Polyethism and Population Dynamics of Honeybees.*

We present basic but important assumptions that can help us understand the complexity of honeybee population dynamics given their nutritional status. We propose a non-linear differential equation system that models the population dynamics of brood and worker bees (nurses and foragers) within a colony. The dynamics of these populations are influenced by the available stored pollen in cells and the current levels of vitellogenin (VG), a major storage protein, in the fat body of nurse bees. Our model shows: (a) the importance of pollen collection and consumption rates, adequate feeding rates to the queen, and the impact of good nutrition during the larvae stage for future foraging activity; (b) the size of both the brood and worker populations at equilibrium are directly dependent upon the increase of levels of VG titers in nurse bees; (c) division of labor regulatory effects determined by the VG titers in nurse bees are important for balancing nurse bee and forager populations; (d) coexistence of both brood and worker populations is dependent upon available food for the brood (i.e. pollen collected and converted to VG and available foragers); (e) taking into account seasonal changes in pollen collection improves the prediction of long term consequences. (Received August 27, 2018)

35 ► Partial differential equations

1144-35-22 **Edward C Waymire*** (waymire@math.oregonstate.edu), Department of Mathematics, Corvallis, OR 97331, and **Radu Dascaliuc**, **Nicholas Michalowski** and **Enrique A Thomann**. *Probabilistic analysis of alpha-Ricatti equations.*

The Lejan-Sznitman cascade, modified to permit explosion and applied to self-similar Navier-Stokes equation, has a mean-field simplification in the form of a Ricatti-type equation, termed alpha-Ricatti, with intriguing probabilistic structure. In this talk we will highlight some of this structure and indicate connections between stochastic explosion and uniqueness theory for the cascade and differential equations, respectively. This is based on joint work with Radu Dascaliuc, Nick Michalowski, and Enrique Thomann. It is partially supported by grants from the National Science Foundation DMS. (Received August 09, 2018)

1144-35-62 **John K. Hunter** and **Jingyang Shu*** (jyshu@ucdavis.edu), Department of Mathematics, University of California at Davis, One Shields Ave., Davis, CA 95616, and **Qingtian Zhang**. *Fronts for the SQG Equation.*

Temperature discontinuities in the Surface Quasi-Geostrophic (SQG) equations support surface waves. For weakly nonlinear surface waves on SQG fronts that are described as a graph, we derive a nonlocal and nonlinear equation with logarithmic dispersion. With the help of Weyl quantization, dispersive decay, and modified scattering, we prove global-in-time well-posedness of the initial value problem for the SQG front equation with sufficiently small and smooth initial data. (Received August 06, 2018)

1144-35-68 **Yannick Sire***, Krieger Hall, 3400 N. Charles street, Baltimore, MD 21218. *Extremals of eigenvalues in conformal classes.*

I will describe several results related to maximizing metrics in conformal classes for eigenvalues of Laplace-Beltrami operators on Riemannian surfaces or conformal laplacians in higher dimension. These extremal metrics provide important informations on the geometry and topology of the underlying manifold. In particular, it gives minimal immersions into spheres by eigenvectors. I will describe Riemannian and also Kahler cases. (Received August 07, 2018)

1144-35-73 **J. Bory Reyes**, **R. Abreu Blaya**, **M. A. Pérez-de la Rosa*** (marco.perez@udlap.mx) and **B. Schneider**. *A Quaternionic Treatment of Inhomogeneous Cauchy–Riemann Type Systems in Some Traditional Theories.*

We provide a necessary and sufficient condition for the solvability of inhomogeneous Cauchy–Riemann type systems where the datum consists of continuous $\mathbb{C}$-valued functions and we describe its general solution by embedding the system in an appropriate quaternionic setting. (Received August 09, 2018)

1144-35-118 **Anthea Cheung*** (antheac@bu.edu), Mathematics and Statistics Department, 111 Cummington Mall, Boston, MA 02215. *Spatio-temporal patterns in the wake of pulse solutions to the Morris-Lecar neuron model.*

Empirical data recorded during human epileptic seizures suggest that waves of voltage activity that appear during seizure are often followed by complex spatio-temporal patterns, which present challenges for identifying realistic mathematical neural models that exhibit such phenomena. Motivated by this behavior, we present traveling wave pulse solutions with irregular wakes in a reaction-diffusion system of the Morris-Lecar neuron model. We identify such solutions near T-points in the parameter space, where two branches of homoclinic orbits to equilibria in the moving coordinate frame meet at a heteroclinic loop, and discuss the bifurcations that lead to such instabilities. We compare the patterns exhibited by such solutions with our empirical seizure data, and discuss solutions in our model with two spatial dimensions. (Received August 19, 2018)

1144-35-172 **Keng Deng*** (deng@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, P.O. Box 43568, LAFAYETTE, LA 70504-3568. *Asymptotic Behavior of an SIR Reaction-Diffusion Model.*

We consider an SIR reaction-diffusion model with spatially heterogeneous parameters. We discuss the existence of disease-free equilibrium and endemic equilibrium of the model. We also analyze the asymptotic behavior of the model. (Received August 23, 2018)

1144-35-174 **P. Auscher**, **S. Bortz*** (sibortz@uw.edu), **M. Egert** and **O. Saari**. *Improvement of regularity for weak solutions to linear parabolic systems.*

We discuss some of the ideas involved in showing that weak (local) solutions to linear parabolic systems in the Lion's class are, in fact, locally Hölder in time with values in spatial L^p. This involves studying the global

solution to the inhomogenous equation obtained by multiplying the solution by a cut-off function. The global formulation brings the Fourier transform and singular integrals into play. This allows us to produce 1/2-order time regularity in L^2, which means the desired Hölder regularity is a matter of improving the integrability of this fractional time derivative to L^p for some $p > 2$. The techniques involved have applications to other (local and non-local) systems. (Received August 23, 2018)

1144-35-175 **James Scott** and **Tadele Mengesha*** (mengesha@utk.edu). *A Potential space estimate for solutions of system of coupled nonlocal equations.*

In this talk, we will discuss that weak solutions to the strongly-coupled system of nonlocal equations of linearized peridynamics belong to a potential space with higher integrability. Specifically, we show a function that measures local fractional derivatives of weak solutions to a linear system belongs to Lp for some p that is larger than 2 with no additional assumption other than measurability and ellipticity of coefficients. This is a nonlocal analogue of an inequality of Meyers for weak solutions to an elliptic system of equations. We also show that functions in Lp whose Marcinkiewicz-type integrals are in Lp do in fact belong to a Bessel potential space. (Received August 23, 2018)

1144-35-177 **Igor Verbitsky*** (verbitskyi@missouri.edu), Department of Mathematics, University of Missouri, Columbia, MO 65211. *Positive solutions to nonlocal sublinear elliptic equations.*

We study solutions $u > 0$ to nonlocal sublinear equations of the type $(-\triangle)^{\frac{\alpha}{2}} u = \sigma\, u^q + \mu$ in the case $0 < q < 1$ in a domain $\Omega \subseteq \mathbf{R^n}$, where σ, μ are nonnegative measures, and $(-\triangle)^{\frac{\alpha}{2}}$ $(0 < \alpha < n)$ has a positive Green's function G. We discuss pointwise estimates of solutions, as well as related weighted norm inequalities, and necessary and sufficient conditions for the existence of finite energy solutions. More general nonlocal equations and inequalities $u \geq G(u^q\sigma) + f$, where G is an integral operator with positive kernel which satisfies a weak maximum principle, are treated as well. This talk is based on joint work with Alexander Grigor'yan, and Adisak Seesanea. (Received August 23, 2018)

1144-35-194 **Oliver Ruff*** (oruff@kent.edu) and **Gro Hovhannisyan**. *The direct method for time-scale solitons.*

Hilger's time-scale calculus is a theory that incorporates continuous and discrete analysis. Many well-known equations (including KdV, KP, and sine-Gordon) have time-scale generalizations which still admit soliton solutions, although the extent to which the amazingly rich algebraic and geometric structure of soliton equations extends to the time-scale case is not generally apparent. We apply a suitable version of Hirota's direct method to some of these time-scale examples, and study some of the resulting Young diagram combinatorics. (Received August 24, 2018)

1144-35-221 **Pablo Raúl Stinga***, Department of Mathematics, Iowa State University, 396 Carver Hall, Ames, IA 50011. *The obstacle problem for a fractional Monge–Ampère equation.*

We study the obstacle problem for a degenerate fractional Monge–Ampère equation. This nonlocal operator was introduced by Caffarelli and Charro. We show the existence of a unique, globally Lipschitz and semiconcave classical solution, at which the fractional Monge–Ampère equation becomes locally uniformly elliptic. The uniform ellipticity is used to deduce local regularity of the solution and the free boundary. Joint work with Yash Jhaveri, graduate student at ETH Zürich. (Received August 26, 2018)

1144-35-249 **Petronela Radu*** (pradu@unl.edu), Lincoln, NE 68502. *Regularity of solutions to nonlocal nonlinear systems of second and fourth order.*

Nonlocal systems of equations appear in a variety of applications ranging from dynamic fracture (as modeled by the theory of peridynamics), nonlocal diffusion, to image processing. In this talk I will focus on integro-differential systems where the nonlocality is expressed through operators with integrable kernels, and as such, Sobolev embedding theorems are not available. However, using the convolution structure of the operators we show higher integrability, as well as Sobolev differentiability of solutions for systems where the nonlinearity satisfies satisfies some mild conditions, with no growth assumptions. (Received August 27, 2018)

37 ► Dynamical systems and ergodic theory

1144-37-84 **Zoe Cooperband** and **Erin P.J. Pearse*** (epearse@calpoly.edu), Mathematics Department, 1 Grand Ave, San Luis Obispo, CA 93407, and **Blaine Quackenbush**, **Jordan Rowley**, **Tony Samuel** and **Matt West**. *On the continuity of entropy of Lorenz maps.*

We consider a one parameter family of Lorenz maps indexed by their point of discontinuity p and constructed from a pair of bi-Lipschitz functions. We prove that their topological entropies vary continuously as a function of p and discuss Milnor's monotonicity conjecture in this setting. (Received August 12, 2018)

1144-37-86 **Ivan Chio*** (ichio@iu.edu), 402 N Blackford St, LD270, Indianapolis, IN 46202, and **Caleb He** (calebhe@college.harvard.edu), **Anthony Ji** (anthony.ji@yale.edu) and **Roland Roeder** (rroeder@iupui.edu), 402 N Blackford St, LD224Q, Indianapolis, IN 46202. *Lee-Yang zeros for the Cayley Tree and expanding maps of the circle.*

I will explain how to use detailed properties of expanding maps of the circle (Shub-Sullivan rigidity, Ledrappier-Young formula, large deviations principle,...) to study the limiting distribution of Lee-Yang zeros for the Ising Model on the Cayley Tree. No background in mathematical physics is expected of the audience. This is joint work with Caleb He, Anthony Ji, and Roland Roeder. (Received August 12, 2018)

1144-37-131 **Eugen Andrei Ghenciu*** (andrei.e.ghenciu@gmail.com), 1296 River Ridge Rd, River Falls, WI 54022. *Almost Specified Iterated Constructions.* Preliminary report.

In this presentation we introduce the concept of Almost Specified Iterated Constructions. The main object of study is the limit set generated by finite or infinite almost specified shifts. We look at the properties of the associated level functions and the existence of a suitable measure supported on the limit set. (Received August 21, 2018)

1144-37-134 **Otávio M. L. Gomide*** (otaviomleandro@gmail.com). *On Structural Stability of* $3D$ *Filippov Systems.*

Nowadays there exists an extensive range of phenomena presenting discontinuous motion and, thus, the Theory of Filippov Systems (FS) has been a common topic of interest in many fields as Mathematics, Physics, Engineering, Geophysics and correlated areas.

The characterization of structural stability of FS is a very active research topic due to the interest to know the efficiency of a model with respect to the initial conditions and parameters. In dimensions higher than two, a FS can present a very rich and complex dynamics, which makes it very difficult to classify the structurally stable systems.

In this context, the $3D$-fold-fold singularity has been one of the main obstructions to give a characterization of structural stability for $3D$-FS. In fact, it is an intriguing generic phenomenon having no counterparts in smooth systems which has challenged the researchers over the last 30 years.

In this talk, we discuss the concept of structural stability for FS and we describe the dynamical features of a $3D$-fold-fold singularity in its most basic form. Moreover, we present the fundamental ideas to characterize the local structural stability or instability of a FS at a fold-fold singularity. This is a joint work with M. A. Teixeira. (Received August 21, 2018)

1144-37-155 **Cecilia González-Tokman** and **Anthony Quas*** (aquas@uvic.ca). *Lyapunov spectrum collapse for Perron-Frobenius cocycles.* Preliminary report.

We consider cocycles of Ruelle-Perron-Frobenius operators driven by an ergodic base dynamical system. We are concerned with the stability of the Lyapunov exponents of the cocycle with respect to perturbations of the cocycle. We exhibit some natural perturbations of the Perron-Frobenius operators of a family of random analytic expanding mappings of the unit circle that exhibit a collapse of the Lyapunov spectrum. (Received August 22, 2018)

1144-37-156 **Anthony Quas*** (aquas@uvic.ca) and **Terry Soo**. *Universality of quasi-hyperbolic toral automorphisms.*

A topological dynamical system (Y, S) is called *universal* if it 'contains a copy' of every ergodic measure-preserving transformation whose measure-theoretic entropy is strictly smaller than the topological entropy of S. Krieger showed that full shifts and mixing shifts of finite type are universal. We prove an analogous result for quasi-hyperbolic toral automorphisms (those with no roots of unity as eigenvalues). The proof is based on a weak notion of specification, as well as the Burton–Rothstein method for constructing isomorphisms of dynamical systems. (Received August 22, 2018)

1144-37-163 **Yuri Kifer*** (kifer@math.huji.ac.il), Institute of Mathematics, Hebrew University, Givat Ram, Jerusalem, Israel. *Geometric law for numbers of multiple returns until a hazard.*

For a ψ-mixing stationary process $\xi_0, \xi_1, \xi_2, ...$ we obtain a geometric distribution for the number of multiple recurrencies $\{\xi_{q_i(n)} \in \Gamma_N,\, i = 1, ..., \ell\}$ to a set Γ_N for n until the moment τ_N (called a hazard) when another multiple recurrence $\{\xi_{q_i(n)} \in \Delta_N,\, i = 1, ..., \ell\}$ occurs for the first time where $\Gamma_N \cap \Delta_N = \emptyset$ and $q_i(n)$ are nonnegative increasing functions taking on integer values on integers. A similar result is obtained in the dynamical systems setup considering a ψ-mixing shift T on a sequence space Ω and studying the number of multiple recurrencies $\{T^{q_i(n)}\omega \in A_m^a,\, i = 1, ..., \ell\}$ until the first occurence of another multiple recurrence $\{T^{q_i(n)}\omega \in A_m^b,\, i = 1, ..., \ell\}$ where A_m^a, A_m^b are cylinder sets of length m constructed by sequences $a, b \in \Omega$, respectively. In the case of ϕ-mixing shifts we obtain geometric limit law for the number of single returns to a cylinder until the first return to another cylinder. The motivation comes from papers on asymptotics of numbers of single and multiple returns to shrinking sets, as well as from papers on open systems studying their behavior until an exit through a "hole". (Received August 23, 2018)

1144-37-169 **Lior Fishman*** (lior.fishman@unt.edu), **Keith Merrill** and **David Simmons**. *A Continued Fraction Algorithm for Spheres.*

Building upon the theory of intrinsic Diophantine approximation on quadratic hypersurfaces first developed by Fishman, Kleinbock, Merrill, and Simmons (preprint 2015), we define a "continued fraction algorithm" which assigns to every irrational point on a rank one hypersurface a sequence of rationals which are best approximants in a technical sense. We exhibit numerous striking similarities between the resulting theory and that of the theory of classical continued fractions for real numbers. This is joint work with K. Merrill and D. Simmons. (Received August 23, 2018)

1144-37-188 **Michael Burr** and **Christian Wolf*** (cwolf@ccny.cuny.edu), 160 Convent Ave, New York, NY 10031. *Computability at temperature zero.*

In this talk we discuss the computability of certain thermodynamic invariants at zero temperature for one-dimensional subshifts of finite type. In particular, we show that the residual entropy (i.e., the joint ground state entropy) is an upper semi-computable function on the space of continuous potentials, but it is not computable. Next, we consider locally constant potentials for which the zero-temperature measure is known to exist. We characterize the computability of the zero-temperature measure and its entropy for potentials that are constant on cylinders of a given length k. In particular, we show the existence of an open and dense set of locally constant potentials for which the zero-temperature measure can be computationally identified as an elementary periodic point measure. Finally, we show that our methods do not generalize to treat the case when k is not given. (Received August 24, 2018)

1144-37-196 **Sean Gasiorek*** (sgasiore@ucsc.edu). *Billiards Inside, Circles Outside: Charged Particles in a Piecewise Constant Magnetic Field.*

Consider a magnetic field orthogonal to the Euclidean plane which is zero inside a fixed convex domain while having constant strength B outside. The dynamics of a charged particle starting in the domain can be viewed as a perturbation of usual billiard dynamics, the perturbation parameter being $1/B$. If the boundary is smooth and B is greater than the maximum of the curvature of the boundary we show that the resulting map is a twist map, with all the consequences regarding periodic orbits, etc ensuing. (Received August 24, 2018)

1144-37-207 **Vasileios Chousionis*** (vasileios.chousionis@uconn.edu), University of Connecticut, 341 Mansfield Road U1009, Storrs, CT 06269. *On the dimension spectrum of continued fractions.*

The dimension spectrum of an iterated function system is the set of all possible values of the Hausdorff dimension of its subsystems. We study the dimension spectrum of general conformal graph directed Markov systems, with emphasis on conformal iterated function systems associated to real and complex continued fractions. According to the Texan conjecture, proven by Kessebohmer and Zhu in 1996, the dimension spectrum of real continued fractions is full. We consider the dimension spectrum of continued fractions with coefficients restricted to infinite subsets of natural numbers. We prove that if the alphabet $E \subset \mathbb{N}$ is any arithmetic progression, the set of primes, or the set of squares then the continued fractions whose digits lie in E have full dimension spectrum. On the way we employ the computational approach of Falk and Nussbaum in order to obtain rigorous effective estimates for the Hausdorff dimension of continued fractions whose entries are restricted to infinite sets. Finally we show that the system resulting from the complex continued fractions algorithm has full dimension spectrum. We thus give a positive answer to the Texan conjecture for complex continued fractions. Based on joint works with Dmitriy Leykekhman (UConn) and Mariusz Urbanski (UNT). (Received August 25, 2018)

1144-37-238 **Giulio Tiozzo***, 40 St George St, Toronto, ON M5S 2E4, Canada. *Random walks on the Cremona group.*

The Cremona group of birational transformations of $\mathbb{CP}^2$ is a classical object in algebraic geometry. In the last decade, incredible progress (by Cantat, Lamy and several others) has been made by combining complex dynamics and geometric group theory, using the action of the Cremona group on an infinite dimensional hyperbolic space. In new work with J. Maher, we use these techniques to study random compositions of birational maps. For instance, we prove that the dynamical degree of random Cremona transformations grows exponentially fast, we give a characterization of the Poisson boundary, and we produce using random walks many different normal subgroups. (Received August 26, 2018)

1144-37-247 **Meagan Carney*** (meagan@math.uh.edu) and **Matthew Nicol** (nicol@math.uh.edu). *Modeling Extremes in Dynamics under Stationary and Nonstationary Assumptions.*

An extreme value law concerns the distributional convergence of the maxima by the extremal index parameter typically under certain stationary assumptions. In this talk we discuss extreme value statistics for Sinai dispersing billiards and investigate how the geometry of the map relates to maximization of the observable at a periodic or generic point where the extremal index differs in each case. We also introduce a model for real world summer temperature recordings throughout Texas 1941-2017. In this case the Generalized Extreme Value distribution model needs to be adapted to account for nonstationarity in the time series. (Received August 27, 2018)

1144-37-253 **Tamara Kucherenko***, The City College of New York, Convent Ave at 138th Street, New York, NY 10031, and **Daniel J. Thompson**. *Measures of maximal entropy for suspension flows over the full shift.*

We consider suspension flows with continuous roof function over the full shift on a finite alphabet. For any positive entropy subshift of finite type we show there exists a roof function such that the measure(s) of maximal entropy for the suspension flow over the full shift are exactly the lifts of the measure(s) of maximal entropy for the subshift. In the case when the subshift is transitive, this gives a unique measure of maximal entropy for the flow which is not fully supported. If the subshift has more than one transitive component, all with the same entropy, this gives explicit examples of suspension flows over the full shift with multiple measures of maximal entropy. This contrasts with the case of a Hölder continuous roof function where it is well known the measure of maximal entropy is unique and fully supported. (Received August 27, 2018)

1144-37-258 **Alexandro R Luna*** (capitala677@csu.fullerton.edu), 800 North State College Blvd., Fullerton, CA 92831, and **Sattarov** and **Rozikov**. *p-adic Dynamical Systems of* $(3,1)$*-Rational Functions with unique fixed point.*

We describe the set of all $(3,1)$-rational functions given on the set of complex p-adic field $\mathbb{C}_p$ and having a unique fixed point. We study p-adic dynamical systems generated by such $(3,1)$-rational functions and show that the fixed point is indifferent and therefore the convergence of the trajectories is not the typical case for the dynamical systems (Received August 27, 2018)

1144-37-267 **James E Reid*** (jreid@centenary.edu). *Continuity of the numerical value of packing measures for conformal iterated function systems.*

In the context of fractal geometry, the natural extension of volume in Euclidean space $\mathbb{R}^d$ is given by Hausdorff and packing measures. These measures arise naturally in the context of iterated function systems (IFS). For example, if the IFS is finite and conformal, then the Hausdorff and packing dimensions of the limit sets agree and the corresponding Hausdorff and packing measures are positive and finite. Moreover, the map which takes the IFS to its dimension is continuous. Developing on the work of Olsen (2008), Qiu (2012), and Urbanski and Zdunik (2016), we show that the map which takes a finite conformal IFS to the numerical value of its packing measure is continuous (assuming the strong separation condition) . We will emphasize the importance of density theorems (as in Lebesgue density theorem) when working with the numerical values of Hausdorff and packing measures. (Received August 27, 2018)

1144-37-279 **J Ding*** (jiudin@gmail.com), 14 SUMMER PLACE, HATTIESBURG, MS 39402, and **C Jin**, Department of Mathematics, Zhejiang Sci-Tech University, Hangzhou, Zhejiang 310018, Peoples Rep of China. *Estimating invariant measures of random maps via maximum entropy method.*

The maximum entropy principle was proposed by physicist Jaynes in statistical physics for the recovery of density functions with finitely many known moments with respect to given moment functions. We apply this principle together with the idea of finite elements to compute the density function of an absolutely continuous invariant

measure associated with a random map defined on the unit interval. Convergence will be proved and numerical examples will also be presented. (Received August 27, 2018)

1144-37-283 **J Ding***, 14 SUMMER PLACE, HATTIESBURG, MS 39402, and **T Upadhyay**. *On the stationary density of random maps.* Preliminary report.

We use concepts and methods of regular dynamical systems and Markov operators to give the functional analysis and numerical analysis for the stationary density of random maps. (Received August 27, 2018)

1144-37-285 **Marco Antonio López*** (lopezma@wfu.edu), **Leonard Carapezza** and **Donald Robertson**. *Equilibrium states for (α, β)-transformations.*

We consider interval maps of the form $x \mapsto \alpha + \beta x \bmod 1$ and their associated shift spaces, where $\beta > 1$. In 2013, Climenhaga and Thompson proved that every Hölder potential has a unique equilibrium state in the case when $\alpha = 0$. In our work we investigate uniqueness of equilibrium states in the general case. (Received August 27, 2018)

1144-37-286 **Ami Radunskaya*** (aer04747@pomona.edu), Math Department, Pomona College, 610 N. College Ave., Claremont, CA 91711. *Statistical properties of dynamic networks.* Preliminary report.

Dynamic networks are popular models of societies, biological systems and information systems. In this talk we look at the evolution of a network over time in the context of a dynamical system on the space of possible networks. We will focus on understanding the dynamic behavior of networks with distinguishable nodes, answering questions about ergodicity and the existence of stable behavior. We show one application where we look at the effect of the cell of origin on the progression of a particular type of glioma. (Received August 27, 2018)

1144-37-290 **Joanna Furno*** (jfurno@math.uh.edu). *A structure theorem and natural extensions for p-adic scaling maps.*

Many standard examples of transformations on the p-adic integers are p^n-Lipschitz on each ball of radius p^{-n}. We show that maps with this scaling property can be expressed as an iterate of the one-sided shift composed with an isometry. Then we use this decomposition to give a formula for the natural extension. (Received August 27, 2018)

1144-37-295 **Sara Lapan*** (slapan@ucr.edu). *Existence of a domain of attraction along a characteristic direction of higher degree.*

In this talk, we will consider holomorphic self-maps of $\mathbb{C}^2$ that fix the origin and are tangent to the identity (e.g., $f(0) = 0$ and $\mathrm{d}f(0) = \mathrm{Id}$). We are interested in how points near the origin move under iteration. Do they converge to the origin and, if so, do they converge along a direction? When this happens, such a direction must be a characteristic direction. We will discuss what is known in $\mathbb{C}^2$, focusing on degenerate characteristic directions and the role that higher degree terms can play in the existence of a domain of attraction along those directions. (Received August 27, 2018)

1144-37-308 **Grace Work***, grace.work@vanderbilt.edu, and **Spencer Dowdall**. *Shrinking targets in moduli space.* Preliminary report.

Consider a decreasing family of targets in a measure space. The shrinking target problem characterizes when the set of points which hit the targets infinitely often under a given flow is of full measure. We will examine this problem in the setting of Teichmüller flow on the moduli space of unit-area quadratic differentials. (Received August 28, 2018)

1144-37-330 **Tushar Das*** (tdas@uwlax.edu). *Intersecting limit sets for Kleinian subgroup pairs.*

Since the work of Bernard Maskit in the 1970s, there has been sustained interest in developing results that elucidate the relationship between (the limit set of) the intersection of a pair of subgroups of a Kleinian group, and the intersection of their respective limit sets. In this vein, we construct a non-elementary Fuchsian group that admits two non-elementary subgroups with trivial intersection and whose radial limit sets intersect non-trivially. This negatively answers a question of Perry Susskind (1989) that was stated as a conjecture by James W. Anderson (2014). This work is joint with David Simmons (York). (Received August 28, 2018)

41 ► Approximations and expansions

1144-41-40 **Yang Wang** and **Zhiqiang Xu*** (xuzq@lsec.cc.ac.cn), Zhongguancun East Road No.55, Haidian, Beijing, 100190, Peoples Rep of China. *Generalized phase retrieval.*

Phase retrieval is an active topic recently. In this talk, we will introduce the generalized phase retrieval which includes as special cases the standard phase retrieval as well as the phase retrieval by orthogonal projections. We first explore the connections among generalized phase retrieval, low-rank matrix recovery and nonsingular bilinear form. Motivated by the connections, we present results on the minimal measurement number needed for generalized phase retrieval. Our work unifies and enhances results from the standard phase retrieval, phase retrieval by projections and low-rank matrix recovery and also explore the connection among phase retrieval, nongsingular bilinear form and topology. (Received July 27, 2018)

1144-41-149 **Uwe Kaehler*** (ukaehler@ua.pt), Departamento de Matematica, Universidade de Aveiro, Aveiro, Portugal. *Interpolation of monogenic functions based on reproducing kernels.*

One of the principal differences between complex and hypercomplex analysis is the lack of the Blaschke products. While there are several attempts to generalize Blaschke products to higher dimensions none can provide all the properties of classic Blaschke products. This is particularly evident in the study of interpolation of monogenic functions. While in the complex case Lagrange interpolation leads more or less automatically to Blaschke products this does not happen in higher dimensions due to the two-fold fact that neither Möbius transformations are monogenic, nor monogenicity is preserved under multiplication. One way out of this problem is to consider interpolation via reproducing kernels, like the monogenic Bergman kernel in the case of the unit ball. But to do this effectively we need to take into account the underlying geometry. In this talk we will show who the proper geometrical choices will allow us to provide density theorems and provide efficient practical algorithms. (Received August 22, 2018)

1144-41-151 **Armenak Petrosyan*** (petrosyana@ornl.gov), 1 Bethel Valley Rd, bld 4100, Oak Ridge, TN 37830, and **Hoang Tran** and **Clayton Webster**. *Reconstruction of jointly sparse vectors via manifold optimization.*

We consider the recovery problem of jointly sparse vectors from their linear measurements. We utilize the rank of the data matrix to reduce the problem to a full column rank case. This cuts the computation complexity of the problem and allows the implementation of joint sparse recovery algorithms like the MUSIC algorithm [**?**, **?**] to be computationally more efficient and fast. We also offer a new method for recovery of jointly sparse vectors in the form of a (non-convex) optimization problem on the non-compact Steifel manifold. Our method generalizes the ℓ_1/ℓ_2 minimization method. We numerically demonstrate that it outperforms the Euclidean minimization of the $\ell_{2,1}$ norm commonly used for solving the joint sparse recovery problem. (Received August 22, 2018)

1144-41-210 **Fei Lu**, **Mauro Maggioni** and **Sui Tang***, 3400 North Charles St, Department of Mathematics, Johns Hopkins University, Baltimore, MD 21218. *Learning interaction laws in high dimensional agent dynamics from observations.* Preliminary report.

In different disciplines, inferring the laws of interaction of agents in complex dynamical systems from observational data is a fundamental challenge. We propose a non-parametric statistical learning approach to estimate the governing laws of distance-based interactions, with no reference or assumption about their analytical form, from data consisting trajectories of interacting agents. We demonstrate the effectiveness of our learning approach both by providing theoretical guarantees, and numerical tests on several prototypical systems. (Received August 25, 2018)

1144-41-214 **Wenjing Liao*** (wliao60@gatech.edu), Skiles 258, 686 Cherry St NW, Atlanta, GA 30313, and **Mauro Maggioni** and **Stefano Vigogna**. *Multiscale methods for high-dimensional data with low-dimensional structures.*

Many data sets in image analysis and signal processing are in a high-dimensional space but exhibit a low-dimensional structure. We are interested in building efficient representations of these data for the purpose of compression and inference. In the setting where a data set in R^D consists of samples from a probability measure concentrated on or near an unknown d-dimensional manifold with d much smaller than D, we consider two sets of problems: low-dimensional geometric approximations to the manifold and regression of a function on the manifold. In the first case, we construct multiscale low-dimensional empirical approximations to the manifold and give finite-sample performance guarantees. In the second case, we exploit these empirical geometric approximations of the manifold and construct multiscale approximations to the function. We prove finite-sample guarantees showing that we attain the same learning rates as if the function was defined on a Euclidean domain

of dimension d. In both cases our approximations can adapt to the regularity of the manifold or the function even when this varies at different scales or locations. (Received August 25, 2018)

42 ► Fourier analysis

1144-42-32 **A. Fannjiang***, One Shields Avenue, Davis, CA 95616-8633, and **P. Chen** and **Z. Zhang**. *Ptychography: uniqueness and reconstruction.*

Ptychography with an unknown mask and object is analyzed for both the lattice scheme and the non-lattice mixing schemes under general mask phase constraint and object support constraints.

Furthermore, we show that in the case of the mixing schemes the only ambiguities are a constant scaling factor and an affine phase factor.

In the case of the lattice scheme, the mask and object errors have additional τ^2 degrees of uncertainty where τ is the stepsize of the raster scan, consistent with the raster grid pathology reported in literature.

We present a reconstruction scheme informed by the mask phase constraint whose numerical performance matches the predictions of the theory. (Received July 19, 2018)

1144-42-33 **Semyon Dyatlov*** (dyatlov@math.berkeley.edu). *Fractal uncertainty principle.*

Fractal uncertainty principle (FUP) states that no function can be localized near a fractal set in both position and frequency. I will present two versions of the fractal uncertainty principle in dimension 1 (joint works with Jean Bourgain and with Long Jin). These statements have applications to quantum chaos such as lower bound on mass of eigenfunctions (joint with Long Jin) and spectral gaps for open systems (joint works with Joshua Zahl and with Maciej Zworski). I will also discuss the case of higher dimensions, where new ideas (including those from fractal geometry) will be needed to prove an FUP. (Received July 20, 2018)

1144-42-35 **Eyvindur Ari Palsson*** (palsson@vt.edu), Department of Mathematics, McBryde Hall, Virginia Tech, Blacksburg, VA 24061, and **Alex Iosevich**. *An improved threshold for the Falconer angle problem.*

Finding and understanding patterns in data sets is of significant importance in many applications. One example of a simple pattern is the distance between data points, which can be thought of as a 2-point configuration. Two classic questions, the Erdos distinct distance problem, which asks about the least number of distinct distances determined by N points in the plane, and its continuous analog, the Falconer distance problem, explore that simple pattern. Questions similar to the Erdos distinct distance problem and the Falconer distance problem can also be posed for more complicated patterns such as angles, which can be viewed as 3-point configurations. In this talk I will present recent progress on the Falconer angle problem which was obtained using a novel group-theoretic viewpoint. (Received July 22, 2018)

1144-42-56 **Eddy Kwessi*** (ekwessi@trinity.edu), 1 Trinity Place, San Antonio, TX 78212, and **Lloyd Edwards** (ljedward@uab.edu), Birmingham, AL. *Non standard Discrete Model in Neurosciences: The FitzHugh Nagumo model with time delay.* Preliminary report.

It is well known that the human brain contains a large number of neurons that often evolve in large neural networks. These neural networks represent groups of neural populations where each element interacts, under excitement impulses with other elements. One model used to model the behavior of these ensembles of neurons is the FitzHugh-Nagumo system. This system consists of two ordinary differential equations linking an activator and an inhibitor, and represents the excitability of the neural network. In this paper, we propose a non-standard discrete version of the FitzhHugh Nagumo model. We make the case that this version, unlike a standard discretization using for example an Euler Method, preserves the dynamics of the continuous original system. This model also has a time-delay parameter that is useful to explain delay response in neuron firing. We also show that this discretization is well suited for parameter estimation using Monte-Carlo simulations. (Received August 05, 2018)

1144-42-89 **Eric Weber***, Department of Mathematics, 411 Morrill Rd, Iowa State University, Ames, IA 50011. *Stability of Fourier Series Expansions for Singular Measures.*

For a singular measure μ on the unit interval $[0, 1]$, every square-integrable function $f \in L^2(\mu)$ possesses a Fourier series expansion. This result was originally proven by Poltoratski, but in work with John Herr, we reproved this result using the Kaczmarz reconstruction algorithm.

Unlike the classical Lebesgue case, these Fourier series expansions converge conditionally, and are therefore unstable in the presence of noise. We demonstrate several methods for stabilizing these reconstructions, including

via Abel summation. Moreover, we demonstrate that the modified and stabilized reconstruction can be described in terms of an augmented Kaczmarz algorithm.

This is joint work with Caleb Camrud, Evan Camrud, and Lee Przybylski. (Received August 13, 2018)

1144-42-97 **Marcin Bownik*** (mbownik@uoregon.edu) and **Itay Londner**. *Exponential frames and syndetic Riesz sequences.*

Employing the solution to the Kadison-Singer problem, we deduce that every subset $\mathcal{S}$ of the torus of positive Lebesgue measure admits a Riesz sequence of exponentials $\{e^{i\lambda x}\}_{\lambda\in\Lambda}$ in $L^2(\mathcal{S})$ such that $\Lambda \subset \mathbb{Z}$ is a set with gaps between consecutive elements bounded by $\dfrac{C}{|\mathcal{S}|}$. This talk is based on a joint work with Itay Londner (Tel Aviv University). (Received August 14, 2018)

1144-42-130 **Allan Greenleaf** (allan@math.rochester.edu), Allan Greenleaf University of Rochester, Department of Mathematics, Rochester, NY 14627, **Alex Iosevich***, University of Rochester, Department of Mathematics, Rochester, NY 14627, and **Sevak Mkrtchyan** (mkrtchyan@math.rochester.edu), University of Rochester, Department of Mathematics, Rochester. *Similar configurations in thin sets.*

We will prove that if a subset of the Euclidean space has sufficiently large Hausdorff dimension, then it contains main similar pairs of simplexes. This is a thin set analog of the celebrated resuts of Bourgain, Furstenberg, Katznelson, Weiss, Ziegler and others in the setting of sets of positive upper Lebesgue density. Group actions and Fourier analytic estimates play a key role in the proofs. (Received August 21, 2018)

1144-42-132 **Itay Londner***, itayl@math.ubc.ca. *Interpolation sets and arithmetic progressions.*

Given a set S of positive measure on the unit circle, a set of integers Λ is an interpolation set (IS) for S if for any data $\{c(\lambda)\}_{\lambda\in\Lambda}$ in $\ell^2(\Lambda)$, there exists a function $f \in L^2(S)$ such that its Fourier coefficients satisfy $\hat{f}(\lambda) = c(\lambda)$ for all $\lambda \in \Lambda$. In my talk I will discuss the relationship between the concept of IS and the existence of arbitrarily long arithmetic progressions with specified lengths and step sizes in Λ.

Multidimensional analogue and recent developments will also be considered.

Based on joint work with A. Olevskii. (Received August 21, 2018)

1144-42-136 **Jean-Pierre Gabardo*** (gabardo@mcmaster.ca), Department of Mathematics & Statistics, McMaster University, 1280 Main Street West, Hamilton, Ontario L8S 4K1, Canada, and **Chun-Kit Lai** (cklai@sfsu.edu), Department of Mathematics, San Francisco State University, 1600 Holloway Ave, San Francisco,, CA 94132. *Frames of exponentials with spectrum contained in a finite union of lattices.*

Suppose that $E \subset \mathbb{R}^d$ is a measurable subset with finite Lebesgue measure. We study conditions on E under which an associated collection of exponentials $\{e^{2\pi i\lambda\cdot x}\}_{\lambda\in\Lambda}$, where the set frequencies Λ is a finite union of m lattices in $\mathbb{R}^d$, forms a frame for $L^2(E)$. (Received August 21, 2018)

1144-42-162 **Paula Cerejeiras*** (pceres@ua.pt), Departamento de Matemática, Universidade de Aveiro, Campus de Santiago, P-3810-193 Aveiro, Portugal. *On quaternionic Gabor frames.*

In this talk we present quaternionic Gabor frames based on the two-sided quaternionic windowed Fourier transform (2sQWF, for short). The 2sQFT is one of the most interesting cases of a quaternionic windowed Fourier transform with applications to image processing. However, the 2sQWF presents several challenges. To begin with, it is neither left- nor right-linear with respect to quaternionic constants. Since methods of classical Hilbert spaces do not work in this case it is required to introduce appropriated versions of translation and modulation operators. In this context, we prove Janssen's and Walnut's representations, as well as modified versions of the Wexler-Raz biorthogonality and Ron-Shen duality based on the concept of correlation function. This will enable us to present a characterization of tight quaternionic Gabor frames.

This is joint work with S. Hartmann and H. Orelma (Received August 23, 2018)

1144-42-203 **Lixiang An*** (anlixianghai@163.com), Wuhan, Hubei 430079, Peoples Rep of China. *Riesz bases of exponential functions for Riesz product measures.* Preliminary report.

Denote a discrete measure with finite support as $\delta_{\mathcal{D},P} = \sum_{i=0}^{q-1} p_i\delta_{d_i}$. In this talk, we will examine the Fourier fram/Riesz bases for the Riesz product measure

$$\mu_{A,\mathcal{D},P_k} = \delta_{A^{-1}\mathcal{D},P_1} * \delta_{A^{-2}\mathcal{D},P_2} * \delta_{A^{-3}\mathcal{D},P_3} \cdots .$$

Under some natural assumption, we will prove that if it has fourier frame/Riesz basis, then it must have a certain uniformity in the sense that the weight is distributed quite uniformly on its support. If it has uniformity, then it has fourier frame/Riesz basis if and only if the self-affine measure $\mu_{A,\mathcal{D}}$ has one . (Received August 25, 2018)

1144-42-205 **Michael C Northington V*** (mcnv3@gatech.edu) and **Josiah Park**. *Finite Balian-Low Theorems and Applications of the Quantitative BLT.*

The Balian-Low Theorem states that the generator of a Gabor Riesz basis for $L^2(\mathbb{R})$ must have poor localization in either time or frequency. Recently, Nitzan and Olsen have shown that Balian-Low type results exist for Gabor systems in the finite dimensional spaces $\ell^2(\mathbb{Z}_d)$. We first extend these results to their higher dimensional analogs in $\ell^2(\mathbb{Z}_d^n)$. Next, we show how many (finite dimensional and continuous) Balian-Low type theorems follow from a quantitative version of the BLT. In particular, we will discuss nonsymmetric verisons of the Balian-Low Theorem in $L^2(\mathbb{R}^n)$. (Received August 25, 2018)

1144-42-225 **Divyang G Bhimani**, Department of Mathematics, College Park, MD 20742, and **Kasso A Okoudjou*** (kasso@mit.edu), MIT, Department of Mathematics, 77 Massachusetts Avenue, Cambridge, MA 02139. *Gabor Frames with arbitrary redundancy and Wilson tight frames in $L^2(\mathbb{R})$.* Preliminary report.

Given a Gabor system $\mathcal{G}(\phi, \alpha, \beta)$ with general lattice parameters $\alpha, \beta > 0$, we propose a Wilson system $\mathcal{W}(\phi, \alpha, \beta)$. Under mild conditions on ϕ, we show that the Gabor system $\mathcal{G}(\phi, \alpha, \beta)$ is a tight with redundancy β^{-1} if and only if the Wilson system $\mathcal{W}(\phi, \alpha, \beta)$ is a Parseval frame for $L^2(\mathbb{R})$. An example of smooth rapidly decaying generator ϕ for the Wilson system $\mathcal{W}(\phi, \alpha, \beta)$ is given. (Received August 26, 2018)

1144-42-231 **Neil Lyall*** (lyall@uga.edu) and **Akos Magyar**. *Geometric Configurations.*

We shall describe some recent results pertaining to the distribution of geometric configurations in a variety of settings. (Received August 26, 2018)

1144-42-260 **Wojciech Czaja**, **Ilya Kavalerov** and **Weilin Li*** (weilinli@cims.nyu.edu). *Time-frequency Scattering Transforms: Theory and Applications.*

Inspired by the success of deep learning, Mallat introduced the wavelet scattering transform and showed that it provides a useful representation of data. In contrast to his wavelet (time-scale) approach, we develop a Gabor (time-frequency) theory. To do this, we introduce the concept of a uniform covering frame, which is a generalization of traditional Gabor frames. When a uniform covering frame is incorporated into a scattering network, we obtain the Fourier scattering transform. This non-linear operator extracts time-frequency characteristics in a hierarchal manner by cascading convolutions with functions from a uniform covering frame and the complex modulus. It satisfies several provable properties that justify its use as a feature extractor for classification. We demonstrate how to use this for the classification of hyper-spectral data. (Received August 27, 2018)

1144-42-276 **Kyle Hambrook***, San Jose State University, Department of Mathematics and Statistics, One Washington Square, San Jose, CA 95192. *Problems on the Fourier Decay of Measures on Fractal Sets.*

I will discuss my recent work on some problems related to the Fourier decay of measures on fractal sets. (Received August 27, 2018)

1144-42-335 **Naomi Feldheim**, **Ohad Feldheim**, **Benjamin Jaye**, **Fedor Nazarov** and **Shahaf Nitzan*** (shahaf.nitzan@math.gatech.edu). *Trigonometric polynomials and Gaussian Stationary processes.*

We will discuss the relation between certain spectral properties of a Gaussian Stationary process (GSP) and the probability that this process remains positive over a long interval. In particular we will be interested in GSP's who's spectral measure has a gap around zero, and in the use of trigonometric polynomials to obtain, in this case, a sharp estimate on the above mentioned probability. (Received August 28, 2018)

1144-42-348 **Nahyun Kim*** (nahyunkim@choicerg.com), NJ , and **Richard Kyung** (richardkyung@choicerg.com), NJ. *Study on Alternative Algorithms to Enhance the Quality of Digital Images Using Numerical and Computational Analysis.*

This paper presents how a large k-space in the frequency domain was obtained using computational and Fourier analysis. To produce a final digital image in MRI process, the big data from the frequency domain can be reduced by using different filters.

To enhance the quality of the final image and to decrease the amount of processing time, an alternative algorithm was developed in this paper. Different Gaussian functions and absolute functions were tested to reduce the ringing artifact that causes spurious signals near sharp transitions.

The resolution of the final digital image appeared differently depending on the width of the LPF(Low Pass Filter) functions. The ringing artifact was detected when the domain of the LPF function over the k-space became narrower.

In contrast, when the domain of the LPF function became wider, the resolution of the image was enhanced due to the sufficient amount of frequency information obtained.

In this MRI digital image processing, a new LPF functions were applied. Also the magnitude of amplitude of the functions over the frequency domain was adjusted to produce better output images. As a result, it was found that the main factor that affects the quality of the output image is the width of the LPF functions. (Received August 29, 2018)

43 ► Abstract harmonic analysis

1144-43-82 **Hartmut Führ** and **Vignon Oussa*** (voussa@bridgew.edu), Bridgewater, MA 02325-0001. *Frames of translates.* Preliminary report.

It is a well-known fact that a collection obtained by translating a single function on the real line is at best a frame for a proper subspace of $L^2(\mathbb{R})$. In other words, a sequence consisting of translates of a function is never a frame for $L^2(\mathbb{R})$. Given a locally compact group G, we say that G has the frame of translates property if there exist a countable set $\Gamma \subset G$ and a function $\varphi \in L^2(G)$ such that Γ-translates of φ is a frame for $L^2(G)$. In this talk we will characterize locally compact groups having the frame of translates property. Additionally, we will present a (surprisingly) extensive collection of groups enjoying such a property. This talk is based on joint work with H. Führ. (Received August 12, 2018)

1144-43-280 **Marina Iliopoulou*** (m.iliopoulou@berkeley.edu), Department of Mathematics, 849 Evans Hall, Berkeley, CA 94720, and **Michael Christ**. *The Riesz-Sobolev inequality on compact connected Abelian groups.*

The Riesz-Sobolev rearrangement inequality in $\mathbb{R}$ states that the 'number' of pairs of elements of two sets $A, B \subset \mathbb{R}$ whose sum lies in another set C, i.e. $\int_C \mathbf{1}_A * \mathbf{1}_B$, is smaller than what it would be if the sets A, B, C were intervals with appropriate centers. In this talk we will discuss a version of the Riesz-Sobolev inequality for compact connected Abelian groups, as well as the structure that A, B and C have if the above integral is nearly maximal. This is joint work with M. Christ. (Received August 27, 2018)

46 ► Functional analysis

1144-46-83 **Longxiu Huang*** (longxiu.huang@vanderbilt.edu), 1326 Stevenson Center, Nashville, TN 37240, **Akram Aldroubi**, 1326 Stevenson Center, Nashville, TN 37240, and **Armenak Petrosyan**. *Frames induced by the action of continuous powers of an operator.*

The dynamical sampling problem is to recover an unknown signal from spatio-temporal samples of an evolving process for which the signal is the initial state. In the present study, we assume the samples are taken in continuous time at fixed locations and find conditions on $A, \mathcal{G}$, and L that make the iterated system $\{A^t g : g \in \mathcal{G}, t \in [0, L]\}$ complete, Bessel or a frame for $\mathcal{G}$. Additionally, we also study the connection between the semi-continuous frame $\{A^t g : g \in \mathcal{G}, t \in [0, L]\}$ and its discretization $\{A^{t_i} g\}_{g \in G, i \in I}$ with $|I| < \infty$, where the semi-continuous frame is generated by the continuous action of the operator $A \in B(\mathcal{H})$, and the discrete system is obtained from the time discretization of this system. (Received August 12, 2018)

1144-46-88 **Deguang Han*** (deguang.han@ucf.edu), Department of Mathematics, University of Central Florida, Orlando, FL 32816. *Phase-retrievable representation frames and related topics.* Preliminary report.

In this talk we will discuss some recent work on phase-retrievable projective representation frames for finite groups as well as some other related topics such as exact phase-retrievable frames and phase-retrievable operator-valued frames. (Received August 13, 2018)

1144-46-91 **Marc A. Rieffel*** (rieffel@math.berkeley.edu). *Dirac operators for "Matrix algebras converge to the sphere".* Preliminary report.

In the high-energy quantum-physics literature one finds statements such as "matrix algebras converge to the sphere". Earlier I provided a general setting for understanding such statements, in which the matrix algebras are

viewed as compact quantum metric spaces, and convergence is with respect to a quantum Gromov-Hausdorff-type distance. More recently I have dealt with corresponding statements in the literature about vector bundles on spheres and matrix algebras. I will very briefly indicate how some of this works.

But physicists want, even more, to treat structures on spheres (and other spaces) such as Dirac operators, Yang-Mills functionals, etc., and they want to approximate these by corresponding structures on matrix algebras. I am currently exploring how to make precise the situation for Dirac operators. This is confusing because in the physics literature there are at least 3 inequivalent suggestions as to what the Dirac operators on the matrix algebras should be. This is work in progress. I will report on what I have found by the time of the meeting. (Received August 13, 2018)

1144-46-98 **S. Kaliszewski**, **Magnus B Landstad** and **John Quigg*** (quigg@asu.edu).
Tensor-Product Coaction Functors. Preliminary report.

Baum-Guentner-Willett introduced "exotic crossed products" in an attempt to "fix" the Baum-Connes Conjecture. The exotic crossed products are required to form an exact functor of actions, and are desired to be as small as possible. We have modified the [BGW] program by casting it in terms of coaction functors. One particularly interesting exotic crossed product of [BGW] involves tensoring with a fixed action, and Buss-Echterhoff-Willett showed that the smallest such involves $\ell^\infty(G)$. To incorporate this into our coaction-functor program, we need to tensor with a fixed coaction. For this we must restrict to a "G-balanced tensor product" sitting inside the (maximal) tensor product. We introduce and develop the basic theory of these balanced tensor products, including a crucial technical isomorphism involving crossed products of actions. Our techniques require the group G to be discrete. We prove versions for coaction functors of the theorems of [BGW] and [BEW], namely, our "tensor coaction functors" are exact, are minimal when tensoring with the crossed product of $\ell^\infty(G)$, and reproduce the tensor-crossed-product functors of [BGW] when composed with the full crossed product. This is joint work with Steve Kaliszewski and Magnus Landstad. (Received August 14, 2018)

1144-46-112 **Michael Hartglass*** (mhartglass@scu.edu), Department of Mathematics and Computer Scienc, 500 El Camino Real, Santa Clara, CA 95053-0290, and **Brent Nelson**. *Free Araki-Woods factors associated to weighted graphs and a connection to infinite-index subfactors.*

Given a finite graph with a suitable weighting on the edges, I will construct a von Neumann algebra associated to this graph. In the event that this von Neumann algebra is not finite, it is always a free Araki Woods factor. In this case, I will outline an interesting subfactor of this algebra first studied by Dave Penneys and Corey Jones. This is joint work with Brent Nelson. (Received August 16, 2018)

1144-46-125 **Asuman Guven Aksoy*** (aaksoy@cmc.edu), Dept of Mathematical Sciences, Claremont McKenna College, Claremont, CA 91711. *Bernstein's Lethargy Theorem and Reflexivity.*

The formal beginnings of approximation theory date back to 1885, with Weierstrass' celebrated approximation theorem. The discovery that every continuous function defined on a closed interval $[a, b]$ can be uniformly approximated as closely as desired by a polynomial function immediately prompted many new questions. One such question concerned approximating functions with polynomials of limited degree. That is, if we limit ourselves to polynomials of degree at most n, what can be said of the best approximation? As it turns out, there is no unified answer to this question. In fact, S. N. Bernstein (1938) showed that there exists functions whose best approximation converges arbitrarily slowly as the degree of the polynomial rises. In this talk, we take this aptly-named "Lethargy theorem" of Bernstein and present two extensions. We'll show one of these extensions shrinks the interval for best approximation by half while the other gives a surprising equivalence to reflexivity in Banach spaces. (Received August 20, 2018)

1144-46-129 **Trubee Hodgman Davison*** (trubee.davison@colorado.edu), University of Colorado, Campus Box 395, Boulder, CO 80309. *Unitary representations of the Baumslag-Solitar group associated to the Cantor Set.*

The Cantor set supports a Borel probability measure known as the Hutchinson measure which satisfies a well known fixed point relationship. Previously it has been shown by P. Jorgensen and D. Dutkay that the Cantor set can be extended to an inflated Cantor set, $\mathcal{R}$, on a subset of the real line, which supports an extended Hutchinson measure μ. Unitary dilation and translation operators can be defined on $L^2(\mathcal{R}, \mu)$ which satisfy the Baumslag-Solitar relation, and give rise to a multi-resolution analysis. The filter function associated to this construction can be used to produce a measure, m, on the solenoid, $\mathcal{S}$, a compact topological group. The Hilbert space $L^2(\mathcal{S}, m)$ also has a unitary representation of the Baumslag-Solitar group, and there exists a generalized Fourier transform between $L^2(\mathcal{R}, \mu)$ and $L^2(\mathcal{S}, m)$. In this talk, we will show that the unitary operators on $L^2(\mathcal{S}, m)$

mentioned above are related to each other via a family of partial isometries, which satisfy some interesting properties. (Received August 21, 2018)

1144-46-147 **Dorin Dutkay*** (ddutkay@gmail.com). *Orthonormal bases generated by Cuntz algebras.*
We show how various orthonormal bases can be generated using representations of the Cuntz algebra. These include Fourier series, Walsh series, generalized Walsh bases, Fourier bases on fractal measures. (Received August 22, 2018)

1144-46-171 **Gabriel Picioroaga***, University of South Dakota, 414 E.Clark Street, Vermillion, SD 57069. *Frames and orthonormal bases generated by Cuntz systems.* Preliminary report.
Irreducible representations of the Cuntz algebra $\mathcal{O}_N$ on $L^2[0,1]$ give rise to orthonormal bases. We use dilation techniques to prove that a set of N operators on a Hilbert space H satisfying part of the Cuntz relations

$$\sum_{i=1}^{N} S_i S_i^* = I$$

gives rise to a Parseval frame on H if and only if the Cuntz representation on the (unique) dilation of (H, S_i) is irreducible.
This is based on joint work with D. Dutkay and E. Weber. (Received August 23, 2018)

1144-46-198 **Edward S. Sichel*** (edsichel@mail.fresnostate.edu), Department of Mathematics, California State University, Fresno, 5245 North Backer Avenue, M/S PB108, Fresno, CA 93740-8001. *On the Nature of Expansions on Compact and Totally Bounded Metric Spaces and More.* Preliminary report.
When proving a known result describing expansive mappings on compact metric spaces as isometric surjections, we observe that relaxing the condition of compactness to total boundedness preserves the isometry property, and nearly so that of surjectivity.

While a counterexample is found showing that the converse statements to the above descriptions do not hold, we are still able to characterize boundedness in terms of a certain specific type of expansions we call *anticontractions*. (Received August 24, 2018)

1144-46-216 **Jack Spielberg*** (jack.spielberg@asu.edu), **Xin Li**, **Tron Omland**, **David Pask** and **Adam Sorensen**. *Semigroup C^*-algebras from permutations.* Preliminary report.
Let f be a permutation of a set S, and define a semigroup by the presentation $\langle S \mid af(a) = bf(b) \text{ for } a, b \in S\rangle^+$. One can show that this semigroup is left cancellative, and therefore one can construct from it an ample étale groupoid. We will describe the structure of these groupoids and their C^*-algebras, including K-theory calculations. This is joint work with Xin Li, Tron Omland, David Pask, and Adam Sørensen. (Received August 25, 2018)

1144-46-232 **Andrea Arauza Rivera***, 25800 Carlos Bee Blvd, Office: SF 570, Hayward, CA 94542. *Spectral Triples and Fractal Sets.*
We explore how one can use the tools from operator algebras and noncommutative geometry to study properties of fractal sets. The properties we explore are fractal dimension, metric, and certain fractal measures. The fractal sets known as the Sierpinski gasket and stretched Sierpinski gasket will be our main examples. (Received August 26, 2018)

1144-46-245 **Michael Hartglass*** (mhartglass@scu.edu), Department of Mathematics, 500 El Camino Real, Santa Clara, CA 95053-0290, and **Dave Penneys**. *Weighted graphs as quantum compact metric spaces.* Preliminary report.
Given a weighted graph, one can construct associated graph and loop algebras. I will show that in many cases, the loop algebras possess the structure of quantum compact metric spaces. This is joint work with Dave Penneys. (Received August 27, 2018)

1144-46-273 **Lauren C. Ruth*** (lcruth222@gmail.com). *An observation on the limit multiplicity property and representations of lattice group II_1 factors.*
Let G be a locally compact unimodular group having square-integrable irreducible unitary representations, let $\{\Gamma_i\}_{i\in\mathbb{N}}$ be a family of ICC lattices in G satisfying the limit multiplicity property, and let Γ_{i_0} be any member of this family. After providing background on the limit multiplicity property, we explain how it can be applied to give finite-von-Neumann-dimensional representations of the II_1 factor $R\Gamma_{i_0}$ on a subspace of $L^2(\Gamma_i\backslash G)$ for infinitely many i. (Received August 27, 2018)

1144-46-287 **Judith A. Packer*** (packer@colorado.edu), Department of Mathematics, Campus Box 395, University of Colorado, Boulder, BOULDER, CO 80309-0395. *Monic representations for higher–rank graph C^*-algebras.*

This talk discusses the notion of monic representations for C^*-algebras associated to finite higher–rank graphs without sources, generalizing a concept first defined by D. Dutkay and P. Jorgensen for representations of Cuntz algebras. Monic representations are those that, when restricted to the commutative C^*–algebra of continuous functions on the infinite path space associated to the graph, admit a cyclic vector. We connect these representations to the Λ-semibranching systems studied in earlier joint work with C. Farsi, E. Gillaspy, and S. Kang. The results discussed are based on joint work with C. Farsi, E. Gillaspy, S. Kang, and P. Jorgensen. (Received August 27, 2018)

1144-46-309 **Timothy Rainone*** (trainone@asu.edu). *Finite/infinite dichotomies in operator algebras.*

Notions of paradoxical decompositions appear in the work of Hausdorff, Banach, and Tarski who showed that a group satisfies the amenable/paradoxical divide. In this talk we study paradoxical phenomena in the field of operator algebras; directing our focus on C*-algebras that arise from dynamical systems. Like Tarski, we use the type semigroup construction to move from non-paradoxicality to the existence of traces. When the underlying algebra has a well-behaved K-theory, this semigroup witnesses the stably finite/purely infinite nature of the corresponding reduced crossed product C*-algebra. Moreover, we show that for a large class of these crossed products stable finiteness is equivalent to being MF; i.e. embeddable into a corona of matrix algebras. (Received August 28, 2018)

1144-46-326 **Ian E. Mitscher*** (ian.mitscher@asu.edu) and **Jack Spielberg**. *Investigating when the C^*-algebra of a category of paths is AF.* Preliminary report.

Categories of paths and their C*-algebras were introduced by Spielberg in 2014 which generalize (among other things) C*-algebras of k-graphs. In this talk, we will discuss the current state of our investigation into when such a C*-algebra is approximately finite dimensional, with a focus on a particular example. (Received August 28, 2018)

1144-46-332 **Ian Charlesworth*** (ilc@math.ucsd.edu), **Ching-Wei Ho** and **Todd Kemp**. *A Bi-free Segal-Bargmann Transform.* Preliminary report.

The Segal-Bargmann transform in free probability provides an isometric isomorphism between the L^2 space of a semicircular random variable and the Hardy space of the disc, and can be described with the aid of the conditional expectation from an algebra generated by a pair of free variables – one circular and one semicircular – onto the algebra generated by the circular variable. We extend this idea to the setting of bi-free probability and define a Segal-Bargmann transform on the L^2 space of two commuting (correlated) semicircular variables, one treated as a left variable and one as a right. We show that in this setting the transform is no longer injective, but that the norm induced on its image is equivalent to that of a weighted Bergman space. (Received August 28, 2018)

1144-46-336 **Erik Bédos** and **S Kaliszewski***, SoMSS / ASU, PO Box 871804, Tempe, AZ 85287, and **John Quigg**. *Skew Products: Coactions We Can See.* Preliminary report.

Given a left-cancellative small category $\mathcal{C}$ (in the sense of Spielberg), a discrete group G, and a functor $\eta\colon \mathcal{C} \to G$, we construct a *skew product* category $\mathcal{C} \times_\eta G$. This represents a coaction "we can see" in the sense that there exists a C^*-coaction δ of G on the Cuntz-Krieger algebra $\mathcal{O}(\mathcal{C})$ such that $\mathcal{O}(\mathcal{C} \times_\eta G) \cong \mathcal{O}(\mathcal{C}) \rtimes_\delta G$. Moreover, the skew product carries a natural free action of G that corresponds to the dual action $\hat{\delta}$ under this isomorphism, and this allows us to recover $\mathcal{C}$ as the quotient category $(\mathcal{C} \times_\eta G)/G$. As a sort of converse, we also have a "Gross-Tucker"-type theorem that says that any LCSC that carries a free action of G can be realized as a skew product category.

In this talk, I'll present these results in as elementary a fashion as possible, and say what I can about their proofs. I'll also endeavor to explain how the theory fits into a broader context — one that goes back nearly 20 years to ideas of Kumjian, Pask, and Raeburn for the case of graph C^*-algebras.

This is joint work-in-progress with Erik Bédos and John Quigg. (Received August 28, 2018)

47 ► Operator theory

1144-47-107 **Lara M. Ismert*** (lara.ismert@huskers.unl.edu). *Kernel Stabilization of Derivations on C^*-algebras.*

We consider a weakly-defined derivation on $B(H)$ that is implemented by an unbounded self-adjoint operator. We show that this derivation has a surprising property, which we refer to as *kernel stabilization*. Consequently, a certain class of derivations on C^*-algebras, originally studied in a 1975 article by Bratteli and Robinson, also have kernel stabilization. As another corollary, we provide what we believe are new conditions under which two self-adjoint operators satisfying the Heisenberg Commutation Relation must both be unbounded. (Received August 16, 2018)

1144-47-145 **Yunied Puig de Dios*** (puigdedios@gmail.com), 900 University Ave., Riverside, CA 92521. *Kříž Theorem via dynamics of linear operators.*

The existence of a set A of positive upper Banach density such that $A - A$ does not contain a set of the form $E - E$ with E piecewise syndetic is in essence the content of a popular result due to Kříž in 1987, in which he used a graph-theoretical approach. More recently, a simplification of Kříž's construction has been presented by McCutcheon based on an idea of Ruzsa, using combinatorial number theory. Our goal is to show that a stronger result than the one given by Kříž's can be obtained, and that this can be done via operator theory, namely using dynamics of linear operators. (Received August 22, 2018)

1144-47-179 **Marat V. Markin*** (mmarkin@csufresno.edu), Department of Mathematics, California State University, Fresno, 5245 North Backer Avenue, M/S PB108, Fresno, CA 93740-8001. *On the Non-hypercyclicity of Scalar Type Spectral Operators and Collections of Their Exponentials.* Preliminary report.

We give a straightforward proof of the non-hypercyclicity of an arbitrary *scalar type spectral operator* A (bounded or not) in a complex Banach space as well as of the collection $\{e^{tA}\}_{t\geq 0}$ of its exponentials, which, under a certain condition on the spectrum of A, coincides with the C_0-semigroup generated by it. The spectrum of A lying on the imaginary axis, it is shown that non-hypercyclic is also the generated by it strongly continuous group $\{e^{tA}\}_{t\in\mathbb{R}}$ of bounded linear operators. As an important particular case, we immediately obtain that of a *normal operator* A in a complex Hilbert space. (Received August 24, 2018)

1144-47-186 **Ronald Douglas** (rdouglas@math.tamu.edu) and **Mohammad Jabbari*** (jabbari@wustl.edu), Department of Mathematics and Statistics, Washington University in St. Louis, 1 Brookings Drive, St. Louis, MO 63130, and **Xiang Tang** (xtang@wustl.edu) and **Guoliang Yu** (guoliangyu@math.tamu.edu). *A New Index Theorem for Monomial Ideals by Resolutions.*

I motivate and state an index theorem for the quotient module of a monomial ideal. This is obtained by resolving the monomial ideal by a sequence of essentially normal Hilbert modules, each of which is a direct sum of weighted Bergman spaces on unit balls. (Received August 24, 2018)

1144-47-215 **Linda J. Patton*** (lpatton@calpoly.edu) and **Caixing Gu**. *A Composition Operator Norm Upper Bound on Multivariable Reproducing Kernel Hilbert Spaces.*

If φ is an analytic self-map of the disk, then it is well known that the norm of the corresponding composition operator on the Hardy space $H^2(\mathbb{D})$ satisfies $\|C_\varphi\|^2 \leq \frac{1+|\varphi(0)|}{1-|\varphi(0)|}$. Analogous versions of this result hold on many spaces of analytic functions. In 2007, Jury showed that the inequality follows from the positivity of an associated De Branges-Rovnyak kernel. Jury's alternate proof recovered the usual theorem on the known spaces; it also provided a generalization of the inequality to most standard reproducing kernel spaces on the ball. In joint work with Caixing Gu, we show that with a modification, Jury's method can be extended further to derive the inequality on the Hardy space of the polydisk and to Dirichlet-type spaces on the ball. Some examples will be discussed. (Received August 25, 2018)

1144-47-341 **Xiaochuan Tian*** (xctian.ustc@gmail.com). *Consistent traction boundary conditions for nonlocal models.*

This talk presents a consistent approach to prescribe traction/Neumann boundary conditions for nonlocal continuum models on bounded domains. The idea is to embed the finite domain into infinite system by (nonlocal) harmonic interactions, from which the traction in the far field can be deduced. We will show the equivalence of the proposed nonlocal Neumann boundary value problem with the nonlocal problem on the whole space. Patch test consistency can be easily seen from a Liouville-type property. (Received August 28, 2018)

49 ► Calculus of variations and optimal control; optimization

1144-49-101 **Xiaodong Li*** (xdgli@ucdavis) and **Ji Chen** (ljichen@ucdavis.edu). *Nonconvex Matrix Completion: Assumption-free Local Minimum Analysis and Applications in Memory-efficient Kernel PCA.*

In this talk, we study nonconvex matrix completion from a perspective of assumption-free approximation: with no assumptions on the underlying positive semidefinite matrix in terms of rank, eigenvalues or eigenvectors, we established the low-rank approximation error based on any local minimum of the proposed objective function. As interesting byproducts, when certain assumptions are imposed on the rank, eigenvalues, eigenvectors, and the sampling rates, corollaries of our main theorem improve the state-of-the-art results in the literature of nonconvex matrix completion with no spurious local minima. We also discussed how the proposed low-rank approximation framework is applied to memory-efficient Kernel PCA, and numerical experiments also show that our approach is competitive in terms of approximation accuracy compared to the well-known Nystrom algorithm. (Received August 14, 2018)

1144-49-113 **Matias Delgadino**, **Francesco Maggi** and **Cornelia Mihaila*** (cornelia.mihaila@gmail.com), Department of Mathematics, University of Chicago, 5734 S. University Avenue, Room 108, Chicago, IL 60637, and **Robin Neumayer**. *Bubbling with L^2 almost constant mean curvature and an Alexandrov type theorem for crystals.*

I will discuss a recent result in which an Alexandrov-type theorem for L^2 almost constant anisotropic mean curvature sets is proven. In addition I will provide a description of critical points/local minimizers for elliptic energies interacting with a confinement potential. An improvement on previous almost constant mean curvature results is our use of L^2 versus C^0 closeness, since this should have applications in mean curvature flow and is new even in the isotropic case. This talk is based on a joint work with Matias Delgadino, Francesco Maggi, and Robin Neumayer. (Received August 18, 2018)

51 ► Geometry

1144-51-16 **Hemangi Madhusudan Shah*** (hemangimshah@hri.res.in), Harish-Chandra Research Institute, Chhatnag Road, Jhunsi, Allahabad, 211019, India. *Geometry of asymptotically harmonic manifolds with minimal horospheres.*

(M^n, g) be a complete and simply connected Riemannian manifold without conjugate points. We show that, then M is flat, provided that M is also asymptotically harmonic manifold with minimal horospheres (AHM). The (first order) flatness of M is shown by using the strongest criterion: $\{e_i\}$ be an orthonormal basis of T_pM and $\{b_{e_i}\}$ be the corresponding Busemann functions on M. Then, (1) The vector space $V = span\{b_v | v \in T_pM\}$ is finite dimensional and $\dim V = \dim M = n$. (2) $\{\nabla b_{e_i}(p)\}$ is a global parallel orthonormal basis of T_pM for any $p \in M$. Thus, M is a parallizable manifold. And (3)$F : M \to \mathbb{R}^n$ defined by $F(x) = (b_{e_1}(x), b_{e_2}(x), \cdots, b_{e_n}(x))$, is an isometry and therefore, M is flat. Consequently, AH manifolds can have either polynomial or exponential volume growth, generalizing the corresponding result for harmonic manifolds. In case of harmonic manifold with minimal horospheres, the (second order) flatness was proved by showing that $span\{b_v^2 | v \in T_pM\}$ is finite dimensional. (Received June 18, 2018)

1144-51-152 **Xiaoye Fu*** (xiaoyefu@mail.ccnu.edu.cn), Wuhan, Hubei 430079, Peoples Rep of China, and **Jean-Pierre Gabardo** and **Hua Qiu**. *Open set condition and Pseudo Hausdorff measure of self-affine IFSs.*

Let A be an $n \times n$ real expanding matrix and $0 \in \mathcal{D} \subset \mathbb{R}^n$ be a finite subset . The family of maps $\{f_d(x) = A^{-1}(x + d)\}_{d\in\mathcal{D}}$ is called a self-affine iterated function system (IFS). The self-affine set $K = K(A, \mathcal{D})$ is the unique compact set determined by $(A, \mathcal{D})$ satisfying $K = \bigcup_{d\in\mathcal{D}} f_d(K)$. In this paper, we show that $\mathcal{H}^s_w(K) > 0$, the pseudo Hausdorff measure of K, is equivalent to that the IFS satisfies the open set condition (OSC), where the pseudo Hausdorff measure $\mathcal{H}^s_w(K)$ was introduced by He and Lau in Math. Nachr 281: 1142-1158, 2008, and $s := n \log^{\#\mathcal{D}}_{|\det A|}$ is called the pseudo similarity dimension of K. This extends the well-known result for the self-similar case that the OSC is equivalent to that K has positive Hausdorff measure. Furthermore, we relate the exact value of pseudo Hausdorff measure $\mathcal{H}^s_w(K)$ to a notion of upper s-density with respect to the pseudo

norm $w(x)$ associated with A for the measure $\mu = \lim_{M\to\infty} \sum_{d_0,\ldots,d_{M-1}\in\mathcal{D}} \delta_{d_0+Ad_1+\cdots+A^{M-1}d_{M-1}}$ in the case that $\#\mathcal{D} \leq |\det A|$. (Received August 22, 2018)

1144-51-182 **Franklin Mendivil***, Department of Mathematics and Statistics, Acadia University, 12 University Avenue, Huggins Science Hall Rm, Wolfville, NS B4P 2R6, Canada. *Size of rearrangements of linear Cantor sets.*

Each compact subset of $[0, 1]$ is defined by its (countable) collection of complementary gaps. The collection of all of the lengths of these gaps encodes a great deal of information about the geometry of the set (in particular various dimensions). A "rearrangement" of a set has the same collection of gap lengths (but with a different ordering). In this talk we will give a brief survey of results about the "size" (box-counting, packing, Hausdorff, and Assouad dimensions) of rearrangements of a Cantor set. (Joint work with Ignacio Garcia, Kathryn Hare, and Leandro Zuberman) (Received August 24, 2018)

1144-51-240 **Or Hershkovits*** (orher@stanford.edu) and **Brian White**. *The topology of self-shrinkers and sharp entropy bounds.*

The Gaussian entropy, introduced by Colding and Minicozzi, is a rigid motion and scaling invariant functional which measures the complexity of hypersurfaces of the Euclidean space. It is defined to be the supremal Gaussian area of all dilations and translations of the hypeprsurface, and as such, is well adapted to be studied by mean curvature flow. In the case of the n-th sphere in R^{n+1}, the entropy can be computed explicitly, and is decreasing as a function of the dimension n.

A few years ago, Colding Ilmanen Minicozzi and White proved that all closed, smooth self-shrinking solutions of the MCF have larger entropy than the entropy of the n-th sphere. In this talk, I will describe a generalization of this result, which derives better (sharp) entropy bounds under topological constraints. More precisely, we show that if M is any closed self-shrinker in R^{n+1} with a non-vanishing k-th homology group (with $k \leq n$), then its entropy is higher than the entropy of the k-th sphere in R^{k+1}. (Received August 26, 2018)

1144-51-288 **Xiaolong Li*** (xiaolol1@uci.edu). *Four-dimensional Gradient Shrinking Ricci Solitons.*

I will discuss some recent results on the classification of four-dimensional gradient shrinking Ricci solitons with positivity assumptions on isotropic curvature. (Received August 27, 2018)

1144-51-312 **James A. Francese*** (francese@chapman.edu). *Cohomology of Bicomplex-type Structures on Manifolds.* Preliminary report.

Complexification as an operation on real analytic manifolds leads to classical results allowing one to phrase this operation as a faithful functor into a category of Stein spaces, a collective finding of Bruhat-Whitney, Morrey, and Grauert. However, they are constructively known only up to homotopy. From a moduli space perspective, this is clear, since homotopy classes of non-degenerate 2-forms classify complex structures on manifolds. The situation is completely different for manifolds which are already complex, or carry other G-structure. In such cases the complexified G-structure is automatically equivalent to compatible foliations which provide a canonical model for the resulting manifold. Our focus is on almost bicomplex structures on real manifolds where we establish torsion conditions for the existence of special Hodge structures on de Rham cohomology. (Received August 28, 2018)

1144-51-344 **Richard Kyung*** (nycrick@gmail.com), NJ , and **Jae Mo Shin** (jaemoshin@choicerg.com), NJ. *Study on the Calculus of Variations and Mean Boundary Proof for Isoperimetric Problems.*

Isoperimetric Theorem has been known as a fascinating topic, and the most essential contribution to the topic has been provided by Jacob Steiner. Also, as for the mathematics of the isoperimetric problem, a mathematician Zenodorus (200 B.C.-140 B.C.) studied the area of a figure with fixed diameter, proving that a circle has greater area than any polygon with the same perimeter. Variational method explained that a regular n-gon has greater area than all other n-gons with the same perimeter.

Steiner's mean boundary proof shows that the difference between the smallest and the largest diameter decreases, for by the process, when the new axis is chosen, the largest diameter will be made smaller and the smallest will be made larger. By choosing the appropriate new axes, the diameters can be brought closer to equality faster.

This paper shows that the solution of this isoperimetric problem by means of calculus of variations can be useful for the proof using computational analysis compared to using classical method. (Received August 29, 2018)

53 ► Differential geometry

1144-53-12 **Duong H. Phong**, **Sebastien Picard** and **Xiangwen Zhang*** (xiangwen@math.uci.edu). *The Anomaly flow.*

We discuss the development on geometric and analytic aspects of the Anomaly flow. Such flow naturally arises in the study of a system of equations for supersymmetric vacua of superstrings proposed independently by C. Hull and A. Strominger in 1980s. The system allows non-vanishing torsion and they incorporate terms which are quadratic in the curvature tensor. As such they are also particularly interesting from the point of view of both non-Kaehler geometry and the theory of nonlinear partial differential equations. It turns out that the corresponding flow shares some features with the Ricci flow and preserves the conformally balanced condition of Hermitian metrics. (Received June 01, 2018)

1144-53-13 **Paul Laurain** and **Longzhi Lin*** (lzlin@ucsc.edu). *Energy convexity of intrinsic bi-harmonic map and its heat flow I: spherical target.*

Every harmonic map is an intrinsic bi-harmonic map as an absolute minimizer of the intrinsic bi-energy, therefore intrinsic bi-harmonic map and its heat flow are more geometrically natural to study, but they are also considerably more difficult analytically than the extrinsic counterparts due to the lack of coercivity for the intrinsic bi-energy. In this talk, we will discuss an energy convexity and thus uniqueness for weakly intrinsic bi-harmonic maps from the unit 4-ball $B_1 \subset \mathbf{R}^4$ into the sphere $\mathbf{S}^n$. This is a higher-order analogue of the energy convexity and uniqueness for weakly harmonic maps on unit 2-disk in $\mathbf{R}^2$ proved by Colding and Minicozzi in 2008. In particular, this yields a version of uniqueness of weakly harmonic maps on the unit 4-ball, which is new. We will also discuss a version of energy convexity along the intrinsic bi-harmonic map heat flow into $\mathbf{S}^n$, which in particular yields the long-time existence of the intrinsic bi-harmonic map heat flow, a result that was until now only known assuming the non-positivity of the target manifolds by Lamm in 2005. Moreover, the energy convexity along the flow yields the uniform convergence of the flow, which is not known before. This is joint work with Paul Laurain. (Received June 04, 2018)

1144-53-47 **Shoo Seto*** (shoos@uci.edu) and **Casey Blacker**. *The first eigenvalue of the p-Laplacian on Kähler manifolds.*

We prove a Lichnerowicz type lower bound for the first nontrivial eigenvalue of the p-Laplacian on Kähler manifolds. Parallel to the $p = 2$ case, the first eigenvalue lower bound is improved by using a decomposition of the Hessian on Kähler manifolds with positive Ricci curvature. (Received August 01, 2018)

1144-53-48 **Jasmine Camero*** (jasminecamero@csu.fullerton.edu), 800 N. State College Blvd., California State University, Fullerton, Department of Mathematics, McCarthy Hall 154, Fullerton, CA 92834-6850. *A Ladder of Curvatures in the Geometry of Surfaces and a Curvature Invariant Inspired by Euler's Inequality.*

In the classical differential geometry of surfaces there are two curvature invariants: the Gaussian curvature (introduced by Gauss in 1827) and the mean curvature (introduced by Sophie Germain in 1831). In the present work we propose the investigation of a new curvature invariant, the tangential curvature. Additionally, we show how Euler's classical inequality between circumradius and inradius inspires, by using a duality between triangle geometry and the local geometry of three-dimensional hypersurfaces lying in the four-dimensional Euclidean space, the definition of a curvature invariant. We investigate this quantity by relating it to other known curvature invariants. (Received August 01, 2018)

1144-53-51 **Xin Zhou*** (zhou@math.ucsb.edu), Department of Mathematics, South Hall 6501, University of California Santa Barbara, Santa Barbara, CA 93106, and **Jonathan Zhu**. *Min-max theory for hypersurfaces with prescribed mean curvature.*

In this talk, I will present constructions of closed hypersurfaces of constant mean curvature and more generally closed hypersurfaces with prescribedg mean curvature using min-max method. In particular, given any closed Riemannian manifold, I will show the existence of a closed hypersurface of any prescribed mean curvature. These are joint works with Jonathan Zhu. (Received August 02, 2018)

1144-53-74 **Qiang Guang*** (guang@math.ucsb.edu), Department of Mathematics, University of California, Santa Barbara, CA 93106. *Compactness and generic finiteness for free boundary minimal hypersurfaces.*

Minimal surfaces with free boundary are critical points of the area functional in compact manifolds with boundary. If we do not assume any boundary convexity of the ambient manifold, then the free boundary minimal surfaces may be improper; that is, the interior of the surface may touch the boundary of the ambient manifold.

In this talk, we present recent work on compactness and generic finiteness results for improper free boundary minimal surfaces. This is joint work with Zhichao Wang and Xin Zhou. (Received August 09, 2018)

1144-53-87 **Richard H. Bamler*** (rbamler@berkeley.edu), Department of Mathematics, University of California, Berkeley, Berkeley, CA 94720. *Classification of diffeomorphism groups of 3-manifolds through singular Ricci flow.*

I will present recent work of Bruce Kleiner and myself in which we classify the homotopy type of all spherical and hyperbolic 3-manifolds, with the exception of RP^3 in the spherical case. This partially resolves the Generalized Smale Conjecture in the spherical case and reproves a theorem due to Gabai in the hyperbolic case.

Our proof is based on a new uniqueness theorem for singular Ricci flows, which we have established in previous work. Singular Ricci flows were introduced by Kleiner and Lott and are similar to Perelman's Ricci flows with surgery, as used in his resolution of the Poincaré and Geometrization Conjectures. In contrast to Perelman's surgery process, which is carried out at a positive scale and depends on a number of auxiliary parameters, a singular Ricci flow is more canonical, as it "flows through surgeries" at an infinitesimal scale. Our uniqueness theorem allows the study of continuous families of singular Ricci flows, providing important information on the diffeomorphism group of the underlying manifold. (Received August 13, 2018)

1144-53-90 **Leonard M. Giugiuc** and **Bogdan D. Suceavă*** (bsuceava@fullerton.edu), 800 N. State College Blvd., Department of Mathematics, 154 McCarthy Hall, Fullerton, CA. *Strictly Convex Hypersurfaces Satisfying Weingarten-Type Inequalities.*

Linear Weingarten surfaces in three-dimensional ambient space satisfy a relation between mean curvature and Gaussian curvature: $aH^2+bK = c$. We investigate whether for hypersurfaces invariant to inversions of dimensions 3 and 4 there are curvature inequalities similar to the classical Weingarten condition. We also consider the globalization of these pointwise inequalities. This question is suggested by the investigations of Bang-Yen Chen's fundamental inequalities, as we reflect on the geometric interpretations of these relations. (Received August 13, 2018)

1144-53-133 **Jingyi Chen*** (jychen@math.ubc.ca), Department of Mathematics, The University of British Columbia, Vancouver, BC V6T1Z2, Canada. *Compactification of the space of Hamiltonian stationary Lagrangian submanifolds.*

In this talk, we will discuss sequential convergence of closed Hamiltonian stationary Lagrangian submanifolds in the complex Euclidean space, under the assumption that the volumes and the total extrinsic curvatures are uniformly bounded. A removable singularity result will also be discussed. This is joint work with Micah Warren. (Received August 21, 2018)

1144-53-137 **Noelle Sawyer*** (nsawyer@wesleyan.edu). *Volume and partial length spectrum data.* Preliminary report.

The marked length spectrum of a metric on a compact Riemannian manifold records the length of the shortest closed curve in each free homotopy class. Let S be a surface. It is known that an inequality between the marked length spectra of two metrics on S implies a corresponding inequality between the area with respect to the metrics. I will show that the same conclusion holds if the inequality only holds on particular subsets of $\pi_1(S)$. (Received August 21, 2018)

1144-53-141 **Beomjun Choi*** (bc2491@columbia.edu) and **Panagiota Daskalopoulos** (pdaskalo@math.columbia.edu). *Regularity of Non-compact Inverse Mean Curvature Flow.*

A priori lower bound on the mean curvature is key to obtain smooth regularity of the inverse mean curvature flow. We present a new maximum principle based method for such an estimate. First, the regularity estimates of Huisken-Ilmanen for closed star-shaped solutions will be revisited with this method. Then, new estimates for non-compact solutions will be shown. We use this to obtain the long time existence of smooth solutions for complete non-compact convex hypersurfaces in $\mathbb{R}^{n+1}$. (Received August 22, 2018)

1144-53-142 **Beomjun Choi*** (bc2491@columbia.edu), **Kyeongsu Choi** (choiks@mit.edu) and **Panagiota Daskalopoulos** (pdaskalo@math.columbia.edu). *Convergence of Curve Shortening Flow to Translating Soliton.*

We prove locally smooth convergence of the curve shortening flow to a translating soliton, so called grim reaper solution, as time goes to infinity when the initial curve is (non-compact) convex complete curve whose two ends are asymptotic to two parallel straight lines. This generalizes to the convergence of κ^α power curvature flow of curves for $\alpha > 1/2$ and this is optimal in the sense that there is no translating soliton located between two parallel lines for $\alpha \leq 1/2$. (Received August 22, 2018)

1144-53-165 **Jeff Streets***, 11 WHEATLEY CT, IRVINE, CA 92617. *Classification of generalized Ricci solitons on complex surfaces.*

In joint work with G. Tian we introduced an extension of Kahler-Ricci flow to complex manifolds, called pluriclosed flow, aiming to associate canonical geometric structures to complex manifolds beyond the Kahler setting. A fundamental issue is to understand the possible fixed points of the flow, or more generally, soliton solutions. I will prove that nontrivial soliton structures can only occur on Hopf surfaces, and then construct such solitons on Class 1 Hopf surfaces using a symmetry ansatz. (Received August 23, 2018)

1144-53-241 **Brett Kotschwar*** (kotschwar@asu.edu). *On the maximal rate of convergence of the Ricci flow.*

We show that a solution to the normalized Ricci flow which converges to a round sphere faster than any exponential must coincide with a shrinking sphere, and discuss a connection to asymptotically cylindrical shrinking solitons. (Received August 26, 2018)

1144-53-298 **Yousef K. Chahine*** (ychahine@math.ucsb.edu), Department of Mathematics, University of California, Santa Barbara, CA 93106. *Volume estimates for tubes around submanifolds using integral curvature bounds.*

We generalize an inequality of E. Heintze and H. Karcher for the volume of tubes around minimal submanifolds to an inequality based on integral bounds for k-Ricci curvature. Even in the case of a pointwise bound this generalizes the classical inequality by replacing a sectional curvature bound with a k-Ricci bound. This work is motivated by the estimates of Petersen-Shteingold-Wei for the volume of tubes around a geodesic and generalizes their estimate. Using similar ideas we also prove a Hessian comparison theorem for k-Ricci curvature which generalizes the usual Hessian and Laplacian comparison for distance functions from a point and give several applications. (Received August 28, 2018)

1144-53-299 **Mihaela B Vajiac*** (mbvajiac@chapman.edu), Chapman University, Keck 365, One University Drive, Orange, CA 92866. *Moduli on Multicomplex Spaces.*

Multicomplex analysis describes the theory of holomorphic functions on spaces generated by n commuting complex units. In this context we extend some notions of moduli from the space of bicomplex numbers to the space of multicomplex numbers. We use this approach towards meaningful theory of Riemannian and semi-Riemannian geometries on such spaces. (Received August 28, 2018)

1144-53-343 **Cezar Lupu*** (lupucezar@gmail.com), 2500 Broadway, Lubbock, TX 79409. *Geodesics in the Heisenberg group revisited.* Preliminary report.

In this talk, we discuss some recent work of Hajlasz and Zimmerman (https://www.degruyter.com/downloadpdf/j/agms.2015.3.issue-1/agms-2015-0020/agms-2015-0020.pdf) on the geodesics in the Heisenberg group. Firstly, we show that the isoperimetric inequality proved in the paper for curves in $\mathbb{R}^{2n}$ can be derived directly from the strong form of Wirtinger's inequality. The structure of the geodesics follows immediately from the equality case. Secondly, based on the Wirtinger's inequality idea, we prove some Bonnesen-type inequalities and stability results for curves in $\mathbb{R}^{2n}$. Last but not least, if time allows, we would like to generalize the result to closed curves in $\mathbb{R}^3$, and perhaps to give an interpretation in terms of Sobolev-type inequalities. (Received August 28, 2018)

54 ► General topology

1144-54-100 **Nicholas Cazet***, nicholas.cazet@sjsu.edu. *Distortion of Lattice Stick Knots.* Preliminary report.

Most prototypical knots are the diffeomorphic image of S^1 into S^3, but one may define a knot using sticks. A *stick knot* is a knot comprised of piecewise linear components. A prominent question of stick knot theory is, how few sticks does one need to construct a given knot? When the constituent sticks are each parallel to the x-, y-, or z-axis, and are of integer length, K is called a *lattice stick knot*. The number of sticks required to form a lattice stick knot is bounded below by a multiple of its bridge index. This will allow us to generate a class of minimal stick torus knots and compute the distortion of said knots. The *distortion* of a lattice knot configuration is a measure of its complexity. A knot configuration is highly distorted if there exists a pair of points on the knot that are 'close' in ambient space but 'far' in geodesic length along the closed curve. We will construct a minimal stick configuration of the $(p, p+1)$-torus knot and illustrate that the minimal arclength and distortion are both quadratic functions of p. (Received August 14, 2018)

57 ► Manifolds and cell complexes

1144-57-38 **Kenneth C Millett*** (millett@math.ucsb.edu), Department of Mathematics, UCSB, Santa Barbara, CA 93106. *Local Entanglement in Macromolecules.*

The structure and consequences of local entanglement in a macromolecular chain, i.e. as measured by the linking between one sub chain and another, disjoint, sub chain, will be described using a local linking fingerprint that has been created for this specific purpose. The local linking fingerprint will be applied to several difference circumstances arising in the study of protein structures illustrating the character of local linking in scientifically interesting instances. (Received July 24, 2018)

1144-57-150 **Marion Campisi*** (marion.campisi@sjsu.edu) and **Nicholas Cazet**. *Vertex distortion of knots in the cubic lattice.*

The vertex distortion of a conformation of a lattice knot is the supremum of the ratio of the distance between a pair of vertices along the knot and the distance in the ℓ_1 norm. We generalize results of Gromov and Pardon about the distortion of smooth knots and show that the distortion of a lattice knot is 1 if and only if it is the unknot and that there are minimal stick number knot conformations with arbitrarily high distance. (Received August 22, 2018)

1144-57-176 **Eric J Rawdon*** (ejrawdon@stthomas.edu). *Knots in extreme confinement.* Preliminary report.

We consider models of nearly-equilateral polygonal knots in extreme confinement. In particular, we compare geometric measurements of these extremely confined knots with previous measurements on knots which are equilateral but are not under as much confinement pressure. This work is in collaboration with Yuanan Diao, Claus Ernst, and Uta Ziegler, as well as students Zach Sorenson and Isaac Vraspir. (Received August 23, 2018)

1144-57-272 **Uta Ziegler*** (uta.ziegler@wku.edu), 1906 College Heights Blvd, Bowling Green, KY 42101, and **Y. Diao**, **C. Ernst** and **E Rawdon**. *The average geometric entanglement of confined random polygons.*

Polymers in spatially confined conditions are on average more entangled than unconfined polymers. The average crossing number and the writhe can be considered measures of spatial entanglement and confinement influences both. This presentation shows the results of an empirical study to answer the question: How does the level of confinement, the polymer length and its knotting affect the average geometric entanglement of polymers?

In this study polymers are modeled using equilateral, freely-joined, random polygons rooted at the origin. Confinement is modeled with a sphere centered at the origin. A very large confinement sphere models the unconfined situation. Confinement pressure increases through decreasing the confinement radius and/or through increasing the number of edges of the polygons. This model allows us to study changes that occur from (nearly) no confinement to very strong confinement. (Received August 27, 2018)

1144-57-274 **Claus Ernst*** (claus.ernst@wku.edu), Western Kentucky University, Department of Mathematics, 1906 College Heights Blvd., Bowling Green, KY 42101. *Knots where the braid index equals the bridge index.* Preliminary report.

The knots where the braid index equals the bridge index seem to have particular physical properties as demonstrated by several experiments. They undergo a periodic motion when sedimenting in a viscous fluid as knotted deformable closed chains, they also seem to achieve a circular minimum as elastic knots when their bending energy (curvature) is minimized. In this talk we study knots where the braid index equals the bridge index from a topological view. (Received August 27, 2018)

1144-57-291 **Harrison Chapman*** (hchaps@gmail.com) and **Andrew Rechnitzer**. *A Markov chain sampler for knot diagrams.*

Knot diagrams provide a model for entanglement in physical polymers whose complexity is precisely the number of crossing regions where the polymer comes close to itself. As a DNA model, these crossing regions may be viewed as sites for the strand-passage action of type II toposiomerases.

Diagrams of fixed type become exponentially rare, and so efficient random generation is a difficult problem. We describe a new Markov chain Monte Carlo sampler for knot diagrams representing any fixed knot type, whose transitions are natural diagram moves. We prove that the limiting distribution of this Markov chain is the uniform distribution. Using this sampler, we examine a number of classical polymer statistics in the knot diagram model. We then explore toposiomerase unknotting pathways for circular DNA in the diagram model. (Received August 27, 2018)

1144-57-311 **Koya Shimokawa***, Saitama University, Saitama, Japan. *Knots, links and spatial graphs in the simple cubic lattice.* Preliminary report.

We will consider knots, links and spatial graphs in the simple cubic lattice. We mainly discuss BFACF moves and ergodicity classes of knots, links and spatial graphs. (Received August 28, 2018)

58 ► Global analysis, analysis on manifolds

1144-58-164 **Michel L. Lapidus*** (lapidus@math.ucr.edu), University of California, Department of Mathematics, 900 University Ave., Riverside, CA 92521-0135. *Analysis on Fractals and Noncommutative Fractal Geometry.*

We plan to give a survey of several aspects of noncommutative fractal geometry, with emphasis on analysis on fractals and via spectral triples, Dirac operators, Dixmier traces, Hausdorff measures, as well as noncommutative and geodesic metrics. This talk is based, in particular, on early work of the author followed by more recent work of the author joint with E. Christensen and C. Ivan (Advances in Math.) and with J. Sarhad (J. Noncommutative Fractal Geometry), respectively. The class of fractals dealt with includes the classic Sierpinski gasket, the harmonic gasket (a typical example of a "fractal manifold"), and more generally, a large family of fractals built on rectifiable curves. If time permits, we will also briefly discuss very recent work (J. Fractal Geometry, in press) of one of the presenter's Ph.D. students, Andrea Arauza, which nicely supplements several aspects of the latter papers. We will also present several open problems in this area. (Received August 23, 2018)

1144-58-355 **Arek Goetz***, 1600 Holloway Ave, Department of Mathematics-SFSU, San Francisco, CA 94132. *Local dynamics of exchanges of cones.* Preliminary report.

We illustrate an exchange of cones leading to an infinite number of periodic disc in a neighborhood of a disc. Joint work with Peter Ashwin. (Received August 29, 2018)

60 ► Probability theory and stochastic processes

1144-60-9 **Jim Pitman** and **Wenpin Tang*** (wenpintang@math.ucla.edu). *The argmin process of random walks, Brownian motion and Lévy processes.*

In this talk, I will introduce the argmin process of Brownian motion B defined by $\alpha_t := \sup\{s \in [0,1] : B_{t+s} = \min_{u\in[0,1]} B_{t+u}\}$ for $t \geq 0$. The argmin process α is stationary, with invariant measure which is arcsine distributed. Surprisingly, the argmin process is a Markov process and its transition kernel can be explicitly computed. The proof is based on excursion theory and storage processes.

I will also discuss Brownian extrema of a given length. I will show that these extrema form a delayed renewal process with an explicit path construction. I also give a path decomposition for Brownian motion at these extrema. If time permits, results for the argmin process of random walks and Lévy processes will be discussed. (Received May 20, 2018)

1144-60-15 **Krzysztof Burdzy*** (burdzy@uw.edu), **Mauricio Duarte**, **Carl-Erik Gauthier** and **Jaime San Martin**. *On stirring coffee and Knudsen reflections.* Preliminary report.

I will discuss a deterministic model inspired by stirring coffee. The analysis of the model will be partly deterministic, and partly based on the Lambertian distribution.

The Lambertian distribution, also known as Knudsen's Law, is a model for random reflections of light or gas particles from rough surfaces. (Received June 11, 2018)

1144-60-19 **Eric Thomas Foxall*** (efoxall@ualberta.ca), 11324 89ave NW, Edmonton, AB T6G2J5, Canada. *Coalescing random walk on unimodular graphs.*

We prove almost sure site recurrence for coalescing random walk (CRW) on any unimodular random graph for which the root has finite expected degree. The proof relies on a linear (in time) bound on the annealed second moment of the cluster size in the dual process, namely the voter model. In turn, this bound is achieved through a first moment estimate on the size-biased cluster, by controlling the adhesion rate to a tagged particle in the CRW. Joint work with Tom Hutchcroft and Matt Junge. (Received June 27, 2018)

1144-60-20 **Indranil SenGupta*** (indranil.sengupta@ndsu.edu), NDSU Dept # 2750, Minard Hall 408, Fargo, ND 58108-6050, and **William Wilson** and **William Nganje**.
Barndorff-Nielsen and Shephard Model for Hedging Energy with Quantity Risk.

In this presentation, the Barndorff-Nielsen and Shephard (BN-S) model is implemented to find an optimal hedging strategy for oil from the Bakken, a new region of oil extraction that is benefiting from fracking technology. One of the main assumptions made in a portfolio model of hedging is that the quantity of inventory or demand is fixed. However, this is inappropriate in many hedging situations, particularly that of oil price increase. Quantity risk compounds the difficulty of determining the optimal size of position under both price and production risk. In this presentation, we provide a novel way of handling the quantity of risk in connection to the BN-S model. The model is analyzed in connection to the quadratic hedging problem and related analytical and numerical results are developed. (Received June 29, 2018)

1144-60-23 **Airam Blancas Benitez**, **Tim Rogers**, **Jason Schweinsberg*** (jschwein@math.ucsd.edu) and **Arno Siri-Jegousse**. *The nested Kingman coalescent: speed of coming down from infinity.*

The nested Kingman coalescent describes the ancestral tree of a population undergoing neutral evolution at the level of individuals and at the level of species, simultaneously. We study the speed at which the number of lineages descends from infinity in this hierarchical coalescent process and prove the existence of an early-time phase during which the number of lineages at time t decays as $2\gamma/ct^2$, where c is the ratio of the coalescence rates at the individual and species levels, and the constant $\gamma \approx 3.45$ is derived from a recursive distributional equation for the number of lineages contained within a species at a typical time. (Received July 04, 2018)

1144-60-29 **Andrey Sarantsev*** (asarantsev@unr.edu) and **Tomoyuki Ichiba** (ichiba@pstat.ucsb.edu). *Rate of Convergence for Reflected and Walsh Diffusions.*

We use coupling methods to find exponential rate of long-term convergence to the stationary distribution, for the following processes: Stochastic differential equations with reflection on the half-line; Walsh diffusions, which move along rays emanating from the origin, and choose randomly rays at the origin. (Received July 13, 2018)

1144-60-63 **Ionel Popescu*** (ipopescu@math.gatech.edu), School of Mathematics, 686 Cherry St., Atlanta, GA 30332, and **Mihai Pascu**, Faculty of Mathematics and Computer Science, Str. Iuliu Maniu Nr. 50, 500091 Brasov, Romania. *Fixed distance couplings of Brownian motions on Riemannian manifolds.*

In this talk I will show a construction of couplings of Brownian motions on a Riemannian manifold for which the distance between them is deterministic. One such particular case is the one with fixed distance for all times. On model manifolds we actually give a complete characterization of the couplings for which the distance function is deterministic. This is joint work with Mihai Pascu. (Received August 07, 2018)

1144-60-67 **Wojbor A Woyczynski*** (waw@case.edu). *Multiscale conservation laws driven by Lévy stable and Linnik diffusions: asymptotics, explicit representations, shock creation, preservation and dissolution.*

Asymptotic behavior of supercritical multifractal fractal conservation laws (CLs) with L_1 initial conditions is dictated by the linearized case. Thus obtaining explicit solutions of the latter is of interest. For $\alpha < 1$, CLs driven by Lévy α-stable diffusions exhibit shocks for bounded, odd, and convex on R^+, initial data. For Lévy α-Linnik diffusions,$0 < \alpha \leq 2$, the local behavior is strikingly different. The relevant CLs display shocks that do not dissipate over time while those for α-stable diffusion ($0 < \alpha \leq 1$) do. (Received August 07, 2018)

1144-60-72 **George Yin***, 656 West Kirby, Detroit, MI 48202. *Switching Diffusions and Applications.*

A switching diffusion is a Markov process. Such processes naturally arise in many control and optimization problems in which continuous dynamics and discrete events coexist. We present a survey of some of our recent work on switching random dynamical systems. In the setup, the discrete event is given by a random process with a finite state space, and the continuous component is the solution of a stochastic differential equation. Seemingly similar to diffusions, the processes have a number of salient features distinctly different from diffusion processes. After providing motivational examples arising from wireless communications, identification, finance, singular perturbed Markovian systems, manufacturing, and consensus controls, we present necessary and sufficient conditions for the existence of unique invariant measure, stability, stabilization, and numerical solutions of control and game problems. (Received August 09, 2018)

1144-60-76 **Jimmy Kenneth Risk*** (jrisk@cpp.edu), 739 Banyan Way, Pomona, CA 91767.
Gaussian Process Models for Mortality Rates and Improvement Factors: An Interactive R Markdown Approach.

We present a detailed analysis of Gaussian process models for mortality rates and improvement factors through an easy to use and understand R markdown format. By presenting the information this way, the ease of implementation is observed, as well as the flexibility of Gaussian processes, which can efficiently provide posterior predictions and credible intervals, both in and out of sample, for both mortality rates and improvement. We provide detailed results for US males with CDC data, and compare them to the gold standard SOA MP-2014 and -2015 models for mortality improvement. Finally, we use the R markdown file to produce figures for US females, as well as Japan and UK males and females. (Received August 10, 2018)

1144-60-96 **Dan Daniel Erdmann-Pham*** (erdpham@math.berkeley.edu), **Khanh Dao Duc** (daoduc@berkeley.edu) and **Yun S Song** (yss@berkeley.edu). *Hydrodynamic limit of the inhomogeneous ℓ-TASEP as a model for translation dynamics.*

Translation is a process during which ribosomes attach to strands of mRNA, advance along them at location specific jump rates, and finally detach, producing functional proteins. Mathematically, such dynamics are modelled well by an interacting particle system called the open-boundary inhomogeneous ℓ-TASEP, which has been explored extensively through simulations and mean field approximations, but whose exact analysis has remained elusive. Here we attempt to close this gap by means of deriving and completely characterising it in the hydrodynamic limit. After solving its associated PDE, we obtain closed form expressions for stationary currents, particle densities and a resulting phase diagram that, surprisingly, depend solely on four parameters: the particle size, and the first, last and minimum jump rates. Interpreting these variables in their biological context, we formulate four design principles that optimise translation efficiency through regulation of production capacities, system sensitivities, current limiting factors and particle expenditure. For each region in the phase diagram, our explicit formulas agree well with Monte Carlo simulations, and we identify evidence of the proposed design principles in a data set of previously inferred jump rates of 850 yeast genes. (Received August 13, 2018)

1144-60-102 **Maria Gordina*** (maria.gordina@uconn.edu). *Gradient bounds for hypoelliptic diffussions.*

We will present recent results on hypoelliptic diffusions such as Brownian motion with values in the Heisenberg group, and Kolmogorov type diffussions. The classical Kolmogorov diffusion has been introduced by Kolmogorov in 1934, and its generator was the simplest example of a hypoelliptic operator in Hormander's famous 1967 paper. While the standard tools for the elliptic operators can not be easily used in these settings, we can use coupling techniques and generalized curvature-dimension inequalities to prove gradient estimates and other functional inequalities.

Coupling is a way of constructing Markov processes with prescribed laws on the same probability space. It is known that the rate of coupling of elliptic/Riemannian diffusions is connected to the geometry of the underlying space. Banerjee and Kendall constructed successful Markovian couplings for a large class of hypoelliptic diffusions. We construct a non-Markovian coupling of Brownian motions on the Heisenberg group, and then use this coupling to prove analytic gradient estimates for harmonic functions for the sub-Laplacian. For Kolmogorov diffusions we use both coupling and generalized curvature-dimension inequalities to prove functional inequalities. Joint work with Banerjee, Baudoin and Mariano. (Received August 15, 2018)

1144-60-110 **David A Levin*** (dlevin@uoregon.edu) and **Yuval Peres**. *Mixing of the Biased Exclusion Process.*

In the biased exclusion process on the path with n sites, k particles perform biased random walks, with the restriction that sites cannot be occupied by more than one particle. We consider the case where the bias of the walks approach zero as n grows. We show pre-cutoff and identify different mixing time regimes based on the size of the bias. (Received August 16, 2018)

1144-60-114 **Wai Tong Fan*** (waifan@iu.edu), Bloomington, IN 47401, and **Timo Seppäläinen**. *Joint distribution of Busemann functions for the corner growth model.* Preliminary report.

We present the joint distribution of the Busemann functions, in all directions of growth, of the exactly solvable corner growth model (CGM). This gives a natural coupling of all stationary CGMs and leads to new results about geodesics. Properties of this joint distribution are accessed by identifying it as the unique invariant distribution of a multiclass last passage percolation model. This is joint work with Timo Seppäläinen. (Received August 18, 2018)

1144-60-117 **Francois Baccelli*** (baccelli@math.utexas.edu), **Mir-Omid Haji-Mirsadeghi** and **Ali Khezeli**. *On the Dimension of Unimodular Discrete Spaces.* Preliminary report.

This work is focused on large scale properties of infinite graphs and discrete subsets of the Euclidean space. It presents two new notions of dimension, namely the unimodular Minkowski and Hausdorff dimensions. These dimensions are defined for unimodular discrete spaces, which are defined in this work as a class of random discrete metric spaces with a distinguished point called the origin. These spaces provide a common generalization to stationary point processes under their Palm version and unimodular random rooted graphs. The main novelty is the use of unimodularity in the definitions where it suggests replacing the infinite sums pertaining to coverings by large balls by the expectation of certain random variables at the origin. In addition, the main manifestation of unimodularity, that is the mass transport principle, is the key element in the proofs. These dimensions are connected to the growth rate of balls. In particular, versions of the mass distribution principle, Billingsley's lemma, and Frostman's lemma are established for unimodular discrete spaces. The dimensions in question are explicitly evaluated or conjectured for examples pertaining to the theory of point processes, unimodular random graphs, and self-similarity. (Received August 19, 2018)

1144-60-122 **Amber Puha*** (apuha@csusm.edu), 333 S. Twin Oaks Valley Road, San Marcos, CA 92096. *Diffusion Limits for Shortest Remaining Processing Time Queues Under Nonstandard Spatial Scaling.*

We develop a heavy traffic diffusion limit theorem under nonstandard spatial scaling for the queue length process in a single server queue employing shortest remaining processing time (SRPT). For processing time distributions with unbounded support, it has been shown that standard diffusion scaling yields an identically zero limit. We specify an alternative spatial scaling that produces a nonzero limit. Our model allows for renewal arrivals and i.i.d. processing times satisfying a rapid variation condition. We add a corrective spatial scale factor to standard diffusion scaling, and specify conditions under which the sequence of unconventionally scaled queue length processes converges in distribution to the same nonzero reflected Brownian motion to which the sequence of conventionally scaled workload processes converges. Consequently, this corrective spatial scale factor characterizes the order of magnitude difference between the queue length and workload processes of SRPT queues in heavy traffic. The rate at which it tends to infinity is determined by the decay rate of the tail of the processing time distribution. For Weibull processing time distributions, we restate this result in a manner that makes the resulting state space collapse more apparent. (Received August 20, 2018)

1144-60-126 **Erin Beckman**, **Natalie Frank**, **Yufeng Jiang**, **Matthew Junge** and **Si Tang*** (si.tang@duke.edu), Department of Mathematics, Duke University, Durham, NC 27708. *The frog model on trees with drift.*

We provide a uniform upper bound on the minimal drift so that the one-per-site frog model on a d-ary tree is recurrent. To do this, we introduce a subprocess that couples across trees with different degrees. Finding couplings for frog models on nested sequences of graphs is known to be difficult. The upper bound comes from combining the coupling with a new, simpler proof that the frog model on a binary tree is recurrent when the drift is sufficiently strong. Additionally, we describe a coupling between frog models on trees for which the degree of the smaller tree divides that of the larger one. This implies that the critical drift has a limit as d tends to infinity along certain subsequences. (Received August 20, 2018)

1144-60-146 **Gerardo Rubino*** (gerardo.rubino@inria.fr), Campus de Beaulieu, 35410 Rennes, France, and **Alan Krinik**, California State Polytechnic University, Department of Mathematics, Pomona, CA 91768. *Duality concepts and applications in difference and differential linear systems.*

Classic performance evaluation using queues is usually done assuming a stable model in equilibrium. However, there are situations where we are interested in the transient phase. In this case, the main metrics are built around the model's state distribution at an arbitrary point in time.

In previous works, we developed an approach to derive this distribution for some Markovian models, built around Jensen's method, transforming the problem into a discrete time one, and duality in stochastic processes, from Anderson's book "Continuous-Time Markov Chains". The latter allows working with absorbing chains, thus providing significant simplifications.

Recently, we discovered that this duality concept is not dependent on the Markovian properties, it is actually more general. We also found that it has a slightly different form when time is discrete. We call now power-dual the latter and exponential-dual the former. They allow a different way of manipulating linear systems of recurrences or of differential equations, even in some cases where systems are infinite.

The talk will describe these concepts and will illustrate them with some examples. (Received August 22, 2018)

1144-60-185 **James T Campbell*** (jcampbll@memphis.edu). *A discrete model for lightning.* Preliminary report.

We explore a discrete model for the formulation of lightning. We place randomly generated numbers (*levels*) in each cell of an $m \times n$ grid, creating a *configuration*. Choosing a starting cell along the top row, we examine the neighboring cells and (i) draw an edge to any neighbor whose level is less than or equal to our current level (such a cell has become *visited*), (ii) list the visited cells in a queue, and (iii) start the process over at the beginning of the queue, proceeding until the queue is empty. We are interested the fate of the resulting path, and would like to compute the probability that some portion of the path reaches the bottom of the grid. We think of this as *success*, or more colloquially, a *lightning strike*.

We also consider variations on this model, in particular: On $\mathbb{Z}^2$, label the vertices independently using the uniform distribution on $[0, 1]$. Start at 0, say, and move to all neighbors v where $x_v \leq x_u + \epsilon$. Question: is there a critical value ϵ_0 for which (i) if $\epsilon < \epsilon_0$, an infinite path does not occur (that is, occurs with probability 0), and (ii) if $\epsilon > \epsilon_0$, infinite path does occur (that is, occurs with probability 1). (Received August 24, 2018)

1144-60-230 **Omer Angel*** (angel@math.ubc.ca), Math department, UBC, Vancouver, BC V6T 1Z2, and **Andrew Rechnitzer**. *Independent sets in random triangulations.*

We prove that with high probability the largest independent set in a random triangulation of the n-gon has size (sqrt2-1)n + o(n). We also derive a central limit theorem and large deviation principles for this quantity. (Received August 26, 2018)

1144-60-259 **Daniel A. Alpay***, alpay@chapman.edu, and **Ismael L. Paiva** and **Daniele C. Struppa**. *Distribution spaces and a new construction of stochastic processes associated with the Grassmann algebra.* Preliminary report.

We associate with the Grassmann algebra a topological algebra of distributions, which allows the study of processes analogous to the corresponding free stochastic processes with stationary increments, as well as their derivatives. (Received August 27, 2018)

1144-60-297 **Alperen Ozdemir*** (aozdemir@usc.edu), 2654 1/2 ORCHARD AVE, Los Angeles, CA 90007. *Random walks generated by Ewens distribution on the symmetric group.*

The Ewens distribution on the symmetric group is defined by probabilities that are exponentially proportional to the number of cycles of permutations, with a base parameter $\theta > 0$. Consider a Markov chain on the symmetric group where at each step a permutation is chosen with respect to Ewens distribution and multiplied by the permutation at the current state. This talk concerns the spectral analysis and the mixing time of the chain. First, representation theory techniques are employed to identify the eigenvalues. We then allow the base parameter θ to be a function of n , where n is the number of elements the symmetric group S_n is defined over, and study the rate of convergence to the uniform distribution. The chain exhibits a total variation cutoff. (Received August 27, 2018)

1144-60-304 **Jeffrey Yeh*** (jeffreyyeh@cpp.edu), CA, and **Malachi C. Demmin**, **Lyheng Phey**, **Tanner J. Thomas**, **Steven L. Marquez** and **Brittney A. Marian**. *Generalized Ballot Box Problem.* Preliminary report.

The traditional two-candidate ballot box problem asks for the probability that candidate A is never behind candidate B during the counting of n ballots, where n is a positive integer. Candidate A is known to have an i-vote lead over B at the beginning of the ballot counting and A is assumed to have won the election with a j-vote margin of victory over B where i, j are non-negative integers. This traditional problem dates back to the 19th century and has an elegant solution when voters are presumed to have independent, equal chance of voting for A or B. In our presentation, the two-candidate ballot box problem is generalized by assuming that voters follow a simple type of birth-death Markov chain in casting their votes. Under our assumptions, a formula for the probability that candidate A is never behind candidate B during the counting of n ballots is determined in terms of known, exact expressions for eigenvalues of a class of transition matrices which depend upon n. Examples are presented and different solution forms are compared as time allows. (Received August 29, 2018)

1144-60-307 **Chon In Luk*** (cluk@cpp.edu), **John Kath**, **Yoseph Dawit**, **Mark Dela**, **Christine Hoogendyk** and **David Perez**. *An Eigenvalue Approach for Determining Certain Birth-Death n-step Transition Probabilities.* Preliminary report.

We present examples of birth-death chains and processes whose one-step transition matrix P (or whose infinitesimal rate matrix Q) have explicit formulas for distinct eigenvalues. In particular, we are interested in formulas that scale-up to an arbitrary number of states H. Our examples either have constant (or alternating) birth and death probabilities or rates. We describe our computer programs that solve for the nth power of P or expQt where t is time. One of our examples corresponds to the classical single server queuing system having a finite buffer of H states, M/M/1/H. We also solve for the nth power of P and consider a boundary problem for a general circular birth-death random walk having constant birth and death probabilities. These results for the nth power of P may be viewed as formulas that give us the probability of going from state i to state j in n-steps on birth-death type lattice paths on a cylinder. We conclude with some related results for more general (non birth-death) Markov models. (Received August 29, 2018)

1144-60-313 **Arnab Sen*** (arnab@umn.edu) and **Michael Damron**. *Majority dynamics on the infinite 3-regular tree.* Preliminary report.

The majority dynamics on the infinite 3-regular tree can be described as follows. Each vertex of the tree has an i.i.d. Poisson clock attached to it, and when the clock of a vertex rings, the vertex looks at the spins of its three neighbors and flips its spin, if necessary, to come into agreement with majority of its neighbors. The initial spins of the vertices are taken to be i.i.d. Bernoulli random variables with parameter p. In this talk, we will discuss a couple of new results regarding this model. In particular, we will show that the limiting proportion of 'plus' spins in the tree is continuous with respect to the initial bias p. A key tool in our argument is the mass transport principle. (Received August 28, 2018)

1144-60-322 **Aaron M. Smith*** (asmi28@uottawa.ca), , Canada, and **Natesh S. Pillai**. *Coupling in Kac's Walks.*

Kac's walks on the sphere and on the special orthogonal group, introduced in 1953 and 1970, have long histories in the statistical physics and computational statistics literatures. I will describe the history of these walks and review some of the many results on the mixing properties of these processes. I then present some work of myself and Pillai, which uses a coupling construction to relate some bounds in random matrix theory to the mixing of these two walks. Finally, I will discuss some other contexts in which a similar approach may be used. (Received August 28, 2018)

62 ► Statistics

1144-62-11 **Guangliang Chen*** (guangliang.chen@sjsu.edu), San Jose, CA 95192, and **Khiem Pham**. *Recent advances in landmark-based large scale spectral clustering.*

Spectral clustering has emerged as a very effective clustering approach, due to its capability of separating nonconvex, non-intersecting manifolds, however, it is computationally very expensive. As a result, there has been considerable effort in the machine learning community to develop fast, approximate spectral clustering algorithms that are scalable to large data, most of which use a small set of landmark points selected from the given data. In this talk we present two new scalable spectral clustering algorithms that are also landmark based but derived through novel document-term and bipartite graph models. We demonstrate the superior performance of our proposed algorithms by comparing them with the state-of-the-art methods on some benchmark data sets. Finally, we provide a unified view of all the old and new landmark-based spectral clustering methods. (Received May 30, 2018)

1144-62-45 **Alexander Aue*** (aaue@ucdavis.edu), **Haoyang Liu** and **Debashis Paul**. *Limiting spectral distributions for a class of high-dimensional time series.*

This talk discusses extensions to the time series case of the Marcenko-Pastur law on limiting spectral distributions (LSDs) for the eigenvalues of high-dimensional sample covariance matrices. The main result will be on establishing a non-linear integral equation characterizing the LSD in terms of its Stieltjes transform. Intuition will be presented for the simple case of a first-order moving average time series and evidence will be provided, indicating the applicability of the result to problems involving to the estimation of certain quadratic forms as they arise, for example, when dealing with the Markowitz portfolio problem. The talk is based on joint work with Haoyang Liu (New York Fed) and Debashis Paul (UC Davis). (Received August 01, 2018)

1144-62-66 **Shuangge Ma*** (shuangge.ma@yale.edu), 60 College ST, LEPH 206, New Haven, CT 06520. *Human disease network (HDN) analysis of disease prevalence.* Preliminary report.

In "classic" biomedical research, the prevalence of different diseases has been separately. Accumulating evidences have suggested that diseases can be "correlated". In most existing studies, such correlation has only been studied for a small number of pre-selected diseases. In our study, we conduct big-data analysis of the Taiwan National Health Insurance Research Database (NHIRD). Novel HDN analysis is conducted to "globally" examine the interconnections among disease prevalence. Important characteristics of the HDN are quantified. (Received August 07, 2018)

1144-62-79 **Lifeng Lai*** (lflai@ucdavis.edu). *Statistical Inference over Time Varying High-Dimensional Models.*

Most of existing work on high-dimension estimators assume that the training data come from the same underlying model. In practice, data may come from time-varying models. In this talk, we discuss our recent work on sparse linear regression problems for which the underlying model undergoes multiple changes. Our goal is to estimate the number and locations of change-points that segment available data into different regions, and further produce sparse and interpretable models for each region. To address challenges of the existing approaches and to produce interpretable models, we propose a sparse group Lasso based approach for linear regression problems with change-points. Under certain mild assumptions and a properly chosen regularization term, we prove that the solution of the proposed approach is asymptotically consistent. In particular, we show that the estimation error of linear coefficients diminishes, and the locations of the estimated change-points are close to those of true change-points.We further propose a method to choose the regularization term so that the results mentioned above hold. In addition, we show that the complexity of the proposed algorithm is much smaller than those of existing approaches. Numerical examples are provided to validate the analytic results. (Received August 10, 2018)

1144-62-95 **Rex Cheung*** (rexcheung@sfsu.edu), Decision Sciences Department, San Francisco State University, 1600 Holloway Avenue, San Francisco, CA 94132, and **Alexander Aue** and **Thomas Lee**. *Segmenting Dynamic Network Data.*

Networks and graphs arise naturally in many complex systems. Often times they exhibit a dynamic behavior that can be modeled using dynamic networks. Two major research problems in dynamic networks are 1) community detection, which aims to find specific sub-structures within the networks, and 2) change point detection, which tries to find the time points that the sub-structures change. This project proposes a new methodology to solve both problems simultaneously, by casting this as a model selection problem and utilizing the Minimum Description Length Principle (MDL) as the minimizing objective criterion. The derived detection algorithm is compatible with many existing methods, and is supported by empirical results and data analysis. (Received August 13, 2018)

1144-62-183 **Ramchandra Rimal*** (ramchandra@knights.ucf.edu), 3781 Khayyam Ave, Orlando, FL 32826, and **Marianna Pensky**. *Density Estimation with Small Berkson Errors.*

Density Estimation with Small Berkson Errors

Consider a sample of independent and identically distributed observations of variables Y=X+E where measurements of X and E are unavailable, the probability density function of X is unknown but the probability density function of E is known. The objective is to estimate the probability density function of W = X+Z, where Z has a known probability distribution, on the basis of the observations of Y.

The problem is known as density estimation with Berkson errors and has applications in econometrics, astronomy, biometrics, medical statistics, and image reconstruction. It is known that presence of the Berkson errors improves the accuracy of estimation of the desired density function. The focus of our work is an investigation of the case when Berkson errors have variances which may be very small. We construct kernel estimators of the density function of W and obtain the upper bounds of the risk. We further conclude in which cases the kernel estimator is necessary for improvement of the error bounds. (Received August 24, 2018)

1144-62-202 **Tao He*** (hetao@sfsu.edu), 1600 Holloway Ave, San Francisco State University, San Francisco, CA 94132, and **Yuehua Cui**, **Ping-Shou Zhong** and **V. Mandrekar**. *Testing High-dimensional Non-parametric Functions with Applications in SNP/Gene Set Analysis.*

High-dimensional data arise in a wide range of areas, such as biology, imaging and climate. A common feature of high-dimensional data is that the number of features could be much larger than the sample size, the so-called "large p, small n" problem. This study is motivated by a specific example in genomic studies when the question of interest is to detect SNP sets or gene sets that are associated with certain trait. To model the systematic

mechanism and potential complex interactions among genetic variants, we consider a flexible nonparametric function in a reproducing kernel Hilbert space. We propose a test statistic and study its asymptotic distributions under the null hypothesis and a series of local alternative hypotheses, under the "large p, small n" setting. We demonstrate our methods through extensive simulation studies and apply to a real data analysis. (Received August 25, 2018)

1144-62-204 **Wanrong Zhang** and **Yajun Mei*** (ymei@isye.gatech.edu), 756 Ferst Drive, Atlanta, GA 30332-0205. *A Multi-Armed Bandit Approach for Online Monitoring High-Dimensional Data in Resource Constrained Environments.* Preliminary report.

In this talk, we investigate the problem of online monitoring high-dimensional streaming data in resource constrained environments, where one has limited capacity in data acquisition, transmission or processing, and thus can only observe or utilize partial, not full, data for decision making. It is assumed that an undesired event might occur and change the distributions of some unknown components of data at some unknown time, and one wants to decide how to smartly observe a limited number of local components of data at each time step so that one can detect the undesired event as quickly as possible subject to the false alarm constraint. We propose a multi-armed bandit approach to adaptively sampling useful local components of data, and our method, termed as Thompson-Sampling-Shiryaev-Roberts (TSSR) algorithm, is able to balance between exploiting those observed local components that maximize the immediate detection performance and exploring new local components that might accumulate new information to improve future detection performance. The usefulness of our proposed TSSR algorithm is validated through theoretical analysis, numerical simulations and a real case study of solar flare detection. (Received August 25, 2018)

1144-62-234 **Li Zhang*** (li.zhang@ucsf.edu), 550 16th Street, UCSF Box 3211, San Francisco, CA 94158, **Iryna Lobach** (ryna.lobach@ucsf.edu), 550 16th Street, San Francisco, CA 94158, **Joshua Sampson**, Bethesda, MD, **Alexander Alekseyenko**, Charleston, SC , and **Siarhei Lobach**, Minsk, Belarus. *Case-control studies of gene-environment interactions: when a case might not be the case or a control might be a silent disease.*

Case-control Genome-Wide Association Studies (GWAS) provide a rich resource for studying the genetic architecture of complex diseases. A key is to elucidate how the genetic effects vary by the environment, i.e., Gene-Environment interactions (GxE). Two major overlooked complication are that 1) distinct pathophysiologic mechanisms may lead to the same clinical diagnosis and often these mechanisms have distinct genetic bases; and 2) a subset of the controls have silent, or undiagnosed, disease. These complications are not trivial mainly because the frequency of the pathologic disease of interest within the set of clinically diagnosed cases and the frequency of the silent disease vary by the environmental variable. We first show that using case–control status without accounting for misdiagnosis can lead to severely biased estimates of GxE interactions. We further propose a pseudolikelihood approach to correct the bias and accurately estimate how the relationship between the genetic variant and the true disease status varies by the environmental variable. Finally, we demonstrate our methods with a GWAS of Alzheimer's disease and a GWAS of prostate cancer. (Received August 26, 2018)

1144-62-244 **Shaoyu Li***, sli23@uncc.edu, **Yanqing Sun**, yasun@uncc.edu, **Liyang Diao**, ldiao@serestherapeutics.com, and **Xue Wang**, wang.xue@mayo.edu. *Distance-based analysis with quantile regression model.*

Suitable pairwise distance measure which defines how dissimilar any two samples are can be used to study the association between multivariate, especially non-vectorially structured multivariate data, which are emerging in many important research areas including genomics, ecology, and neuron imaging. In this work, we consider a quantile regression model for matrices of pairwise distance. We derive large sample properties of estimators in the model and propose corresponding statistical inference procedure. Intensive simulation studies illustrate great finite sample characteristics of the proposed method in terms of accurate coverage probability, and well controlled empirical type I error rate. Finally, we apply our method to re-analyze a Microbiome association study and a plant ecological study to illustrate its utility. (Received August 27, 2018)

1144-62-251 **Luella Fu*** (luella@sfsu.edu), **Wenguang Sun** and **Gareth M. James**. *The Mountain Comes to Muhammad: Dangers from Using Standardized Statistics in Multiple Testing.* Preliminary report.

In multiple testing procedures, two common techniques are to pool information across testing units in order to boost power and to standardize statistics, usually yielding p-values or z-values. We show through analytical and intuitive arguments that for heterogeneous data, it is better not to standardize the data and instead use the original bivariate data. We propose a method, "Heterogeneity Adjusted Test Statistics" (HATS) that produces

test statistics which use the original bivariate data. Through theory and simulation, we establish the ability of HATS to improve power while controlling type I error. To provide a concrete idea of how HATS performs versus z- and p-value multiple testing methods, we consider an application to microarray data. (Received August 27, 2018)

1144-62-252 **Yuehua Cui*** (cuiy@msu.edu). *Omics data integration with kernel fusion.* Preliminary report.

High throughput omics data are generated almost with no limit nowadays. It becomes increasingly important to integrate different omics data types to disentangle the molecular machinery of complex diseases with the hope for better disease prevention and treatment. In this talk, I will briefly introduce the idea of kernel fusion for data integration. We focus on a fused kernel partial least squares (fKPLS) model for disease classification and prediction with multi-level omics data. The fused kernel can deal with effect heterogeneity in which different omic data types may have differennt effect contribution to the trait of interest. We optimize the kernel parameters and kernel weights with the genetic algorithm (GA). The proposed GA-fKPLS model can substantially improve disease classification performance by integrating multiple omics data types, demonstrated via simulation studies and real data analysis. (Received August 27, 2018)

1144-62-278 **Fang Han**, **Xi Chen**, **Honglang Wang*** (hlwang@iupui.edu), **Lexin Li** and **Brian Caffo**. *Robust Graph Change-point Detection for Brain Evolvement Study.*

This paper studies brain structural evolvement from resting-state functional magnetic resonance imaging. The brain structure is characterized by a series of Gaussian graphical models, and we propose a robust data-driven method for inferring the structural changes of multiple graphs. The graphs correspond to different subjects, are aligned by, e.g., the ages of the subjects, and need to be estimated from the subject level data. We propose to estimate the structural changes of these graphs through a three-step procedure. First, we employ a kernel-smoothing approach to estimate multiple graphs at different ages simultaneously. Secondly, we summarize graphical information, such as the number of edges, global and local efficiency, for each estimated graph, and align them as a curve. Lastly, we propose a robust least-absolute-deviation (LAD) type penalization procedure with the fused Lasso (FL) penalty, named LAD-FL, to infer the change-points in those graph summary metrics. Our method is theoretically well understood, and results show that it could effectively capture the brain evolvement pattern. (Received August 27, 2018)

1144-62-292 **Yuzhen Zhou*** (yuzhenzhou@unl.edu), Lincoln, NE 68583. *Hierarchical models for predicting above ground biomass with 3D LiDAR signals.*

Recent advancements in remote sensing technology, specifically Light Detection and Ranging (LiDAR) sensors, provide the data needed to quantify forest characteristics at a fine spatial resolution over large geographic domains. In this talk, we'll introduce Bayesian hierarchical models for prediction of above ground biomass with high resolution 3D LiDAR signals. Details of modeling strategies will be given and be illustrated with a real dataset. (Received August 27, 2018)

1144-62-300 **Alexandra Piryatinska*** (alpiryat@sfsu.edu), 1600 Holloway ave, San Francisco, CA 94132, and **Boris Darkhovsky**. *Detection of structural breaks for panel data via the ϵ-complexity of continuous maps.*

In statistics and econometrics, panel data are multi-dimensional data involving measurements over time. The problem of detection of structural breaks (or change points) has drawn increasing attention from the theoretical, applied economic and financial fields. Such phenomena may be produced by governmental policy changes, the introduction of a new technology, etc. We propose a model-free method for detection of structural breaks in panel data. This approach is based on our theory of the ϵ-complexity of a continuous map, in particular, continuous vector-functions. We will provide the main results of our theory for the case when a continuous map is given by its values on some uniform grid. We show that in this case the ϵ-complexity can be effectively characterized by two real numbers - the complexity coefficients - for "almost all" Hölder maps. A sequence of ϵ-complexity coefficients will be our diagnostic sequence. After that, we implement the non-parametric change-point detection procedure of Brodsky-Darkhovsky to detect changes in the mean of a diagnostic sequence. The results of the simulations will be presented. (Received August 28, 2018)

1144-62-306 **Lily S Khadjavi*** (lkhadjavi@lmu.edu), 1 LMU Drive Suite 2700, Los Angeles, CA 90045. *An empirical look at race and police practice, for our classrooms and our communities.*

In recent years, the country has been gripped by news of tragic encounters between police and unarmed civilians of color. Traffic stops are, in fact, the most common way that the public encounters law enforcement, and

therefore studying these stops shines a light on a significant aspect of police practice. Data which were collected by the Los Angeles Police Department under a Consent Decree with the U.S. Department of Justice provide a prime opportunity to better understand policing, well beyond counting who is stopped. For example, when a driver is pulled over, the stop may include a frisk or search but only if certain legal criteria are satisfied. Who is searched, and under what basis? Are particular drivers asked to consent to a search? Who declines? A statistical analysis not only illuminates racial and ethnic disparities in stops, frisks, searches, and outcomes, but in fact points to concrete policy recommendations. We'll discuss how this material can be used in the classroom as well, inviting students to conduct their own analysis. These topics can also take instructors beyond the classroom to unexpected places. (Received August 28, 2018)

1144-62-314 **Lilit C Moss***, chemenya@usc.edu, and **William J Gauderman**, **Juan Pablo Lewinger** and **David V Conti**. *Using Bayes Model Averaging to Leverage Both Gene Main Effects and GxE Interactions to Identify Genomic Regions in Genome-Wide Association Studies.*

Genome-wide association studies (GWAS) typically search for marginal associations between a single nucleotide polymorphism (SNP) and a disease trait while gene-environment (GxE) interactions remain generally unexplored. More powerful methods beyond the simple case-control approach leverage either marginal effects or case-control ascertainment to increase power. However, these potential gains depend on assumptions whose aptness is often unclear a priori. Here, we review GxE methods and use simulations to highlight performance as a function of main and interaction effects and the association of the two factors in the source population. Substantial variation in performance between methods leads to uncertainty as to which approach is most appropriate for any given analysis. Our framework is based on Bayes model averaging, which provides a principled statistical method for incorporating model uncertainty. The resulting method exploits the joint evidence for main and interaction effects while gaining power from a case-only equivalent analysis. Through simulations we demonstrate that our approach detects SNPs within a wide range of scenarios with increased power over current methods. We illustrate the approach on a gene-environment scan in the USC Children's Health Study. (Received August 28, 2018)

1144-62-316 **Can M. Le*** (canle@ucdavis.edu). *Edge sampling using network local information.*

Edge sampling is an important topic in network analysis. It provides a natural way to reduce network size while retaining desired features of the original network. Sampling methods that only use local information are common in practice as they do not require access to the entire network and can be parallelized easily. Despite promising empirical performance, most of these methods are derived from heuristic considerations and therefore still lack theoretical justification. To address this issue, we study in this paper a simple edge sampling scheme that uses network local information. We show that when local connectivity is sufficiently strong, the sampled network satisfies a strong spectral property. We quantify the strength of local connectivity by a global parameter and relate it to more common network statistics such as clustering coefficient and Ricci curvature. Based on this result, we also derive a condition under which a hypergraph can be sampled and reduced to a weighted network. (Received August 28, 2018)

1144-62-319 **Adam J King*** (king@cpp.edu). *Bayesian Modeling of Discrete Time Discrete State Space Processes.*

We present a general Bayesian statistical model for discrete time, discrete state space stochastic processes. Applications include the modeling of recurrent and episodic disease processes, such as episodes of illicit drug use, as well as social processes such as educational enrollment and employment. We also present Markov chain Monte Carlo inference algorithms for our model, along with a freely available software package called BREA which implements these methods in the R programming language. (Received August 28, 2018)

65 ► Numerical analysis

1144-65-49 **Miles Lopes*** (melopes@ucdavis.edu), **Shusen Wang** and **Michael W Mahoney**. *Error Estimation for Randomized Numerical Linear Algebra via the Bootstrap.*

Randomized Numerical Linear Algebra (RandNLA) is an interdisciplinary research area that exploits randomization as a computational resource to develop improved algorithms for large-scale linear algebra problems. While the motivating applications for RandNLA are in large-scale machine learning and data analysis, most work in RandNLA so far has come from the perspectives of theoretical computer science and numerical linear algebra. This has begun to change, and many of the most exciting current developments in RandNLA have to do with focusing on statistical and optimization considerations. Here, we describe recent results that use the statistical

bootstrap method to enhance error estimation in the contexts of large-scale matrix multiplication and least squares. (Received August 02, 2018)

1144-65-61 **Thai Anh Nhan*** (nhan@hnu.edu), Math and Sciences, Holy Names University, 3500 Mountain Blvd., Oakland, CA 94619, and **Relja Vulanovic** (rvulanov@kent.edu), Department of Mathematical Sciences, Kent State University, North Canton, OH 44720.
Analysis of the truncation error and barrier-function technique for a Bakhvalov-type mesh.

In this talk, we prove the parameter-uniform convergence for a linear singularly perturbed convection-diffusion problem in one dimension,

$$\mathcal{L}u := -\varepsilon u'' - b(x)u' + c(x)u = f(x),\ x \in (0,1),\ u(0) = u(1) = 0,$$

where ε is a small positive perturbation parameter, discretized by a finite-difference scheme on a Bakhvalov-type mesh by means of the truncation error and barrier-function approach. To our knowledge, this is the first analysis of this kind in the research literature. Numerical experiments are illustrated to support our theoretical findings. (Received August 09, 2018)

1144-65-135 **Mark Iwen**, **Brian Preskitt**, **Rayan Saab** and **Aditya Viswanathan*** (adityavv@umich.edu).
Phase Retrieval from Local (Ptychographic) Measurements.

Certain imaging applications such as x-ray crystallography and ptychography require the recovery of a signal from phaseless (or magnitude-only) measurements - a problem commonly referred to as Phase Retrieval. This is a challenging (and non-linear) inverse problem since the phase encapsulates a significant amount of structure in the underlying signal. In this talk, we will discuss a framework for solving the discrete phase retrieval problem from deterministic local measurements. We summarize a recently introduced fast (essentially linear-time) and robust phase retrieval algorithm based on solving highly structured (block-circulant) linear systems to infer relative phase information, followed by an eigenvector based approach to learning individual phases from relative phase estimates. Theoretical recovery guarantees as well as numerical results demonstrating the method's speed, accuracy and robustness to measurement errors will be provided. (Received August 21, 2018)

1144-65-284 **J Ding***, 14 SUMMER PLACE, HATTIESBURG, MS 39402, and **N Rhee** and **D Zhou**.
A Quadratic Spline Least Squares Method for Computing Absolutely Continuous Invariant Measures.

We present a numerical method for computing absolutely continuous invariant measures associated with a piecewise monotonic interval map by using quadratic spline approximations. Using a rigorous matrix analysis and the Lasota-Yorke inequality, we prove the norm convergence of the method. We also present numerical examples for the efficiency of the approach. (Received August 27, 2018)

68 ► Computer science

1144-68-24 **Namratha Mohan*** (namrathmohan@gmail.com) and **Thanos Gentimis** (genitmisth@gmail.com).
Predicting Post-Procedural Complications using Neural Networks. Preliminary report.

As a core component, this paper involves analysis and prediction on large data sets through Machine Learning algorithms. The input dataset contains structured data extracted from MIMIC III, a large Health Record database of more than 40,000 patients. The main question was to predict if a patient will have complications during certain specified procedures performed in the hospital. These events are denoted by the icd9˙code 996 in the individuals health record. The output of our predictive model is a binary variable which outputs the value 1 if the patient is diagnosed with the specific complication or 0 if the patient is not. Our prediction algorithm is based on a Neural Network architecture, with a 90%-10% training-testing ratio. Our preliminary analysis yielded a prediction accuracy above 80%, outperforming various multi-linear models. (Received July 05, 2018)

1144-68-144 **Jianpeng Xu*** (jianpeng.xu@gmail.com) and **Pang-Ning Tan** (ptan@msu.edu).
Incremental Learning on Large-scale Spatio-temporal Prediction via Tensor Decomposition.

Predictive modeling of spatio-temporal data is an important task for many application domains. Such a task typically requires making robust predictions of a target variable at multiple geo-locations based on their historical observation and predictor variables. The multi-location prediction problem is naturally cast into a multi-task learning framework. While previous studies take into account the spatial smoothness on modeling the predictions at multiple locations, they are often developed for batch learning, which is not efficient for large-scale spatio-temporal data growing over time and space. As many of the previous works have focused primarily on

improving prediction accuracy, the learned models are often too complicated for interpretation by the domain experts. Incorporating known patterns that drive the variability of the spatio-temporal data into a predictive modeling framework is also non-trivial. In this abstract, we introduce our work named WISDOM to overcome the aforementioned challenges. Specially, WISDOM applies tensor decomposition to learn the latent factors over space and time, while these factors are used for accuracy prediction. Incremental learning algorithm is developed to optimize the objectives when new data becomes available over space or time. (Received August 22, 2018)

1144-68-166 **Dongmian Zou*** (dzou@umn.edu), Institute for Mathematics and its Application, Lind Hall 433, University of Minnesota, Minneapolis, MN 55455, and **Gilad Lerman**. *Scattering transform on graphs.*

We construct a convolutional neural network on graphs by generalizing the scattering transform. The construction is based on graph wavelets or graph frames. Any feature generated by such a network is approximately invariant to permutations and stable to graph manipulations. Numeral results show that the graph scattering transform works effectively for classification and community detection problems. (Received August 23, 2018)

1144-68-302 **Hui Yang*** (huiyang@sfsu.edu), Dept of Computer Science, San Francisco State University, San Francisco, CA 94022, and **Swati Patel** and **Hui-ming Deanna Wang**. *Using topical interests and social interactions to measure user similarity on Twitter.* Preliminary report.

Social networks such as Twitter have become an important medium for the diffusion of information. In this study, we designed two user similarity measures, where the first is based on users' topical interests and the other utilizes users' social connections. Specifically, for the first measure, we use a user's historical tweets to infer her topic interests. Various topic modeling approaches are evaluated towards understanding their ability to distinguish the different types of Twitter user pairs. For the second measure, we use interactions between Twitter users, such as retweeting, quoting, replying, and mentioning to measure users' similarity. Our analysis indicates that the above two types of similarity measures have no inter-correlations and exhibit significantly different averages across three groups of user pairs under evaluation. (Received August 28, 2018)

1144-68-334 **Maria De-Arteaga***, 4800 Forbes Avenue, Office 2005, Pittsburgh, PA 15213. *Guiding public service agencies with machine learning: Opportunities and risks.*

In this talk I present work on discovery of complex anomalous patterns of sexual violence in El Salvador, and discuss challenges of incorporating machine learning-based decision support systems in this context, with an emphasis on fairness-related risks. When sexual violence is a product of organized crime or social imaginary, the links between sexual violence episodes can be understood as a latent structure. This enables the use of data science to uncover complex spatio-temporal patterns. We provide evidence of phenomena that have not been previously reported in literature. Such analyses could be conducted in real-time, enabling early detection of emerging patterns to allow stakeholders to react accordingly. However, the use of machine learning to assist public service agencies is both promising and concerning. The characteristics of available data and the context in which algorithms would be deployed give rise to several challenges, many of which have not been sufficiently addressed in the machine learning literature. The presence of selective labels, unobservables, and the effects of omitted payoff bias are some of the issues that arise. I discuss how, when left unaddressed, these may lead to systemic biases, self-fulfilling prophecies and loss of human trust in the systems. (Received August 28, 2018)

1144-68-338 **Kourosh Modarresi*** (kouroshm@alumni.stanford.edu). *Effectiveness of Representation Learning for the Analysis of Human Behavior.*

The digital space is increasingly the main venue that individuals spend their time and conduct their businesses. The phenomenon has led to an explosion of online experience data resulting from human interaction with the contents in the digital space. Obviously, many businesses have vital interest in analyzing this data and using its insights to attract more online users to their contents and products. The human online-behavior data has also attracted the attention of AI and machine learning scientists to try to understand the patterns hidden in the data. It has been observed that human behavior entails very complex features. Studying these complex features requires the deployment of models that could deal with this high complexity. A major contribution of deep neural network model is in its application of "hierarchical representation learning" approach. This "feature representation" aspect of deep learning models make it possible to represent many complex structures and patterns. This work explains how deep learning models, using representation learning, could be applied effectively in the analysis of human behavior data. (Received August 28, 2018)

1144-68-351 **Rahul Singh*** (rahul@sfsu.edu). *Locally-Sensitive Epidemiological Modeling of Disease Outbreaks Using Social Media.* Preliminary report.

The behavioral patterns of afflicted individuals and their social-behavioral contexts are amongst the crucial factors governing the dynamics of diseases spread. However, the complexity of determining such information accurately has often stymied precise modeling of disease outbreaks; at the state-of-the-art, most computational models simplify the challenge by assuming contact networks that are homogeneous both in terms of their topology as well as infectiousness of nodes. In this talk I will present results of research being carried out in my lab that demonstrate how social media can be used as an emerging source of epidemiologically relevant information which can be used to construct disease propagation models that are significantly more discerning than their traditional counterparts. In particular, by considering epidemics governed by the susceptible-infected (SI) model, such as those arising in substance misuse, HIV, HCV, or their confluence, we demonstrate how highly sensitive population-level compartmental models can be constructed by taking into account specificities of afflicted individuals extracted from their social media activity. (Received August 29, 2018)

78 ► Optics, electromagnetic theory

1144-78-293 **Alexey Sukhinin***, NDSU, Math Dept, Fargo, ND 58104. *Resonant vs non-resonant collapse events of optical beams.* Preliminary report.

It is well-known that the high-intensity gaussian beam tends to collapse in free space under the effect of self-focusing. Nonlinear Schrodinger Equation in critical dimension is the mathematical model that correctly describes it. Collapse is a fundamental phenomenon and is well-studied. It has an important application in the area of filamentation, collapse leads to ionization of the air and creation of plasma channel. In this talk, I will describe new types of collapse events of two-color beams being both at resonance and non-resonance. (Received August 27, 2018)

81 ► Quantum theory

1144-81-69 **Michael A Bishop*** (mibishop@csufresno.edu), Peters Business Building, Room 355, 5245 North Backer Avenue M/S PB108, Fresno, CA 93740. *Spectral gaps for the Two-Species Product Vacua and Boundary States models on the d-dimensional lattice.*

We study the two-species Product Vacua and Boundary States (PVBS) models on the integer lattice $\mathbb{Z}^d$ and prove the existence and non-existence of a spectral gap for all choices of parameters. The PVBS models are spin-1 quantum spin systems which are translation-invariant, frustration-free, and composed of nearest-neighbor non-commuting interactions with both an exclusion property and an interchange interaction between particle species. These models serve as possible representatives of families of automorphically equivalent gapped quantum spin-1 systems on $\mathbb{Z}^d$. The main result is that the two-species PVBS Hamiltonians have a positive spectral gap when gapped on both of the single-species subspaces and are gapless if gapless on either single-species subspace. The addition of a new particle species does not create any new gapless phases. (Received August 08, 2018)

82 ► Statistical mechanics, structure of matter

1144-82-180 **William M. Gelbart*** (gelbart@chem.ucla.edu), 607 Charles E. Young Drive East, Los Angeles, CA 90095. *Sequence-Dependent RNA Branching and Compactness.* Preliminary report.

Throughout living systems, DNA is present predominantly in double-stranded form – mostly as genomic DNAs. In contrast, RNA is predominantly present in single-stranded form – as ribosomal RNA, messenger RNA, transfer RNA, ribozymal (enzymatic) RNA, and also as the genomic material of viruses. As a consequence, the physical behavior of DNA is essentially that of a stiff, linear, polymer, largely independent of its base-pair sequence. Each RNA molecule, on the other hand, is associated with a sequence-dependent secondary and tertiary structure, much like a protein. In my talk I argue that the secondary structure of RNA – its intramolecular base-pairing between often-widely-separated short sequences of complementary nucleotides – results in the molecule behaving effectively like a branched polymer. Furthermore, this sequence-dependent "branching" leads to a significant compactification of the molecule that is most striking for RNA sequences that correspond to viral genomes. This can be demonstrated both theoretically (using basic graph-theoretical and statistical-mechanical methods) and

experimentally (using radiation scattering and electron microscopy methods), and accounts for the spontaneity of packaging of viral RNA genomes by their capsid proteins. (Received August 24, 2018)

1144-82-266 **Stephen D Levene*** (sdlevene@utdallas.edu), Department of Bioengineering, 800 W. Campbell Road, BSB 11, Richardson, TX 75080, **Riccardo Ziraldo** (rxz074000@utdallas.edu), Department of Bioengineering, 800 W. Campbell Rd., BSB 11, Richardson, TX 75080, and **Andreas Hanke** (hanke@phys.utrgv.edu), Department of Physics and Astronomy, 80 Fort Brown, Brownsville, TX 78520. *Kinetic Pathways of Topology Simplification by Type-II Topoisomerases in Knotted Supercoiled DNA.*

The topological state of covalently closed, double-stranded DNA is defined by the knot type K and the linking-number difference ΔLk relative to unknotted relaxed DNA. DNA topoisomerases are essential enzymes that control the topology of DNA in all cells. In particular, type-II topoisomerases change both K and $\Delta Lk$by a duplex-strand-passage mechanism and have been shown to simplify the topology of DNA to levels below thermal equilibrium at the expense of ATP hydrolysis. Using numerical simulations, we consider the non-equilibrium dynamics of transitions between topological states $(K, \Delta Lk)$ in DNA induced by type-II topoisomerases. For a biological process that delivers DNA molecules in a given topological state $(K, \Delta Lk)$ at a constant rate we fully characterize the pathways of topology simplification by type-II topoisomerases in terms of stationary probability distributions and probability currents on the network of topological states $(K, \Delta Lk)$. In particular, we observe that type-II topoisomerase activity is significantly enhanced in DNA molecules that maintain a supercoiled state with constant torsional tension. This is relevant for bacterial cells in which torsional tension is maintained by homeostatic mechanisms such as DNA-gyrase activity. (Received August 27, 2018)

1144-82-317 **Chris Soteros*** (soteros@math.usask.ca). *Knotting statistics for polygons in lattice tubes.* Preliminary report.

Random polygons in lattice tubes have been used to study questions arising from DNA experiments for DNA confined to nano-channels or nano-pores. This talk will review what's known about the knotting statistics of the underlying lattice polygon models. Results have been obtained using a combination of Monte Carlo simulation, exact generation and transfer matrix theory. Our recent numerical results for small tube dimensions confirm the conjectured asymptotic form for the probability of specific knot-types as a function of polygon size; these results will be highlighted. (Received August 28, 2018)

90 ► Operations research, mathematical programming

1144-90-108 **Sheldon M Ross*** (smross@usc.edu), CA, and **Gideon M Weiss** and **Zhengyu Zhang** (zhan892@usc.edu). *A Stochastic Assignment Problem with Unknown Eligibility Probabilities.* Preliminary report.

We suppose that balls are sequentially put into one of n boxes. Each ball has an eligibility set attached to it, telling which of the boxes are eligible to accept that ball. When the ball arrives, its eligibility set is revealed, and one must decide which empty and eligible box the ball will be put in. Balls that are ineligible for all empty boxes are discarded. The collecting process ends when all boxes are filled. We compare two "random policies", the first of which puts an incoming ball into a randomly chosen one of the boxes that is both empty and eligible for that ball; whereas the second policy starts by randomly permuting the boxes and then puts each incoming ball into the empty and eligible box that is earliest in the permutation. We show that the number of balls needed to fill all boxes is stochastically smaller when the second policy is used. When memory of the eligibility sets of previously arriving balls is allowed to be used, we show, when each ball is independently eligible for box i with some given unknown probability, that the policy that always puts a ball into the empty and eligible box that has been eligible the least number of times in the past stochastically minimizes the number of balls needed to fill all boxes. (Received August 16, 2018)

91 ► Game theory, economics, social and behavioral sciences

1144-91-44 **Vishruti Ganesh*** (vishruti721@gmail.com), 651 Karina Court, San Ramon, CA 94582, and **Michael Kotarinos** and **Chris P Tsokos**. *Customized Forecasting Models for Exchange Traded Funds.*

The purpose of the present study is to investigate the applicability and uses of the k-th Moving Average and k-th Weighted Moving Average models on the basis that these models more accurately capture the unique aspects of financial data than the traditional ARIMA (Autoregressive Integrated Moving Average) forecasting model. A set of data is transformed using two methods: the k-th average method and the k-th weighted average method. The data is then modeled on an ARIMA model and the resulting prediction is un-averaged and compared to the true value.

The two subject models are used to predict the short term returns of six Exchange-Traded Funds: iShares MSCI Emerging Markets (EEM), iShares China Large-Cap (FXI), iShares Russell 2000 (IWM), SPDR Barclays Capital High Yield Bnd (JNK), SPDR S&P 500 (SPY), and Financial Select Sector SPDR Fund (XLF). We have found that both the k-th Moving Average Model and the k-th Weighted Moving Average give better results than the traditional ARIMA Model. Thus, we recommend that these methodologies are more appropriate both theoretically and practically for high volume ETFs. (Received July 31, 2018)

1144-91-60 **Nathan N Alexander*** (professornaite@gmail.com), 245 Amal Drive SW, # 1003, Atlanta, GA 30315. *Mathematical Modeling as a Tool for Critical Engagement Pedagogies.*

Mathematical modeling is a conceptual tool that combines real-world applications of mathematics with critical thinking in a community of student practitioners. In this talk, participants learn about critical mathematical modeling as a classroom practice and are introduced to two applications of mathematical modeling using critical theory and social justice praxes. Participants will also be introduced to the Critical Engagement Pedagogies (CEP) framework and explore various mathematical models that can be applied in secondary and post-secondary mathematics settings. This talk will provide attendees with strategies for collaborating with students and curricular development in mathematical modeling with colleagues using digital tools. (Received August 06, 2018)

1144-91-78 **N Mani***, nityam@stanford.edu, and **R Nelakanti**, **S Rubinstein-Salzedo** and **A Tholen**. *$\mathcal{P}$-Play in Candy Nim.*

Candy Nim is a variant of Nim in which both players aim to take the last candy in a game of Nim, with the added simultaneous secondary goal of taking as many candies as possible. We give bounds on the number of candies the first and second players obtain in 3-pile $\mathcal{P}$ positions as well as strategies that are provably optimal for some families of such games. We also show how to construct a game with N candies such that the loser takes the largest possible number of candies and bound the number of candies the winner can take in an arbitrary $\mathcal{P}$ position with N total candies. (Received August 10, 2018)

1144-91-346 **Remy Wu*** (remywu@choicerg.com), NJ , and **Richard Kyung** (nycrick@gmail.com), NJ. *Study on Stock Market Patterns with Economic Fluctuations Using Statistical and Computational Simulations.*

While both the casual investor and large hedge funds thrive off booms in the stock market, the effect that a crash has on society as a whole is much more extreme. Recently, there have been many historic stock market crashes, such as those in 2002 and 2008. These stock market crashes create wide scale unemployment and send waves of fear through the world of business. Although depressions have many different causes, they can be predicted through certain patterns in P/E Ratio, Nasdaq, and VIX. We used many different types of statistical and computational theories to find patterns in these data. Time series analysis allows us to account for the dynamic fluctuations in the stock market and analyze the sequential data. If trends from the time series analysis are too noisy, smoothing is used to distinguish the signal and the noise. Curve fitting allows for the extrapolation of data points, therefore calculating return periods that can be used to predict stock market crashes. Presented research identifies different return periods for stock market crashes based on their size. These patterns can be used to estimate how often a crash of a certain magnitude occurs, helping mitigate its effect on society. (Received August 29, 2018)

1144-91-353 **Yannik K Pitcan*** (pitcany@gmail.com), 1624 Milvia St., Apt. 1, Berkeley, CA 94709. *Analysis of Racial Disparities in Hiring Practices.*

Racial disparities in hiring practices continue to be an issue despite decades of legislative efforts to decrease discrimination, as evidenced by decreased rates of callbacks and increases in discrimination complaints by Muslim-Americans (Bursell, 2007; US Equal Employment Opportunity Commission, 2012). Internal or external motivation to respond without prejudice has been linked to hiring discrimination (Ziegert & Hanges, 2005)]. The use of automated hiring decision-making aids has been proposed as a method of combating the influence of prejudice in hiring discrimination. Supporters of automated hiring decision-making aids cite enhanced decision-making efficiency in comparison to humans, increased objectivity, and lower operator workload (Christin, Rosenblat, & Boyd, 2015; Parasuraman & Manzey, 2010). However, little is known about the influence of automated decision-making aids on the hiring process, nor their impact on discrimination in decisions to invite candidates for interviews. We examine the moderating effect of the awareness that a candidate with an Arabic name has been deemed suitable by an automated hiring decision-making aid on the relationship between internal motivation to respond without prejudice (IMS) and hiring decisions. (Received August 29, 2018)

92 ► Biology and other natural sciences

1144-92-36 **Erica Flapan*** (eflapan@pomona.edu), Department of Mathematics, Pomona College, 610 N. College Ave., Claremont, CA 91711, and **Adam He** and **Helen Wong**. *A new topological theory of protein knot folding.*

How knotted proteins fold has remained controversial since the identification of deeply knotted proteins nearly two decades ago. Both computational and experimental approaches have been used to investigate protein knot formation. In this talk, we introduce a new theory of knot folding that could describe a pathway for the formation of all currently known protein knot types and predict knot types that might be identified in the future. We analyze fingerprint data from crystal structures of protein knots as evidence that particular protein knots may fold according to specific configurations from our theory. In particular, our approach confirms Taylor's twisted hairpin theory of knot folding for the 3_1-knotted proteins and the 4_1-knotted KARI's as special cases, and presents an alternative folding mechanism for the 4_1-knotted phytochromes and the 5_2- and 6_1-knotted proteins. (Received July 23, 2018)

1144-92-93 **Katharine F Gurski*** (kgurski@howard.edu). *Modeling Lifetime Number of Partners and Longterm Partners in Sexually Transmitted Diseases.*

Population models for sexually transmitted diseases are typically based on an infection transmission model that is better suited for the flu by including only the risk that a susceptible partner can be infected as the probability per sexual act with an inherent partnership length of zero. We overcome this weakness by developing a model that can account for the possibilities of an infection from either a casual sexual partner or a longtime partner who was uninfected at the start of the partnership. The model allows for multiple longterm partnerships, which adds the advantage that network models have, the means to include serially monogamous and concurrent relationships, within the traditional strengths of a population model for computational speed and understanding of how each parameter affects the disease spread in an analytic reproduction number. We develop a model with longterm partnerships using a SIR model with differential infectivity and present a new treatment for contact numbers, the average number of sexual partners per year, in disease transmission rates which will result in a more realistic number of lifetime partners. Results include models for homogeneous and heterogeneous groups, along with reproduction numbers, and numerical simulations using HIV and HSV-2 data. (Received August 13, 2018)

1144-92-94 **Jim Michael Cushing*** (cushing@math.arizona.edu), Department of Mathematics, 617 N Santa Rita, University of Arizona, Tucson, AZ 85721. *Difference Equations as Darwinian Models.*

Discrete-time dynamical systems defined by difference equations have a long history of use as models of population dynamics. These equations are (time) autonomous when the coefficients and terms in the equation do not depend explicitly on time. There are, however, important reasons why it is of interest to consider time varying model coefficients. Two important reasons are periodic coefficients (in the case of daily, monthly or annual fluctuating environments) and stochastic coefficients (in the case of stochastically fluctuating environments). Another important reason that model coefficients can change in time is when they are subject to Darwinian evolution. I will discuss a general modeling methodology that can be used to derive evolutionary versions of a population model equation and describe some basic, general theorems concerning model predictions of extinction

or survival by means of bifurcation theory. To illustrate the theorems I will give example Darwinian versions of the classic discrete logistic (Beverton-Holt), Ricker, and Ricker/Allee difference equations. These will also be used to illustrate some biologically interesting phenomena, including backward bifurcations and strong Allee effects, evolutionary stable strategies, and climbing peaks on adaptive landscapes. (Received August 13, 2018)

1144-92-99 **Allison H Moore*** (amoore@math.ucdavis.edu), Davis, CA. *Site-specific recombination and the band surgery model.* Preliminary report.

Site-specific recombinases mediate DNA recombination at sites that are directly or inversely repeated. We model circular DNA as knots or links. In this context, site-specific recombination is modeled as band surgery, a topological operation that transforms a knot into a new knot or link. We will discuss the differences in this model when the sites are directly or inversely repeated, and mention some recent work in the latter case. In particular, we will state some topological obstructions to the existence of non-coherent band surgeries relating pairs of knots and report on the outcome of numerical simulations of non-coherent band surgery along knots in the cubic lattice. Parts of this work are joint with Flanner and Vazquez. (Received August 14, 2018)

1144-92-119 **Chaim Even-Zohar*** (chaim@ucdavis.edu). ***Random Knots are Knotted – A New Approach.***

A variety of random knot models have been proposed and investigated by mathematicians and biologists, who are interested in such models to study the structure of polymers and to compare their knot types to those that arise by random processes.

A desired property for such a random model is that the probability of obtaining every specific knot type decays to zero as the typical complexity of the knot increases. Past approaches to establish this property, in several random models, rely on the prevalence of localized connect summands. However, this phenomenon is not clear in other models that exhibit, in a sense, "a large step length" or "spatial confinement".

In joint work with Joel Hass, Nati Linial, and Tahl Nowik, we use finite type invariants and a coupling argument to establish this property for random knots that arise from petal projections (Adams et al. 2012). We expect our methods to extend to other well-studied knot models, in which local entanglements are similarly believed to be rare, such as random grid diagrams and uniform random polygons. (Received August 19, 2018)

1144-92-160 **Azmy S. Ackleh*** (ackleh@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504, **MD Istiaq Hossain** (mhh9786@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504, and **Amy Veprauskas** (aveprauskas@louisiana.edu), Department of Mathematics, University of Louisiana at Lafayette, Lafayette, LA 70504. *The effect of toxicant resistance evolution in the prey population on the dynamics of a predator-prey system.* Preliminary report.

Long term exposure to an environmental disturbance such as a toxicant has the potential to result in rapid evolution of toxicant resistance in many short-lived species. In this talk, we present an evolutionary discrete-time predator-prey model in which the prey species evolves to resist a toxicant, but the predator does not. Such a scenario may occur if, for instance, the lifespan of the predator is long relative to the lifespan of the prey. Through stability analysis of this model, we study how such prey evolution of toxicant resistance may impact the population dynamics of both species. (Received August 22, 2018)

1144-92-168 **Abdul-Aziz Yakubu*** (ayakubu@howard.edu), Department of Mathematics, Howard University, Washington, DC 20509. *Population cycles in discrete-time infectious disease models.*

The standard next generation matrix approach for calculating the basic reproduction number, an important parameter in understanding the evolution and prevention of infections, suffers from some assumptions that are not always met in real world systems. In this talk, we will explore extensions through discrete-time infectious disease models, a SIR and an ISAv models with and without age structure, and the different dynamic behaviors that arise. (Received August 23, 2018)

1144-92-173 **Patrick De Leenheer*** (deleenhp@math.oregonstate.edu). *Toxin production in a chemostat to avoid the tragedy of the commons.* Preliminary report.

We consider a chemostat with two types of bacteria, cooperators and cheaters. Cooperators produce a common good required for nutrient uptake; cheaters also need this common good but don't produce it. In previous work we have shown that in this case the Tragedy of the Commons occurs: both cooperators and cheaters are doomed when there is a nonzero amount of cheaters present initially. Here we show that this tragedy can be avoided when cooperators also produce a toxin that harms cheaters, but not cooperators, provided that the toxicity rate

is sufficiently large. In this case, cooperators can outcompete the cheaters. Such defense mechanism occurs for instance in Pseudomonas Aeruginosa, where cooperators can produce toxins like cyanide, as well as detoxification products making them resistant to the toxin. It also occurs in other organisms such as eusocial insects like ants, wasps and bees. This is joint work with Hal Smith (Arizona State University), Sergei Pilyugin (University of Florida) and Martin Schuster (Oregon State University) (Received August 23, 2018)

1144-92-187 **Craig J Benham*** (cjbenham@ucdavis.edu). *Topologically Driven DNA Structural Transitions.*

In addition to the B-form, specific DNA sequences can assume many other conformations. These include strand separations, cruciforms, left handed helices, triplex structures, quadriplexes and R-loops. Negative DNA superhelicity can drive transitions from B-DNA to several of these alternate structures. Here I will sketch the theoretical analysis of superhelical transitions, and describe their essential properties. Because transitions alter twist, they change the level of superhelical stress throughout the domain, and hence the propensities of other regions to transform. Thus, superhelicity couples together the transition behaviors of all the base pairs in the domain. This enables a rich conformational repertoire, depending on base sequence and superhelicity level. We analyze competitions involving three types of alternate structures - strand separation, cruciforms, and BZ transitions. This was done for 12,841 sequences from the mouse genome, each 5 kb long, at superhelix density -0.06. Every sequence was predicted to undergo one or more of these transitions. Moreover, a toy domain constructed to contain unique sites susceptible to each type of transition was predicted to experience every transition, and every combination of transitions, under some conditions. (Received August 24, 2018)

1144-92-224 **Mikahl Banwarth-Kuhn*** (mbkuhn@math.ucr.edu), **Ali Nematbakhsh**, **Stephen Snipes**, **Kevin Rodriguez**, **Carolyn Rasmussen**, **G. Venugopala Reddy** and **Mark Alber**. *Study of how Regulation of Mechanical Properties of Stem Cells in Plants Determines Shape of a Developing Tissue.*

One of the central problems in animal and plant developmental biology is deciphering how chemical and mechanical signals interact within a tissue to regulate cell behavior and produce the final shape, size and function of an organ. To address this problem, a novel, multi-scale, cell-based computational model of the stem cells of the shoot apical meristem (SAM) of Arabidopsis thaliana is developed and calibrated using experimental data. Novel features of the model include separate, detailed descriptions of cell wall extensibility and mechanical stiffness, the middle lamella and the dynamics of increase in cytoplasmic pressure generating internal turgor pressure. Model simulations are used to test a novel hypothesized mechanism of formation of the shape and structure of the growing, multilayered SAM. It combines contributions of mechanical properties of sub-cellular components of individual cells determining anisotropic cell expansion across three different SAM layers, and varied cell growth rates based on WUS concentrations of individual cells. Model predictive simulations also provide a detailed distribution of stresses in the growing tissue which can be tested in future experiments. (Received August 26, 2018)

1144-92-268 **Massa Shoura*** (massa86@stanford.edu), 300 Pasteur Dr., Stanford, CA 94305-5324, **Victoria Parikh** (vparikh@stanford.edu), 300 Pasteur Dr., Palo Alto, CA 94305-5324, **Alex Dainis** (adainis@stanford.edu), 300 Pasteur Dr., Palo Alto, CA 94305-5324, **Euan Ashley** (euan@stanford.edu), 300 Pasteur Dr., Stanford, CA 94305-5324, **Stephen Levene** (sdlevene@utdallas.edu), 800 W. Campbell Rd., RICHARDSON, TX 75080, and **Andrew Fire** (afire@stanford.edu), 300 Pasteur Dr., Stanford, CA 94305-5324. *Affairs of the Heart: How Circular-DNA-mediated Scars in the Titin Gene May Contribute to Cardiac Diversity.* Preliminary report.

Our chromosomes are classically depicted as floppy pieces of spaghetti. However, there exits another flavor of DNA in a circular form. This class, called Extrachromosomal circular DNA (eccDNA), comprises products of genomic shuffling (or recombination) that cause somatic changes in gene length and sequence. These circular molecules are derived (or "shed") from linear chromosomal loci, expanding the diversity in coding and regulatory capacity within eukaryotic genomes. Using a brand-new multidisciplinary approach to investigate eccDNA-mediated allelic diversity, I have identified various coding regions of eccDNA fromation, such as Titin and Mucin loci. In order to systematically investigate the biological implications and mechanisms of eccDNA formation, this talk will focus on Titin eccDNAs as a prototype for eccDNA-mediated chromosomal rearrangements. Titin is an extremely large protein that is responsible for the passive elasticity of muscle, functioning as a molecular spring. TTN is expressed in various isoforms, each with its own associated "spring constant" conferring a specific rigidity to cardiac muscle fiber. Preliminary data we obtained suggest a novel mechanism of TTN diversity involving circular-DNA excision that generates recombinant TTN loci at the DNA level. (Received August 27, 2018)

1144-92-269 **Eleni Panagiotou*** (eleni-panagiotou@utc.edu) and **Kevin Plaxco**. *A topological model for protein folding kinetics.*

Our aim is to introduce a new model of protein folding kinetics that supports the prediction of a protein's folding rate from the topological and geometrical structure of its native state. Focusing on a small set of proteins that i) fold in a concerted, "all-or-none" fashion and ii) do not contain knots or slipknots, we show that the Gauss linking integral, the torsion and the "contact order" (a measure of the mean sequence-localness of interacting parts of the chain) provide information regarding the folding rate. We next use the topomer search model as our basis, to study a topological model for protein folding. (Received August 27, 2018)

1144-92-270 **Sally Blower***, sblower@mednet.ucla.edu, and **Laurence Palk**. *Time, travel and HIV elimination: the case of Malawi.* Preliminary report.

Background: Malawi has a severe HIV epidemic, prevalence is 11%. Treatment coverage is 67%; the governments' goal is to reach UNAIDS' goal of 90% coverage by 2030 and eliminate HIV. We determine the time it would take for 90% of HIV-infected individuals to travel for treatment. Methods: We construct a treatment accessibility map by integrating a map of the healthcare infrastructure, a density of infection map, and a friction-surface map. We use geo-referenced HIV-testing data from 16,000 participants in the 2015 Malawi Demographic and Health Survey, and demographic data from WorldPop. For the friction-surface map we use data on road and river networks, land cover and topography. Using the accessibility map, we calculate the relationship between the HIV epidemic and travel-time to clinics. Results: Nation-wide, 90% of HIV-infected individuals can access treatment in 80 minutes or less. However, we found considerable inequities in access. In the most urban healthcare district (HCD), travel-time for 90% coverage is 35 minutes or less; in the most rural HCD, travel-time is 160 minutes or less. Conclusions: To eliminate HIV, innovative strategies will need to be developed to minimize travel-times in rural HCDs and additional clinics will be needed in the most urbanized HCDs. (Received August 27, 2018)

1144-92-303 **Maryann E. Hohn*** (hohn@pstat.ucsb.edu), Dept. of Statistics and Applied Probability, UC Santa Barbara, Santa Barbara, CA 93106-3110. *A parasite for sore eyes: Living together in a social network.*

Individuals who live in close, collaborate groups are susceptible to infectious diseases such as pathogens and parasites through their social network. Ectoparasites, external parasites that may be spread through social grooming, differ from pathogens in that the number of parasites impacts an individual's fitness. In this talk, we will discuss two approaches to understanding the effects of ectoparasites on social groups. The first is a system of differential equations that shows the importance of a hub-like structure in a social network, and the second is an agent-based model that shows parasite spread based on individual behavior in a dynamic network. (Received August 28, 2018)

1144-92-323 **Linda J. Allen*** (linda.j.allen@ttu.edu), Department of Mathematics & Statistics, Texas Tech University, Lubbock, TX 79409-1042. *Extinction Thresholds in Stochastic Epidemic Models with Periodic Environments.* Preliminary report.

Seasonality and contact patterns due to environmental fluctuations impact the dynamics of disease outbreaks. Recent results applied to deterministic and stochastic epidemic models with periodic environments show that the average basic reproduction number is insufficient to predict an outbreak. New results show that the basic reproduction number for models with periodic environments may be less than or greater than the average reproduction number. We apply these results to stochastic epidemic models with periodic transmission or demographics to show that if the basic reproduction number is greater than one, the probability of a disease outbreak is periodic. Therefore, the time at which an infected individual is introduced into a population impacts the probability of an outbreak. Implications of these results for emerging diseases and disease prevention are discussed. (Received August 28, 2018)

1144-92-333 **Nataša Jonoska*** (jonoska@mail.usf.edu), 4202 E. Fowler Av. CMC 342, Tampa, FL 33620, and **Masahico Saito** (saito@usf.edu), 4202 E. Fowler Av. CMC 305, Tampa, FL 33620. *Detecting complexities in a scrambled genome through spacial graphs.*

DNA rearrangement is a process found on both developmental and evolutionary scale. The process itself and the molecular shape at the time of the rearrangement can be modeled through 4-regular graphs. These graph models are illustrated through the rearrangement processes in a well studied ciliate species Oxytricha trifallax where DNA recombination is observed on a massive scale. Our studies show that there are two general patterns, reoccurring genome-wide, that describe over 90% of the Oxytricha's scrambled genes. Further, gene segments that recombine during DNA rearrangement processes may be organized on the chromosome in a variety of ways. They can overlap, interleave or one may be a subsegment of another. We use colored directed graphs

to represent contigs containing rearranged segments where edges represent recombining segment organization. Using graph properties we associate a point in a higher dimensional Euclidean space to each graph such that cluster formations and analysis can be performed with methods from topological data analysis. The analysis shows some emerging graph structures indicating that segments of a single gene can interleave, or even contain, all of the segments from several other genes in between its segments. (Received August 28, 2018)

1144-92-337 **Kai Ishihara**, **Kevin Lamb**, **Georgina Gonzalez*** (ginaglezi2000@gmail.com), **Mariel Vazquez**, **Koya Shimokawa** and **Javier Arsuaga**. *Can Chromosome Conformation Capture Data reveal the topology of the genome?* Preliminary report.

Chromosome Conformation Capture Data (CCC) consist of pairwise contact frequencies between regions in the genome. Loci with high CCC contact values are believed to be physically close in space and are used for downstream analysis, including the generation of 3D models of the genome. A key issue that is commonly addressed in the generation and discussion of 3D models is that of the topology of the genome. Most models claiming to be correct by the lack of knots. We here argue however that the topology of the genome cannot be directly determined from Hi-C data. Instead we suggest other methods, topological and geometrical, that may help infer properties of such topologies. (Received August 28, 2018)

1144-92-345 **Javier Arsuaga*** (jarsuaga@ucdavis.edu), Department of Molecular and Cellular Biology, On Shields Avenue, University of California, Davis, Davis, CA 95616, and **Brian Cruz** and **Mariel Vazquez**. *Molecular modeling of DNA packing in bacterial viruses.* Preliminary report.

The conformation of DNA inside bacteriophage viruses remains to be determined. A key factor contributing to this conformation is the packing reaction by which DNA is pumped inside the virus by a molecular motor. Several models have been proposed to correlate final features of DNA arrangement and the packing reaction but they are to some extent contradictory. In this presentation we discuss the effects of different packing motor mechanisms and the ionic conditions in the environment in the final conformation of the DNA molecule

This work is in collaboration with Dr. C. Calderer. (Received August 28, 2018)

1144-92-347 **Jonathan M. Fogg**, Houston, TX 77030, **Erik Stricker**, Houston, TX 77030, and **E. Lynn Zechiedrich*** (elz@bcm.edu), Houston, TX 77030. *Interplay between supercoiling-induced localized denaturation and DNA dynamics.* Preliminary report.

The nuclease Bal-31 cleaved exposed bases in negatively or positively supercoiled 336 bp DNA at distinct thresholds of superhelical density. The equivalent threshold occurs in larger 672 bp minicircles, with reduced curvature, indicative of the relationship between DNA bending and DNA denaturation. Bal-31 cleaves extremely positively supercoiled DNA minicircles. Exposed bases in positively supercoiled DNA is somewhat counterintuitive and presumably results from curvature-induced denaturation in the highly writhed three-dimensional conformations observed by cryo-electron microscopy. We found two hotspots of Bal-31-mediated DNA cleavage 180 degrees apart along the DNA circumference, suggesting that exposed bases are predominantly located at superhelical apices. Kinking at one apex facilitates kinking at the site diametrically opposite leading to disruptions in base-pairing at the opposing apex. The relative probability of Bal-31 cleaving at either of the two sites varied as a function of supercoiling, providing further evidence of the interplay between the dynamics and structure of supercoiled DNA on the local and global level. These conformational changes should profoundly influence the interactions between proteins, including topoisomerases, and supercoiled DNA. (Received August 29, 2018)

1144-92-349 **An Do*** (an.do@cgu.edu), 232 Briar Creek Rd, Diamond Bar, CA , and **Blerta Shtylla**. *A stochastic model for protein localization in Caulobacter Crescentus bacterium: mechanisms for asymmetric division.*

We propose a stochastic model for protein localization patterns in a dividing bacterial cell. Specifically, in Caulobacter crescentus, there is a minimal three component Par partition complex that generates the directional movement of a DNA copy during division and also affects the placement of the division plane. Unlike the more well-known E. coli Min system, the Par proteins do not oscillate in wild type and interestingly produce asymmetric steady state protein patterns that guide an asymmetric cell division program. We employ our stochastic model to describe a rich set of dynamics of protein localization and DNA copy movement in this bacterial cell. We also explore parameter ranges for which asymmetric protein patterns emerge by using global sensitivity analysis of several key model parameters. We employ our model to predict parameter regions for which various types of Par complex behavior can emerge such as pure diffusion, directive or oscillating movement of DNA copies and associated proteins. This minimal bacterial system can be used a simple system for understanding asymmetric cell division principles. (Received August 29, 2018)

94 ► Information and communication, circuits

1144-94-212 **Nader Motee**, Bethlehem, PA 18015, and **Qiyu Sun*** (qiyu.sun@ucf.edu), Department of Mathematics, Orlando, FL 32816. *Localized Stability Analysis on Sparse Proximity Graphs.* Preliminary report.

In this talk, we will discuss a finite or infinite dimensional class of spatially distributed linear systems with Hermitian and sparse state matrices. We show that exponential stability of this class of systems can be inferred in a decentralized and spatially localized manner. We proposed some necessary and sufficient stability certificates which are independent of the dimension of the entire system and only require localized knowledge about the state matrix of the system. As an application, we obtain several sufficient conditions that allow us to adjust strength of existing couplings in a network in order to sparsify or grow a network, while ensuring global stability. (Received August 25, 2018)

97 ► Mathematics education

1144-97-41 **Jess E Hagman*** (jess.ellis@colostate.edu), 1874 Campus Delivery, Fort Collins, CO 80523. *College Calculus as a Vehicle of Social Change.*

In this talk I will first describe the main findings from the MAA's study on college calculus, CSPCC. I will then provide a critique of this work and these findings through the lens of social justice, and reexamine and update our recommendations based on this critique. Lastly, I will provide ways for mathematics departments to approach their calculus programs in light of the original findings, critique, and updated recommendations. (Received July 27, 2018)

1144-97-85 **Kari Kokka*** (kokka@pitt.edu), 230 South Bouquet St., WWPH Department of Instruction and Learning, Pittsburgh, PA 15232. *Empowering students and supporting their well-being through Healing Informed Social Justice Mathematics.*

Using Social Justice Mathematics (Gutstein, 2006), an ecological approach to Trauma Informed Care (Harvey, 1996) and Radical Healing (Ginwright, 2016), and this session explores how the intersection of these three approaches may offer a new framework for engaging in mathematics instruction through Healing Informed Social Justice Mathematics. Social Justice Mathematics aims to develop students' academic proficiency and students' sociopolitical consciousness, or conscientização (Freire, 1970), to critically analyze and change the world (Gutstein, 2006). Social Justice Mathematics tasks typically investigate a social issue relevant to students' local contexts using mathematics as a tool. A healing informed approach to this considers how discussing emotions and identifying structural factors related to trauma (e.g. socioeconomic status, access to stable housing, health care, and food security) may engage students and empower them to create change. Findings will be shared from a case study of one urban middle school mathematics classroom, where students discussed their emotions, engaged in structural analyses of local social issues to resist stereotypes, and expressed plans to take action. We will consider how this approach might work in various grade levels and settings. (Received August 12, 2018)

1144-97-106 **Esther R. Widiasih*** (widiasih@hawaii.edu), 91-1001 Farrington Hwy, UHWO, Kapolei, HI 96815. *Enhancing Math Instruction for Native Hawaiian Students through Peer Academics Leaderships.*

The University of Hawai'i West O'ahu is an indigenous serving institution on the leeward side of the island of O'ahu. Challenges in math instructions, which is abound, include students' under-preparedness, as they come from a diverse academics and socio-economics background. In this talk, I will share a recent approach to the math (and science) instruction based on the four-pillar foundation of inquiry, community, placed-based, and indigenous knowledge,

Mathematics instruction for foundational courses at UHWO was recently enhanced by utilizing Peer Academic Leaders (PALs). PALs are students selected by faculty to collaborate in instructional activities, much like classroom embedded tutors. The PAL program has found success in the effort of recruiting underrepresented STEM, to provide tutoring in Math and Science courses, and to increase retention of students of Native Hawaiian and Pacific Islands descends. The program is supported by NSF TCUP ICE TI Award 1461439. (Received August 15, 2018)

1144-97-190 **Aditya P Adiredja*** (adiredja@math.arizona.edu), The University of Arizona, ENR2 Rm. S317, 1064 E. Lowell St., Tucson, AZ 85719. *Constructing and Analyzing Everyday Examples about Basis: An Anti-deficit Approach in Teaching.*

I share insights about anti-deficit perspectives in teaching from my recent studies about basis in linear algebra. Instead of focusing on students' misconceptions and lack of knowledge, the perspective focuses on productive resources students bring to learn mathematics. In my research about basis, we asked students to construct an example from an everyday context that captures the definition of a basis and then to critique it mathematically. The first set of data comes from individual interviews with 8 undergraduate women of color. They altogether constructed 22 different examples using contexts like friendship and religion. Arguing against dominant deficit narratives about women of color in mathematics, the women presented their creativity and offered productive learning resources. We learned that this task was productive in uncovering some of these resources. A mathematician colleague was inspired by the findings and decided to implement this task independently in her course. She found similar creativity and higher level thinking in her students' responses. Together we were able to deepen our knowledge of what it means to approach students' work from an anti-deficit perspective. We use these insights to generate a conversation about this practice in undergraduate mathematics. (Received August 24, 2018)

1144-97-206 **Benjamin Braun***, 715 Patterson Office Tower, Lexington, KY 40506. *Communicating with mathematicians about social and educational change.* Preliminary report.

We will discuss various insights regarding effectively communicating with new and experienced mathematics faculty regarding social and educational change and development. (Received August 25, 2018)

1144-97-217 **Vanson Nguyen*** (vansonnguyen@peralta.edu), CA. *Co-constructing mathematical knowledge in the classroom.*

As many mathematics faculty have extensive coursework in the field of mathematics, they often have little to no coursework on the teaching of mathematics. Consequently, mathematics faculty reproduce classroom experiences they had as a student: lectures. Perhaps this is a reason why there is underrepresentation of students of color and women succeeding in mathematics courses. This talk investigates a possible way to increase participation of learning mathematics with groups of students who traditionally have not succeeded in math.

Co-construction of mathematics knowledge is particularly important as faculty draw on the mathematics that students bring with them to the classroom. This talk highlights teaching techniques to co-construct mathematical knowledge with students of all backgrounds, experiences and mathematical knowledge. The result of co-construction is a development of sociomathematical norms where students and faculty negotiate what constitutes an acceptable mathematical explanation including mathematical difference, the differing solutions to a problem. The negotiation of acceptable explanations and difference evolve over time. (Received August 25, 2018)

1144-97-219 **Kamaldeen O Okuneye*** (olatundekamaldeen@yahoo.com). *The role of Intergenerational Equity in Making Changes in the Learning and Application of Mathematics.*

In the learning and application of mathematics, intergenerational equity can be described as a notion that views the learning and research community as a partnership among all generations, especially among students and faculty members. Moreover, sustaining the learning and application of mathematics can be met when the academic requirements and needs of senior faculties are met equitably and without sacrificing the ability of future generations to meet their academic and future needs. Thus, while there are moral and academic obligations of students to their respective supervisors, it is important that students are given the freedom to pursue their own curiosity in an academic environment and especially, given an avenue to make conscious decision of their professional futures. To incorporate intergenerational equity in the learning and application of mathematics and education in general, students, faculties as well as institutions have vital roles to play. (Received August 26, 2018)

1144-97-262 **Dagan Karp*** (dagan.karp@gmail.com), 301 Platt Blvd, Claremont, CA 91711. *Panel on Equity and Social Justice in Mathematics.*

This panel discussion will explore how mathematicians and mathematics educators, together, can promote social change and broaden participation in mathematics through teaching, mentoring, and research. The panel will break down the false dichotomy between mathematicians and math educators and learn from the similarities and differences from various perspectives. We will share research based best practices and provide opportunity for future collaboration and exploration. (Received August 27, 2018)

1144-97-329 **Maxine T. Roberts*** (mtrobert@usc.edu). *Black Student Success in Developmental Mathematics—Creating A New Narrative about Learners in Community College.*

Research on community college students tends to focus on their deficits and failures rather than assets and achievements. This presentation features results from a project exploring Mathematics Identity and Sense of Belonging in Mathematics of Black students who succeeded in developmental mathematics. Despite academic challenges, racialized math experiences, and relational barriers in their classrooms and institution, study participants successfully completed the remedial mathematics sequence and entered college-level mathematics. It is rare that the successes of historically marginalized students in community college are illuminated. This presentation features stories about these students' lives, shows how they achieved success, and shares the ways that their instructors and classroom environments supported and hindered their success. (Received August 28, 2018)

1144-97-342 **Rochelle Gutierrez*** (rg1@illinois.edu). *Risk Taking in Mathematics (Education): Toward a Future that Rehumanizes.*

Mathematics education has a long history of theorizing and implementing equity. Over the past decade, we have moved beyond thinking merely about access (opening the doors for more diverse people) and achievement (mending leaky pipelines) and have placed a greater emphasis on identity and power. Most recently, scholars have suggested we shift our thinking from equity to rehumanizing mathematics. Doing so involves providing more windows/mirrors for students, attending to the sociopolitical history of the discipline, presenting math as a living practice, and making the body/emotions more central (Gutierrez, 2018). What we have learned in mathematics education is that rather than changing one's belief system, it might be more fruitful to change one's practices first. We act ourselves into new ways of thinking, not the reverse.

Making these kinds of shifts in our own practice and thinking will involve taking risks. In order to be fruitful, such risk taking should be strategic and built upon our understanding of previous risk taking that has been productive. I offer my perspective on what I have learned about risk taking and being creatively insubordinate in mathematics education and suggest how mathematicians might also incorporate an action-oriented stance in their work. (Received August 28, 2018)

2010 MATHEMATICS SUBJECT CLASSIFICATION

Compiled in the Editorial Offices of MATHEMATICAL REVIEWS and ZENTRALBLATT MATH

00 General
01 History and biography
03 Mathematical logic and foundations
05 Combinatorics
06 Order, lattices, ordered algebraic structures
08 General algebraic systems
11 Number theory
12 Field theory and polynomials
13 Commutative rings and algebras
14 Algebraic geometry
15 Linear and multilinear algebra; matrix theory
16 Associative rings and algebras
17 Nonassociative rings and algebras
18 Category theory; homological algebra
19 *K*-theory
20 Group theory and generalizations
22 Topological groups, Lie groups
26 Real functions
28 Measure and integration
30 Functions of a complex variable
31 Potential theory
32 Several complex variables and analytic spaces
33 Special functions
34 Ordinary differential equations
35 Partial differential equations
37 Dynamical systems and ergodic theory
39 Difference and functional equations
40 Sequences, series, summability
41 Approximations and expansions
42 Fourier analysis
43 Abstract harmonic analysis
44 Integral transforms, operational calculus
45 Integral equations
46 Functional analysis
47 Operator theory
49 Calculus of variations and optimal control; optimization
51 Geometry
52 Convex and discrete geometry
53 Differential geometry
54 General topology
55 Algebraic topology
57 Manifolds and cell complexes
58 Global analysis, analysis on manifolds
60 Probability theory and stochastic processes
62 Statistics
65 Numerical analysis
68 Computer science
70 Mechanics of particles and systems
74 Mechanics of deformable solids
76 Fluid mechanics
78 Optics, electromagnetic theory
80 Classical thermodynamics, heat transfer
81 Quantum theory
82 Statistical mechanics, structure of matter
83 Relativity and gravitational theory
85 Astronomy and astrophysics
86 Geophysics
90 Operations research, mathematical programming
91 Game theory, economics, social and behavioral sciences
92 Biology and other natural sciences
93 Systems theory; control
94 Information and communication, circuits
97 Mathematics education

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